UNIVERSITAT DE BARCELONA

Departament de Psicologia Bàsica

Facultat de Psicologia, Universitat de Barcelona

Neural correlates of word learning and meaning acquisition

Dissertation presented by:

Anna MESTRES MISSÉ,

to obtain the grade of Doctor by the University of Barcelona

Supervisor:

Dr. Antoni Rodriguez Fornells

Programa de doctorat Ciència Cognitiva i Llenguatge

Bienni 2002-04

Barcelona, June 2007

Acknowledgements

The work presented in this thesis would not have been possible without the support of many people. I would like to express my deepest gratitude to Dr. Antoni Rodriguez Fornells who has been and is more than a supervisor; he is my mentor, my ‘doctor father’ and a friend. Without his constant support and friendship I will not have fulfilled my dream of becoming a researcher. I am also thankful to Prof. Thomas F. Münte who opened the doors of his lab to me and gave me the opportunity of conducting some of the research that is reported here. Also I want to express my gratitude to Dr. Núria Sebastián Gallés who introduced me to the fascinating field of language processing.

Many other individuals at the Barcelona and Magdeburg universities supported my work in different ways. I thank all the colleagues and coworkers from both universities who have supported me and contributed to my work. I am thankful to Toni Cunillera with whom I’ve shared not only scientific discussions and problems but also the beginning of our careers. Thanks to Estela Camara who is always willing to help a friend and who helped me with fMRI methodological issues and programming. Josep Marco Pallarés for patiently helping me with ERPs recordings and analysis. David Cucurell for the laughs and train trips. Xavier Mayoral for his help with technical or programming problems. Lluís Fuentemilla for his help with the biosemi. Agnès Canyo for being a friend. Rafael García for helping me to find myself. Cristina Baus and Begoña Díaz for being the best friends I will ever have. From Magdeburg, I thank Anke Hammer, Ivonne Gerth, Ulrike Krämer, Jürn Möller, Marcus Heldmann, Jascha Rüsseler, Gregor Szycik, Daniel Wiswede, Claus Templemann and Michael Rotte for dicussions, data acquisition and analysis, for the nights out, in short, for being really nice colleagues. My special thanks to the best ‘office-mate’, Boukje Habets, thanks for the support, the listening, the laughs, and all the pizza and beers.

I would like also to thank my parents, Josep Mestres Canals and Georgina Missé Suñol, for bringing me to this world and making me the person I am today. To my sister Natàlia who always knows how to cheer me up. At last, I thank Marcus who is always there for me.

Contents

Preface

Language is a human capacity that has made such unique aspects of human thought as creativity, the ability to think about the past and the future, logic, and all higher forms of cognition possible. Language provides us with the ability to hold information from the environment in our memory so we can manipulate it and, hence, have a tool to communicate ideas. Language is the main way to store and transmit knowledge and culture. Due to the importance of this remarkable and complex ability, humans have to learn it within the first few years of life. One of the first steps in the enigmatic process of language acquisition is learning the labels of the world. Giving a name to something optimizes the information; it allows categorization, which in turn allows a generalization of existing knowledge to be applied to new exemplars, objects and/or concepts. The characteristics, functions, and composition of a certain concept, along with its relation to other words, are stored under an arbitrary label (a social convention). The learning of these labels is one of the primary challenges children have to face. In order to become skilled and proficient language users, children first have to learn what things are called and, then, which things belong together and which do not. In other words, they must learn to categorize the world and generalize the information they take in. Children are extremely good at this. They start to produce words at approximately the age of 12 months, and go on to learn roughly 10 new words a day through the end of high school. However, vocabulary development does not stop at late adolescence. We constantly encounter new words, neologisms, and slang that we must learn. Furthermore, most people have to learn at least one foreign language in their lives. However, adult vocabulary acquisition is much slower and likely to be more dependent on social factors.

This dissertation is devoted to the understanding of how adults learn the meaning of novel words from sentential contexts, the binding of a word form with a concept using the semantic information provided by the sentences in which the new word is embedded.

In the first chapter of this study, an introduction to first and second language acquisition in both children and adults will be provided. Special emphasis is given to research on word learning. Chapters 2 and 3 describe two event-related brain potentials (ERP) experiments, a behavioral study and a functional magnetic resonance imaging (fMRI) study centered on the effect of context congruence on lexical acquisition. The following two chapters describe two behavioral experiments and an fMRI study on meaning acquisition of concrete and abstract words. The results of each experiment are discussed in detail within the chapters. The final chapter offers a summary of the experimental results and an integrative discussion.

Chapter 1

1. How do we learn new words and their meaning?

The infant's acquisition of a mother tongue and the adult's acquisition of a second language share a number of features, but they also differ in many respects. In order to understand language acquisition processes and how different aspects of language are attained, we should take a closer look at how first and second languages are learned and how this process varies with age. Thus, the first part of the introduction will focus on first language acquisition, while the second will deal with second language acquisition.

1.1. Infants' acquisition of their first language.

Language acquisition is one of the central topics in cognitive science and, yet, no one knows exactly how children learn the meaning of words. At first glance, word learning may seem as simple and straightforward as an adult pointing to objects and naming them for children. In this case, the only task of the child is to associate the word he/she is currently hearing with the thing he/she is presently seeing. As John Locke (1690/1964, p.104) posited:

> For if we observe how children learn languages, we shall find that, to make them understand what the names of simple ideas or substances stand for, people ordinarily show them the thing whereof they would have them have the idea; and then repeat to them the name that stands for it: as white, sweet, milk, sugar, cat, dog.

Although Locke's suggestion seems plausible, his view of word learning in infants is flawed. Notwithstanding the fact that a crucial source of word learning is noticing the real-world contingencies for the use of a particular word, in itself this is not sufficient. Children experience words in the ongoing flow of social interaction in which adults utilize different types of words in a variety of contexts. Adults do not typically utter words in isolation and, while pointing objects out to children, they neither stop other activities in which they are engaged nor merely name these objects for children. Instead, children usually discern an adult's focus of attention in much more complicated situations (Tomasello, 2003). Although in some situations adults may point and name an object, usually they only do so for object labels; parents do not say "Look! Giving" or "Look! With". Children must learn these types of words by means of a less straightforward process. Moreover, several studies have shown that words can be learned without a strict spatial and temporal cooccurrence between words and meaning (Tomasello and Barton, 1994; Akhtar et al., 1996; Tomasello et al., 1996). Another piece of evidence against Locke's empiricist viewpoint comes from deaf and blind children. Locke argued for a direct relation between knowledge and the experience of the senses. Thus, deaf and blind children should be unable to learn certain words, such as those that are available for experience only to the ear (in the case of deaf children, words such as *noise*, *listen* and *loud*) or to the eye (for blind children, words such as *picture*, *see* and *red*). However, deaf children who learn sign language do so at exactly the same pace and learn the same type of words as normal children who learn spoken languages (Petitto, 1992). The same has been demonstrated in blind children (Gleitman, 1990). Furthermore, a general problem exists in explaining how children know that an adult is naming an object and not referring to a particular property, part or action of that object.

William Van Orman Quine's parable (1960, p.29) offers us insight into the problems children must face in order to learn the meanings of words. Suppose we have a linguistic explorer and a native subject: a rabbit runs past and the native exclaims "Gavagai!" The linguist forms the hypothesis that *gavagai* means "rabbit", but how can he be sure? He could test his hypothesis by asking the native in a series of different situations the simple question "Gavagai?" and see if the responses confirm his hypothesis. However, even if the answer is yes and the hypothesis can be proved, there is no guarantee that any finite set of observations determine the correct meaning of *gavagai*. The native may use the word in exactly those situations in which the linguist would use *rabbit*, but it could still mean something different: "temporal section of a rabbit" or "set of undetached rabbit parts". Despite these problems, children around the world learn words on a daily basis; adults are proficient in ordinary conversation and often translate between languages; so, then, the question is, how exactly are the meanings of words learned?

Quine's parable points out three different problems that must be solved in order to learn word meanings: (1) the segmentation problem, (2) the reference problem and, (3) the generalization problem. First, when the linguist hears *gavagai*, how does he know that *gavagai* is a name at all, as opposed to the native talking to himself, clearing his throat, or saying the equivalent of "Watch out" or "Look?" How does the linguist know that it is one word and not two? This problem is known as the segmentation problem. People do not typically use words in isolation; most words are used in the context of sentences. When an infant hears an adult speaking or when we hear someone speaking in a foreign language it is often extremely difficult to determine the component words of the utterance. Although conversational speech provides some acoustic pauses, these do not reliably signal word boundaries (Jusczyk, 1999). Infants must first learn to categorize perceptually different sounds. At an early age, infants show an ability to distinguish between many different phonetic contrasts, whether in their own language or not (native and non-native). Later, during the second semester of life, the universal ability to perceive non-native contrasts yields a native-language phonetic pattern of discrimination (Werker and Tees, 1984; Kuhl, 2004). The discrimination of phonetic units is essential for the acquisition of language, as phonemic categories are the elementary units upon which words depend.

1.1.1. The segmentation problem

Speech segmentation into words is accomplished by four basic mechanisms (Jusczyk, 1999). First, infants rely heavily on prosodic cues when they begin to segment words from fluent speech. At 7.5 months of age, English-learning infants can segment words from speech that reflect the stress pattern of their language (Jusczyk et al., 1999). English is a trochaic language in which stress falls on the first syllable of a word (strong-weak pattern), while other languages, for example French, have a predominant iambic pattern (weak-strong). All languages contain words of both kinds, but one pattern typically predominates. Infants benefit from these prosodic cues to identify potential words candidates. For instance, in Jusczyk et al. (Jusczyk et al., 1999), when infants heard "guitar is" they perceived "taris" as a word, because it begins with a stressed syllable. Second, attention to the particular contexts in which variants of the same phoneme appear (allophones) also provides clues about word boundaries (Church, 1987). Different allophones of the same phoneme are often restricted in terms of the positions in which they can appear within a word (Jusczyk, 1999). For instance, Church (1987) found that the allophone of /t/ that begins words in English (as for example, “top”, i.e., [t^h]), is not found in other positions in English words, such as the /t/s in “stop” or “hot”. A third suggested cue to word boundaries is the distributional or statistical cue (Saffran et al., 1996b; Saffran et al., 1996a). Awareness of the likelihood that one syllable follows another helps infants discover word boundaries. Saffran et al. (Saffran et al., 1996a) examined whether 8 month-olds might be able to take advantage of this sort of statistical regularity to learn about word boundaries in a nonsense language. They exposed a group of 8 month-olds to 2 minutes of a continuous stream of speech, consisting of four trisyllabic nonsense words, repeated in a random order. The only cues to word boundaries in this continuous stream were the transitional probabilities between syllable pairs, which were higher for syllable pairs within words. The study found that these infants could distinguish between trisyllables that conformed to words and trisyllables that did not. Fourth, each language has certain restrictions on the possible sequences of phonetic segments in words, including predictable sequences of sounds that often occur together and others that almost never do (called phonotactic constraints). Some sequences of consonants never occur together within a word, and so hearing such a sequence in fluent speech may be used to infer a word boundary (Friederici and Wessels, 1993; Mattys et al., 1999).

1.1.2. The reference problem

Before learning the meaning of words, children have partially solved the problem of speech segmentation. However, children must still learn that a word is an arbitrary sign, with a concept on one side and a form on the other (Bloom, 2000). Learning a word requires memorizing the arbitrary relationship between form and meaning. A problem that arises is how to extend the word in the appropriate way in new circumstances.

Another problem the linguist from Quine’s parable has to solve is the one of what the word *gavagai* is describing. The native could be referring to the “rabbit”, but also to a part of the rabbit, or to the kind of action the rabbit is performing. Perhaps it is the name of the native’s pet, or he is referring to a physical characteristic of the rabbit, or to animals in general. Language learning is an inductive problem in which there exists an infinite number of possibilities or hypotheses for a finite sample of environmental information. How do children solve the reference and generalization problem, then?

Young children can grasp aspects of the meaning of a new word on the basis of a few incidental exposures, without any explicit training or feedback. This process of quick initial learning is known as "fast mapping" and simulates natural language acquisition (Carey and Barlett, 1978). Carey and Barlett (1978) investigated how much young children learn about new words when they are exposed to one of them. In their study, 3- and 4-year-old children were presented with two plates of different colors, and told to "Bring me [the experimenter] the chromium plate. Not the red one, the chromium one." The new label was defined by the experimenter's reference to familiar concepts in the environment. The results showed that after just one exposure to the new word, and when tested a week later, half of the children displayed some knowledge of the word. Carey (Carey, 1978) suggested that children are able to acquire new names and their referents during an early stage of vocabulary acquisition termed "fast mapping". In this early stage, after initial exposure to a word and its context, information about the word (phonemic, orthographical, semantic and syntactic characteristics) may be stored in memory in a temporary form; this first representation of the word will then be redefined through further experience with the word (Carey, 1978). For instance, in Markson and Bloom (1997) children and adults were exposed to new words (e.g., *koba*) for six novel objects, but children were not asked to repeat the new word and were not tested to ensure that they had heard it. A month later, the same objects were presented to the test subjects and they were asked to point out "the koba". The children and adults successfully learned the novel object, and were able to remember the correct word-object mapping after all tested delays. Even 3-year-olds chose the correct object above chance. In addition to the new word task, half of the subjects were given a linguistically presented fact in the same way. They were told that one of the objects was given to the experimenter by her uncle. The other half of the subjects were given a visually presented fact. They watched as a sticker was placed on one of the unfamiliar objects. In the linguistically presented fact task, the results were basically identical to those in the new word task. However, in contrast to the visually presented fact task, adults and children showed a significant decline over time and did significantly worse than in the other two conditions. Fast mapping emerges from a general capacity to learn socially transmitted information, which includes, but is not limited to, the meaning of words (Markson and Bloom, 1997).

Children are able to solve the problems of reference and generalization, which suggests that they are somehow biased to favor some interpretations over others. When taught a new word in the presence of an object, children are prone to interpret it as a labeling of the entire object (Golinkoff et al., 1994; Baldwin, 1989; Markman and Wachtel, 1988; Soja et al., 1991; Waxman and Markow, 1995). These facts have led many researchers to conclude that children possess a whole object bias, a preference to interpret novel words as referring to object categories (Macnamara, 1972; Markman, 1989). Children's predisposition toward objects reflects a bias, not a conceptual limitation. In fact, adults show precisely the same bias; when participating in experiments involving the interpretation of a new word, adults also tend to favor the object interpretation, even though they are fully capable of reasoning about parts, properties, actions, and so on (Bloom, 2000). Children might be biased to assume that when adults use words in certain contexts, they are intending to refer to particular objects (Tomasello, 2003). The object bias will be suppressed if children understand that an adult is not intending to refer to an object. If an object already has a name, then another word in reference to this object is taken by children as likely to have some other meaning, such as a part or property of the object (e.g., Markman and Wachtel, 1988). Markman and Wachtel (Markman and Wachtel, 1988) showed preschool children two objects, one familiar and one novel (such as a spoon and a whisk), and said "Show me the fendle". Most children gave them the novel object in this situation, presumably because they know that a spoon is called "spoon," so the adult would have used this familiar label if he/she had been referring to it. Markman and Wachtel also found that when a novel word was used when only a familiar object was present, children often inferred that the novel word indicated a part of the object. To account for this phenomenon, Markman (1989) proposed the concept of mutual exclusivity bias. He and his colleagues conceived this bias and the object bias as innate constraints that help children learn the meaning of words. However, other authors (Clark, 1983; Clark and Svaib, 1997; Tomasello, 2003) have succeeded in explaining both phenomena without resorting to the use of innate principles (so-called lexical contrast by these authors; see section 1.1.4.2 for further details on this topic). The (whole-)object bias and the mutual exclusivity bias (Markman, 1989), or lexical contrast (Clark, 1993; Clark, 1983; Tomasello, 2003), are a possible solution to the reference problem.

1.1.3. The generalization problem

When learning a new word for a novel category, how do children generalize this word? One consideration is the word's syntactic category. For instance, nouns are treated differently from adjectives. If children hear an unfamiliar object named as "a zav," they will tend to generalize the word on the basis of shape. However, if they hear it described as "a zavish one," they tend to generalize on the basis of a property such as color or texture (Hall et al., 1993; Smith et al., 1992). Generalization is essential for inductive learning as many concepts correspond to categories that have certain relevant properties in common. Murphy and Lassaline (Murphy and Lassaline, 1997) propose that the basic level is an optimal compromise between informativeness and distinctiveness: many unobserved properties can be inferred once one knows which basic-level category something belongs to (informativeness) and depending on how easy it is to make this categorization (distinctiveness). For instance, Gelman and Markman (Gelman and Markman, 1986; Gelman and Markman, 1987) showed that children use category membership to infer deeper properties in animals. In a set of experiments, children were told that a brontosaurus has cold blood and a rhinoceros has warm blood and were then asked which type of blood a triceratops has. A triceratops looks more like a rhinoceros than a brontosaurus, so if children's inductions are solely based on perception, they would be expected to guess that the triceratops has warm blood like the rhinoceros. However, when both the triceratops and the brontosaurus were described as "dinosaurs," the children inferred that the triceratops had cold blood. Thus, the children used the fact that the triceratops and the brontosaurus share the same label to infer that they fall under the same category, which is to say that members of the same category share the same deep properties, despite perceptual likeness. However, evidence suggests that children also rely on perceptual properties, especially shape, when generalizing words. For example, when told a new noun that refers to a rigid object, children will extend that noun to other rigid objects of the same shape, but not to those of the same size, color, or texture (so-called shape bias) (Baldwin, 1989; Smith et al., 1992; Jones et al., 1991; Landau et al., 1992). In addition, Kemler Nelson et al. (Kemler Nelson et al., 2000b; Kemler Nelson et al., 2000a) showed that 2-year-olds extended the name of an unfamiliar artifact with a salient function to other artifacts that share the same function, regardless of perceptual similarity (for an example of the objects used, see Figure 1.1). Early in development, children possess intuitive theories of natural objects and artifacts. The results of these studies demonstrate that children not only generalize based on perceptual similarity but that they also possess a general intuition that concepts correspond to reality and not just to their outward appearance (Bloom, 2000).

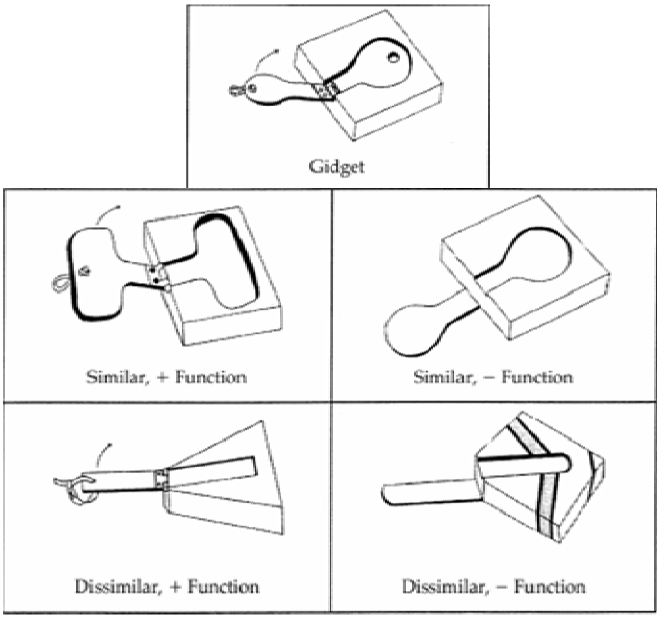

Figure 1.1. Top: Illustration of a standard novel artifact with a novel function. Bottom: Illustration of the four test artifacts. Similar: more similar in appearance to the standard object; Dissimilar: less similar to the standard object; +Function: test object that functioned as the standard; -Function: test object that did not function as the standard. (From Kemler Neslon, Russel, Duke & Jones, 2000).

1.1.4. Theories of word learning

To account for the facts of word learning so far presented, there are three basic theories of how children learn words. (Tomasello, 2003). The first posits that word learning is nothing more than an association between a set of stimuli and a verbal response. The second suggests that word learning is so special that to learn a word children must use a priori word learning constraints or principles. The third, which is social-pragmatic theory, posits that children do not need specialized constraints or principles for word learning, although associative learning is not by itself sufficient either. This theory proposes that a special form of social learning involving intention reading and known as cultural learning is needed. Attempts to integrate the basic assumptions highlighted by these theories have led Hollich et al. (Hollich et al., 2000) to present a hybrid account of word learning, known as the Emergentist Coalition model.

This theory describes word learning as the product of multiple factors, including cognitive constraints, social-pragmatic factors, and global attentional mechanisms. In the next section, the core assumptions of each of these theories will be briefly described.

1.1.4.1 Associationism

Associative learning is a quite easy and straightforward solution to the word learning problem. This theory proposes that if two thoughts occur at the same time, they become associated and one gives rise to the other. Children learn the meaning of a word, for example "rabbit," because the word is used when they are observing or thinking about rabbits. As a result, the word and the thought become associated, and children have therefore learned what the word means.

Smith (Smith, 2000) has argued that the nature of word learning is associating sounds with salient aspects of perceptual experience. In support of this view, Smith has demonstrated in several experiments that children often assume the meaning of a novel word is the most salient aspect of the current non-linguistic context. Some studies argue against the perceptual salience of an object as the only cue that guides children's successful word learning (for example, see Tomasello and Barton, 1994; Tomasello et al., 1996, section 1.1.4.4). In an attempt to provide an associationistic explanation for the findings of those authors, Samuelson and Smith (Samuelson and Smith, 1998) presented 2-year-olds with three objects, one at a time, and instructed them to play with the objects. The experimenter then invited the children to move to a table (special location), where they were shown a fourth object, and told to play a different game with it. They then moved back to the floor (original location) and the four objects were placed inside a box. After a brief distraction, the experimenter looked at the four objects inside the box and said five times "There is a gazzer in there." Each child played with all four objects, and was then asked to give the experimenter the *gazzer*. The findings showed that most of the children thought a *gazzer* was the object they had played with at the special location. Samuelson and Smith argued that the children were associating the novel word with the most salient possible referent in this situation.

But a recent study from Diesendruck et al. (Diesendruck et al., 2004) suggests a different interpretation of this result. The authors directly replicated and extended the study from Samuelson and Smith and argued that salience was determined by children's social-pragmatic inferences. They compared a similar situation to that of Samuelson and Smith with another situation in which the experimenter accidentally dropped an object so that it rolled over to the same special location, where the experimenter and the child then played with it. They predicted that in this situation the children would not infer that the *gazzer* was the object they played with in the special location, as the object ended up there by accident and there was no pragmatic reason for the adult to distinguish it. The authors found exactly what they had predicted. The children did not think there was anything special about the object that was accidentally introduced, so they did not assign the novel label to it. Even though in both studies an object was made more salient, the results differed depending on the intentionality of the experimenter; in both cases children were trying to infer the communicative intentions of the experimenter.

This result shows that, despite the intuitive likelihood of the associative learning proposal, this theory suffers from certain serious problems. Some of them were exposed before, in the fact that words are not ordinarily used at the same time as their referents are being perceived. If associationism were correct, many mapping errors would occur in word learning among young children. For instance, if someone asks a child, “Want a cookie?” the child will look at this person’s face. But *cookie* does not mean “face”, and the child does not think it does. If pure associative learning would have occurred, the child would think *cookie* means “face” (at least until more information is available). The coocurrence of word and percept is neither necessary nor sufficient. Also, children are capable of learning the meaning of words without ostensive labeling. Furthermore, deaf and blind children are as successful at word learning as children who hear or see. Finally, one has to consider the fact that nonhuman primates, who are excellent at associative learning and have rich perceptual and motor systems, are not nearly as good as children at word learning.

1.1.4.2. Constraints and Principles

The constraints approach is a second theory of word learning (i.e., Markman, 1989). In this approach the problem of word learning is solved, assuming that children possess a series of mechanisms that bias them toward one of several plausible inferences about the meaning of a novel word. The problem of identifying what *gavagai* refers to is one that can only be solved if children are equipped with some additional mechanisms that help them limit the hypothesis space, so that a child is given a starting point to solve the reference indeterminacy. The problem of reference is a kind of poverty of the stimulus problem, as insufficient information is available, over and above a perceived sound pattern and a perceived external scene, to learn the communicative significance of a word; additional information is needed. To solve this problem constraints theorists have posited the existence of certain a priori specialized constraints or principles that children utilize to solve the word learning problem. These constraints imply causal mechanisms that are internal to the child (i.e., innate) and domain-specific.

Researchers have proposed numerous constraints that help children learn the meanings of words. Markman (Markman, 1989) suggested two of the most famous and important constraints. In his account, children approach a new language in possession of these two constraints: the whole object constraint and the mutual exclusivity constraint. The whole object constraint claims that, unless there is any other direct evidence otherwise, children assume a novel word as referring to a whole object. The mutual exclusivity enables the learning of other types of words, parts, properties and actions. The mutual exclusivity blocks the whole object bias constraint when children already have a name for an object. The constraints theory's main proposition is that children assume, a priori, certain kinds of mechanisms or connections between language and the world.

It is important here to emphasize this dissertation's previous reference to the object bias and the lexical contrast (or mutual exclusivity) as possible solutions to the reference problem. Furthermore, as just mentioned, the constraints approach assumes the a priori existence of a mechanism that helps children solve the problems they must face when learning the meanings of words. However, children's propensity to acquire nouns early in development is very likely to have an explanation other than a priori whole object constraint. Children might learn many nouns early in development simply because whole concrete objects are so salient and important in their social interactions with other persons (Tomasello, 2003). In terms of mutual exclusivity, many studies (Clark and Svaib, 1997; Deak and Maratsos, 1998) have demonstrated that children would not accept two names for the same object, unless they understand that an adult is attempting to express different perspectives on that object. However, this is not the case for bilingual children who produce translation equivalents in their very first lexicons, possibly because they know they are acquiring two distinct lexicons (Holowka et al., 2002).

One of the main problems of the constraints approach is that it attributes too much pre-existing mental structure to young children (Nelson, 1988). Nelson (Nelson, 1988) proposed that if constraints are innate they should be invariant across situations and individuals. Some authors (for example, Golinkoff et al., 1994), who used the term “principles” instead of “constraints”), in response to these kind of criticisms, have proposed that those constraints are learned, that is, derived from the same children’s word learning experiences. However, the theorist proposing learned constraints or principles does not explain when or how these are learned; there is no explanation of where the principles come from or how they developed, unless they are explained as innate mechanisms. The most troublesome problem for the constraints/principles approach is that it is limited to concrete vocabulary, such as object labels and simple actions and attributes, whereas word learning involves terms denoting abstract entities and relations that are not approachable from the kind of rules that constraints/principles theories propose (Wittgenstein, 1953). Evidence of this comes from languages such as Korean or Chinese, in which children begin by learning primarily verbs rather than nouns (Choi and Gopnik, 1995).

Nelson (Nelson, 1988) has emphasized that the social context in which language is acquired provides relevant information on the possible meanings of new words. The word learning constraints proposals ignore the social and linguistic context of word learning (Bloom, 1997). As far as language is a symbolic communicative ability these factors should not be overlooked.

1.1.4.3.Social-pragmatic theory

This theory focuses on children’s ability to interpret and infer the communicative intentions of others. The social-pragmatic theory, like the constraints/principles theory, recognizes that associative learning is not sufficient for the acquisition of word meanings. Proposed by Tomasello (Tomasello, 1992; Tomasello, 2003), this theory focuses on the question of how children can understand others’ communicative intentions, and thus how they infer the meanings of words. In the real world there are numerous social and situational clues to the referential intentions of speakers, and infants are highly sensitive to them. This theory recognizes the importance of the informational richness of the social environment in which children learn language. In social-pragmatic theory the focus is on two aspects of the word learning process; namely, the structured social world in which children are born and the social-cognitive capacities of children to participate in this social world (Tomasello, 2003).

Children are born in a cultural environment in which they get involved directly with their parents in regular routines and events, such as feeding, diaper changing, bathing, interactive games, park trips, and many other activities. These routines are recurrent, objects and actions appear, disappear and reappear, and adults are congruent in their use of language in the same contexts. Children have certain social-cognitive abilities that allow them to participate in these situations, which serve as frames for language acquisition. Participation with another person in cultural activities requires the ability to coordinate attention to the person with attention to the objects that person is interacting with, and in many cases, to assume that person's perspective of the object (Tomasello, 2003). The social-pragmatic view highlights the role of parent-child interaction in word learning (Nelson, 1988).

This theory proposes that, to learn the communicative significance of a linguistic item, the child has to engage in a two-level, social-cognitive process. First, a child must establish a common ground with an adult. The routines and events in which both are involved are the joint attentional frames within which the child must read the adult's specific communicative intention when using a particular linguistic item. Thus, joint attention and intention-reading are foundational processes for lexical acquisition. Tomasello (Tomasello, 2003) argues Quine's hypothetical "gavagai" situation is an unrealistic one, because in the way it is formulated there is no shared culture, intentional situation or any other background to the native's communicative intention. For instance, if the linguist knew they were looking for the native's pet rabbit, the linguist would interpret *gavagai* as the proper name of the rabbit and not as a common noun for the class of rabbit or for some part of it. In real situations, children are involved in social interactions in which they share a common ground with their interlocutor and this common ground restricts the space hypothesis without any dedicated constraints or principles.

Several studies have demonstrated that children learn a direct label for an object when an adult is intentionally referring to that object (Baldwin, 1989; Baldwin et al., 1996). In Baldwin's studies, the 18-month-old had to shift his/her attention to the object on which the adult was visually focused in order to learn the new word. Furthermore, in studies from Tomasello and colleagues (Tomasello and Barton, 1994; Tomasello et al., 1996), children had to discern the adult's communicative intentions in using a new word by employing a variety of sophisticated social-pragmatic cues (for further discussion of these studies, see the next section). Interestingly, several studies have demonstrated the learning of words types other than nouns, for example verbs, through these processes of joint attention and intention-reading. For instance, Tomasello and Barton (Tomasello and Barton, 1994) performed an experiment in which an adult announced her intention to "dax Mickey Mouse" and then performed one action accidentally and another intentionally. Twenty-four-month-old children learned the word for the intentional action, but not the accidental one, regardless of which came first in the sequence. Furthermore, in another study, Tomasello and Akhtar (Tomasello and Akhtar, 1995) demonstrated how children use a variety of cues to read adults' intentions to differentiate objects and actions. In their study, an adult showed a group of children a curved pipe, down which objects could be thrown. In one condition, the adult threw a novel object down the pipe, then threw another object, and then announced "Now, modi" as he/she threw a third novel object down the pipe. In this condition, 24-month-olds thought *modi* was the name of that object. In another condition, the adult took a novel object and did one thing with it, then another thing, and then announced "Now, modi" as he/she threw it down the pipe. In this condition, the children thought *modi* was the name of the action of throwing objects down a pipe. In each case the children assumed the adult was talking about the entity, either object or action, that was new in the communicative situation.

In the social-pragmatic view, the acquisition of language does not need external linguistic constraints because children are always participating in and experiencing particular social contexts, and these social contexts serve to constrain the interpretative possibilities. This theory does not deny the existence of some word learning principles that are the result of children learning their first words. Principles like lexical contrast and principles of grammar are relevant to lexical acquisition. The first of these helps young children to specify word meanings more precisely. Then, linguistic contexts help later word learning. The social-pragmatic theory emphasizes that the foundational skills for word learning are social-cognitive skills, and all other participating skills are built on this foundation (Tomasello, 2003).

1.1.4.4.The Emergentist Coalition model

Taking the previous theories as a base, Hollich et al. (Hollich et al., 2000) presented a new theory of word learning, the Emergentist Coalition theory (see Figure 1.2). The authors argued that current theories of word learning have emphasized a single word learning strategy over others; in contrast, they proposed a hybrid view where word learning is seen as the emergent product of multiple factors. The model makes three assumptions: (1) children detect and utilize multiple cues for word learning such as attentional, social and linguistic, (2) their reliance on these cues changes over the course of development, thus differential weights are given to these cues over the course of lexical acquisition, and (3) children develop emergent principles of word learning, which guide subsequent word acquisition. These principles change from domain-general to domain-specific.

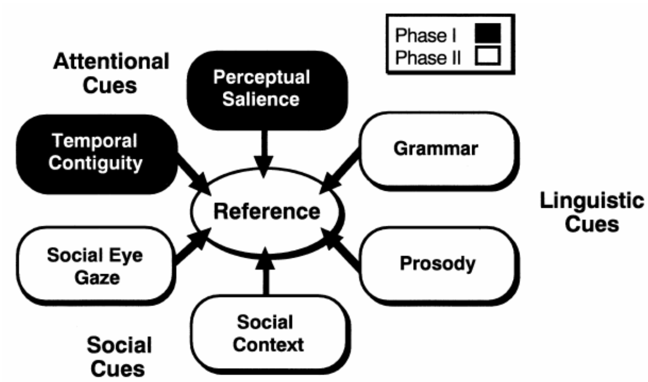

Figure 1.2. The Emergentist Coalition Model: Children shift from a reliance on attentional cues, like perceptual salience, to a greater dependency on social and linguistic cues, like eye gaze and grammar. (From Hollich et al., 2000).

The authors hypothesized that children utilize both perceptual and social cues in word learning. Initially, perceptual cues are more heavily weighted and, thus, infants do not use social cues. Later, infants begin to use social cues to learn words, and they become better at discovering and using the intentionality of adults in word learning (Hollich et al., 2000). Several studies (Hollich et al., 2000; Pruden et al., 2006) have supported this view. Learning words requires that children attend to social information (like eye gaze direction) and read the intentions and communicative intentions of other persons. The role of social intent in word learning seems to be well established. By way of example, Baldwin et al. (Baldwin et al., 1996) found that 18-month-olds learned a name for a novel object when the speaker's intent to name it was clear. Although it is unquestionable that attention to social intent is fundamental to rapid vocabulary learning, Smith (Smith, 2000) argues that social cues are just attentional cues that heighten an object's salience relative to its surroundings. At any rate, Smith continues, words are learned in a simple associative manner. Hollich et al. (Hollich et al., 2000) investigated the effect of social against perceptual cues in word learning in 12-, 19- and 24-month-olds. Children were presented with novel objects, one interesting and one boring, and were prompted to explore the objects. The objects were then placed side by side on a display board while the experimenter looked at, pointed to, and labeled either the interesting or boring toy. For 19- and 24-month-olds, attention to social information was sufficient to guarantee word learning irrespective of whether the speaker labeled the object that, from the infant's perspective, was interesting or boring. However, 12-month-olds showed a different pattern. Social information was necessary, but not sufficient, to ensure word learning. They could learn the novel name only when perceptual and social cues were coincidental and the experimenter labeled the interesting object; when the experimenter labeled the boring object, no word learning occurred. Pruden et al. (Pruden et al., 2006), using the same method as Hollich et al. (Hollich et al., 2000), studied word learning in 10-month-olds when social and perceptual cues were put into conflict. They found that children were insensitive to social cues; they used only the perceptual salience of the objects. Infants mismapped the novel word to the interesting objects even when the speaker named the boring objects. The authors proposed that word learning develops along a continuum. At 10 months, infants are not sensitive to social intent and learn words associatively. A little further along, at 12-month-olds (Hollich et al., 2000), the children are sensitive to social cues but cannot directly utilize them for word learning. Yet, they do not mismap the label for the boring toy to the interesting toy. Completing the continuum are the 1.5-2-year-olds who have mastered the process of word learning and use the social intent of the speaker to attach a label to the boring object (Hollich et al., 2000). It is not until children understand the intentionality of others that they can recognize the relevance of those intentions for learning words. The shift from perceptual to socially-influenced word learning may also explain why early word learning is so slow relative to the fast learning that occurs after a child is 18-months of age (Pruden et al., 2006). In these studies, the infants had to shift their attention to what the adult was focused on visually in order to learn the new word. However, there is evidence that children use more complicated social cues to infer the communicative intentions of adults. For instance, Tomasello and colleagues (Tomasello et al., 1996; Tomasello and Barton, 1994) investigated the effect of social cues in learning new object labels. In the context of a finding game, an adult announced his/her intention to “find the toma” and then searched some buckets, all of which contained novel objects. The adult searched until he/she found the desired object. Sometimes he/she found it in the first bucket, while sometimes he/she rejected unwanted objects by scowling at them and putting them back into the bucket, repeating this until the desired object was found. Children 18 and 24-month-old learned the new word for the object the adult intended to find (indicated by a smile and a termination of the search) regardless of how many objects were rejected during the search. At 18-24 months children can read the communicative intentions of adults, and so they are able to learn new object labels from them in a variety of complex, non-ostensive situations (Tomasello, 2003). Children seemed to use both social and attentional cues for word learning and the respective weight they gave to these cues showed evidence of shifting over time. Furthermore, these studies showed that children, by 24 months of age, overcame competing cues and relied on the speaker’s attentional focus. In contrast, 12-month-olds seemed to learn words best only when they coincided with their own attentional focus. Earlier, at 10 month of age, children seemed to rely exclusively on attentional cues (salience in that case) in order to learn a new word. These studies supported the three assumptions of the Emergentist Coalition model; (1) infants, even at the youngest age tested, showed sensitivity to multiple cues in the word learning situation; (2) across ages, there was a developmental trend, in which children gradually moved from a reliance on attentional cues to a reliance on social cues and, (3) children started by predominantly learning words that coincided with their own perspective and only later were able to learn words from another’s perspective.

Finally, even young children pay attention to the syntax of a word when determining what the word means. Thus, syntactic cues can help children learn words belonging to a range of different categories. For example, in one experiment, infants who spoke only in single words were seated in front of two television screens, each of which featured a pair of adults dressed up as Cookie Monster and Big Bird from Sesame Street. One screen showed Cookie Monster tickling Big Bird; the other showed Big

Bird tickling Cookie Monster (see Figure 1.3). A voice said, "Oh, Look!!! Big Bird is tickling Cookie Monster!! Find Big Bird tickling Cookie Monster!!" (or vice-versa). The children must have understood the meaning of the ordering of subject, verb, and object, because they looked more often at the screen that depicted the scene the voice described (Hirsh-Pasek and Golinkoff, 1991).

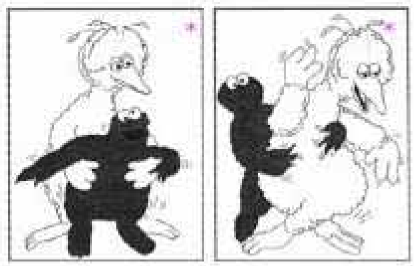

Figure 1.3. Left: Big Bird tickling Cookie Monster. Right: Cookie Monster tickling Big Bird.

The Emergentist Coalition model (see Figure 1.2) unifies the many theories of word learning into a single explanation and provides a common ground in which attentional, social, and linguistic evidence can be considered together.

1.2. Second Language Acquisition

The ability to learn a language does not disappear once our mother tongue is acquired. In fact, many people know and learn more than one language in their lives. Nonetheless, this capacity to acquire a language changes after puberty and becomes less efficient (Klein, 1996). The study of second language acquisition provides some insight into common mechanisms shared by first and second language learning processes. However, at the same time, it shows how and why the two differ, including why it is rare that a second language learner attains a native like level, why certain aspects of language are achieved more efficiently than others, and how the mother tongue and social and biological development influence second language acquisition. This section will discuss second language acquisition and compare to first language learning.

1.2.1. The Critical Period Hypothesis for language acquisition

The Critical Period Hypothesis contributes to a long-standing debate in linguistics and language acquisition over the extent to which the ability to acquire language is biologically linked to age. The hypothesis claims that there is an ideal time window to acquire language in a linguistically rich environment, after which it is no longer possible. The Critical Period Hypothesis states that the first few years of life is the crucial period in which an individual can acquire a first language if presented with adequate stimuli. If language input does not occur until after this time, the individual will supposedly never achieve a full command of language.

The evidence for such a period is limited and support largely comes from analogies to other critical periods in biology, such that in visual development, but nonetheless it is widely accepted. The nature of the critical period has been one of the most debated issues in psycholinguistics and cognitive science for decades. A sensitive period rather than a critical one have been suggested. The term sensitive period has been used to make a distinction between periods with an abrupt decline (critical) versus periods with a more gradual decline (sensitive). The distinction between the terms “sensitive period” and “critical period” is also used to distinguish periods after which no plasticity remains and normal development is no longer possible (critical periods) from periods after which some plasticity remains and under special circumstances recovery to a certain degree is possible (sensitive periods). In spite of these distinctions, recent research has shown that most critical periods in many behavioral domains involve gradual declines in learning and great individual variation. Most researchers use the term critical period for all such periods, or use both terms interchangeably, as we will do throughout the text.

The Critical Period Hypothesis was first proposed by Wilder Penfield and Lamar Roberts in 1959 (Penfield and Roberts, 1959), and was popularized by Eric Lenneberg in 1967 with the Biological Foundations of Language (Lenneberg, 1967). Penfield and Roberts (1959) and, later, Lenneberg (1967) introduced and elaborated the idea that there is a loss of flexibility or plasticity of the brain with age. Lenneberg proposed brain lateralization at puberty as the mechanism that ends the ability of the brain to acquire language. He claimed that if no language is learned before then, it can never be learned. The Critical Period Hypothesis was based on different types of evidences: (1) from feral and/or abused children who grew up without being exposed to human language in childhood and who did not acquire language normally after they were rescued. The most highly scrutinized of these cases is that of Genie, a girl who was deprived of language and social interaction until she was discovered at the age of thirteen (Curtiss, 1977). Her lack of linguistic competence, particularly in syntax, after seven years of rehabilitation supports the Critical Period Hypothesis. However, the abnormal conditions under which Genie was reared have led some investigators to question whether her language difficulties have resulted exclusively from her lack of linguistic exposure during early life. (2) Evidence from deaf children whose development in spoken language stopped after puberty also supports the hypothesis. (3) Evidence that children with aphasia recovered much better than adults with aphasia backs it up, as well.

Studies of deaf children learning American Sign Language (ASL) provide a reliable source of evidence for the Critical Period Hypothesis. Newport and Supalla (Newport and Supalla, 1987) studied ASL acquisition in deaf children differing in age of exposure; few were exposed to ASL from birth, while most of them learned ASL at school. Results showed a linear decline in performance with increasing age of exposure; children exposed to ASL from birth performed better than late learners on all production and comprehension tests. Similarly, Mayberry and Fischer (Mayberry and Fischer, 1989) reported that native and non-native acquisition produce different effects on sign language processing. Non-native signers who first learned to sign in adolescence were overall less accurate, produced more errors and comprehended less than native signers who began signing in early childhood. These studies thusly provide direct evidence that language learning ability decreases with age. However, the declines were shown to be linear, with no sudden fall of ability at a certain age, as would be predicted by a strong Critical Period Hypothesis

The Critical Period theory has also been extended to second language acquisition (SLA). A strong relationship between the age of exposure to a language and the ultimate proficiency achieved in that language has been shown (Oyama, 1976; Mayberry and Fischer, 1989; Johnson and Newport, 1989; Long, 1990; Newport, 1990). Older learners of a second language (L2) rarely achieve the native-like fluency of younger learners. While the window for learning a second language never completely closes, certain linguistic aspects appear to be more affected by age than others. For example, adult second language learners almost always retain a foreign accent (Oyama, 1976). Yet, the acquisition of vocabulary and semantic processing occur relatively normally in late learners. Thus, critical period effects appear to focus on the formal properties of language (phonology, morphology and syntax) and not the processing of meaning (Newport, 2002). Even within the formal properties of language, various aspects may be more or less dependent on the age of language exposure (Johnson and Newport, 1989; Newport, 1990). Late learners show, on average, a lower level of performance in many aspects of language, though some individuals may approach the proficiency of early learners (Coppieters, 1987; Birdsong, 1992; White and Genesee, 1996).

Pulvermüller and Schumann (Pulvermüller and Schumann, 1994) proposed that biological factors explain why the acquisition of phonology and syntax is easy early in life but difficult with age. They claim that myelination reduces plasticity in the language areas of the brain until around puberty, and that this reduction or loss of plasticity in the brain is the key factor in explaining effects of age on language acquisition. They propose that neuronal assemblies corresponding to phonological and syntactic knowledge are restricted to the perisylvian language cortex, while those corresponding to semantic and pragmatic knowledge are present throughout the entire cortex (Pulvermüller and Schumann, 1994). Maturation of brain areas proceeds from primary cortices toward higher order association cortices; thus plasticity is reduced first in perisylvian areas, so that later learning affects acquisition of grammatical and phonological abilities most strongly. Pulvermüller and Schumann (1994) agree that even if plasticity were related to learning, it could only account for the better performance of younger learners and would not explain the great variation in ultimate achievement in L2 among older learners. However, they suggest that motivation plays a determining role in the success of L2 acquisition, noting that all younger learners, but only some adults, will be highly motivated to learn an L2. Nevertheless, the question of whether there is a critical period of language acquisition continues to be controversial.

Effects of age of acquisition have been shown in both first and second language acquisition, independent of modality. One important question is how these effects compare. Mayberry et al. (Mayberry et al., 2002; Mayberry and Lock, 2003) examined this question, comparing normal and deaf individuals' acquisition of English or ASL as either a first or second language. English grammatical abilities were investigated for normal and deaf adults who either did or did not have linguistic experience (spoken or signed) during early childhood. They tested two groups of adults who had learned ASL at school between the ages of 9 and 15. One group was born able to hear, experienced spoken language in early life, and then learned ASL after becoming profoundly deaf. The second group was born profoundly deaf and had little experience of language before being exposed to ASL in school. The results showed that the age of first language acquisition had a significant effect on language acquisition, while language modality did not. The onset of language acquisition in early life is highly related to the ability to learn any other language throughout life (Mayberry et al., 2002; Mayberry and Lock, 2003). These findings support the postulated critical period for language by suggesting that a lack of language experience in early life compromises the capacity to learn any subsequent language.

If there were a critical period for learning, it would have to have certain characteristics. First, there would have to be a negative correlation between L2 proficiency and age of acquisition. Researchers have postulated that a critical period for language learning would have an abrupt end, at a defined and consistent age (Bialystok and Hakuta, 1994). The second precondition is that no late second or foreign language learner would be able to attain a level of success comparable to that of native speakers (Birdsong, 1992; White and Genesee, 1996). Third, language learning limitations would result in the same relation between age and proficiency for different first language/second language (L1/L2) combinations (Birdsong and Molis, 2001).

1.2.1.1. The shape of the age effects on SLA

One of the most important studies dealing with the assumption that there should be a linear relationship between the age of language acquisition and a speaker's accuracy in that language is that of Johnson and Newport (Johnson and Newport, 1989). In this study, 46 adult Chinese and Korean second language learners of English were studied. They were divided into four groups, based on their age of arrival (AoA) in the United States. The control group consisted of native speakers of English. All participants were given a grammaticality judgment test designed to test different morphosyntactic rules. Analyses of the results showed that there was a significantly strong relationship between age of arrival and performance. The youngest group (AoA 3-7 years-old group) was the only group that did not differ significantly from the native group. There was a linear decline in proficiency for the AoA 8-10 and AoA 11-15 groups. The correlation between AoA and performance was higher for the AoA < 15 group. In the AoA 17-39 group, on the other hand, there was no longer a significant correlation between test scores and AoA, and there was a large intersubject variability (see Figure 1.4c). Johnson and Newport conclude from these results that there is a maturationally determined critical period for second language acquisition, which closes down after puberty. However, this study and its conclusions have been criticized. Bialystok and Hakuta (Bialystok and Hakuta, 1994) reanalyzed the data from Johnson and Newport's study. They showed that when the subjects were classified differently according to their AoA, i.e. a group with AoA < 20 and a group with AoA > 20, the correlation between AoA and proficiency was the same for the younger group and almost significant for the older group (see Figure 1.4a).

Figure 1.4. Different patterns of age effects in second language acquisition.

Birdsong and Molis (Birdsong and Molis, 2001) used the original materials from the Johnson and Newport study with Spanish learners of English, divided into early arrivals (AoA $\leq$ 16) and late arrivals (AoA $\geq$ 17). They found a ceiling effect for learners with AoA < 16 and a significant correlation between AoA and performance on the grammaticality judgment task for the late arrival group (see Figure 1.4b). The effects found in this study can be considered as evidence against the Critical Period Hypothesis. The meta-analysis by Birdsong (Birdsong, 2005) of L2 age effects reaches three main conclusions: (a) in all analyses of pooled data from early and late arrivals, age effects persist across AoA; (b) in analyses of disaggregated samples, most studies find significant AoA effects for the late learners; and (c) in analyses of early-arrival data alone, AoA effects are inconsistent.

1.2.1.2. Can late learners attain native-like proficiency in SLA?

The second assumption related to the Critical Period Hypothesis is that no late second language learner should be able to achieve a native level of proficiency. Results from studies on native-like attainment in second language acquisition vary a great deal. For pronunciation, it has been shown that it is possible to achieve a native speaker level (see Bongaerts, 1999; Bongaerts et al., 1997; Bongaerts et al., 2000; Moyer, 1999; Birdsong, 2003). For morphosyntax, there are many studies in which all late learners investigated deviated significantly from native speakers (Johnson and Newport, 1989; Coppieters, 1987; Hyltenstam, 1992). However, there are also studies in which certain late learners performed at a comparable level to native speakers (Birdsong, 1992; White and Genesee, 1996; McDonald, 2000).

Furthermore, it must be noted that some studies have reported native-like proficiency attainment in older learners but not in younger ones. Results from McDonald (McDonald, 2000), for example, showed that two adult Spanish learners, as well as nine early Spanish learners of English, performed like native speakers, whereas many young Vietnamese learners did not and had problems that were similar to those of the adult Spanish learners. Birdsong and Molis (Birdsong and Molis, 2001) found one late learner (AoA > 17) in their study that fell within the range of native speakers.

In studies by Coppieters (Coppieters, 1987) and Hyltenstam (Hyltenstam, 1992), the scores of very advanced late learners differed from those of native speakers. In other studies with highly-proficient late learners, including those of Birdsong (Birdsong, 1992), White and Genesee (White and Genesee, 1996) and Hyltenstam and Abrahamsson (Hyltenstam and Abrahamsson, 2003), some participants attained native-like proficiency in syntax.

The disparity of results and the fact that only a small percentage of late learners attain a native-like level of proficiency in a second language make it difficult to interpret results suggesting a conclusion on the ability of late learners to attain a native level of proficiency. Moreover, differences in participant selection criteria, including their level of proficiency or their AoA independent of proficiency, add more difficulties to the question of whether or not native-like proficiency can be achieved by second language learners.

1.2.1.3. The role of the mother tongue on SLA

The third assumption in the Critical Period Hypothesis is that the effect of the typological distance between the L1 and the L2 should not interact with the relation between AoA and L2 proficiency. In other words, the age function should be the same for all L2 learners groups, independent of the typological distance between the L1 and the L2 (Birdsong and Molis, 2001).

Johnson and Newport’s study (Johnson and Newport, 1989), along with some of the replications of their research (McDonald, 2000; Birdsong and Molis, 2001), shows that the relationship between age of arrival and proficiency does not stay the same between different language pairs. McDonald (McDonald, 2000) compared Vietnamese learners of English with Spanish learners of English. The two Vietnamese groups (AoA < 5 and AoA 6-10) differed significantly from the native speakers in accuracy, but did not differ significantly from each other, whereas the early Spanish learners (AoA < 5) did not differ significantly from the native speakers. This suggests that the age function for the Vietnamese learners looks rather flat for AoA < 10, whereas Johnson and Newport (Johnson and Newport, 1989) found a strong correlation between AoA and proficiency until puberty. Birdsong and Molis (Birdsong and Molis, 2001) studied Spanish learners of English and found a ceiling effect for learners who arrived in the United States before the age of 16 and an inflection point in the age function at age 27.5. These studies indicate that the age function is different depending on the typological distance between L1 and L2, and thus the shape of the age function is not exclusively determined by biological factors.

1.2.1.4. Neural organization for late-learned languages

One of the most basic research issues in cognitive neuroscience is whether processing in the L2 is accomplished in the same way as processing in the L1. Age of acquisition also influences the way language is represented in the brain. Neural organization for late-learned languages is less lateralized and highly variable from individual to individual (Perani et al., 1996; Weber-Fox and Neville, 1996; Kim et al., 1997). In contrast, studies from early bilinguals or highly-proficient late bilinguals report congruent results for native and second languages (Kim et al., 1997; Perani et al., 1998).

Some results of neuroimaging studies with second language learners provide contradictory evidence with respect to the Critical Period Hypothesis for SLA. If late learners are shown to process their second language in different brain areas than early learners, this could support the Critical Period Hypothesis for L2 acquisition. Studies using PET (position emission tomography) and fMRI (functional magnetic resonance imaging) could shed light on the brain organization for L1 and L2. Both PET and fMRI techniques indirectly measure the hemodynamic response related to neural activity in the brain. In PET studies this is measured by injecting into the subject a short-lived radioactive tracer isotope. In fMRI studies, magnetic changes are detected resulting from changes in local blood oxygenation levels. If there is more blood in a certain region of the brain during the test condition than during the rest or control condition, this is interpreted as activation of this brain area. Both techniques are quite accurate at localizing brain activation, but both have a poor temporal resolution. One advantage of fMRI over PET is that the former does not employ radioactive tracers.

Two production studies that compared early and late bilinguals, both using fMRI, report contradictory results. Kim et al. (Kim et al., 1997) compared participants who had been exposed to two languages during early infancy to participants who started learning their L2 after puberty. The main findings of this study was that, in late learners, L1 and L2 were represented in different parts of the inferior frontal regions and in the same regions in the temporal lobe, whereas for early learners overlapping parts were activated in both regions for both languages. On the other hand, Chee et al. (Chee et al., 1999) compared early and late Mandarin-English bilinguals and did not find differences in activation for either language, in either group.

Comprehension studies also provide contradictory results. Two studies (Perani et al., 1996; Dehaene et al., 1997) found differential activation between natives and low-proficiency late learners. Dehaene et al. (Dehaene et al., 1997) studied late low level proficiency French-English bilinguals in an fMRI experiment. They found a different pattern of activation for L2 than for L1. Perani et al. (Perani et al., 1996) did a similar experiment using PET, in which late Italian-English low-proficiency bilinguals were tested. In addition to listening to the participants' L1 and L2, the researchers also measured brain activity as they listened to Japanese (an unknown language). Whereas the activation pattern for English and the unknown language was the same, the activation for listening to L1 was more extensive.

In another PET study, Perani et al. (Perani et al., 1998) compared early and late L2 learners with high levels of proficiency. Spanish-Catalan bilinguals who acquired Catalan before the age of four were compared to high proficiency Italian-English bilinguals who acquired English after the age of ten. The results showed a similar activation pattern for both languages and for both types of learners. A comparison between the late high-proficiency bilinguals from this study with the late low-proficiency bilinguals from Perani et al. (Perani et al., 1996), showed that highly proficient bilinguals had a different pattern of activation for L2 than late bilinguals with a low proficiency level (highly proficient late bilinguals showed activation in the temporal poles and the left middle temporal gyrus whereas those with low proficiency did not). These results suggest that proficiency might be more important as a determinant of cortical representation than age of L2 acquisition.

Similar conclusions can be drawn from ERP (event related brain potentials) studies (Hahne, 2001; Hahne and Friederici, 2001; Stowe and Sabourin, 2005). ERPs are small voltage fluctuations of electrical brain activity in a continuously measured electroencephalogram (EEG). ERP are time-locked to an external event and averaged over many trials in order to reduce the signal-to-noise ratio. ERP components can vary on amplitude, topography, latency, and polarity. Compared to PET and fMRI, ERPs technique has a good temporal resolution (within the millisecond range), but is much less accurate at locating brain activation. Four important ERP components that have been found for native speakers in the domains of syntax and semantics are the N400, the P600, the LAN (left anterior negativity) and the ELAN (early left anterior negativity). The N400 is a centropartietal negative deflection at around 400 milliseconds (ms) after the presentation of a semantically anomalous word. The P600 is a positive deflection at about 600 ms after the presentation of a syntactic anomaly. The LAN is a negativity occurring at the 300-500 ms time window and is more pronounced at the anterior or left anterior electrodes. It is elicited by morphosyntactic errors. The ELAN is a left frontal early negative deflection elicited by word category violations.

With respect to L2 comprehension, ERP evidence suggests that lexico-semantic processing in proficient L2 speakers and native speakers are not qualitatively different. Ardal, Donald, Meuter, Muldrew, and Luce (Ardal et al., 1990) found in L2 speakers an N400 in response to semantic violations in sentences that peaked later compared to the L1. Subsequent studies using comparable paradigms obtained similar results, namely that L2 speakers showed similar N400s to those from native speakers (although they were delayed in some cases) (Hahne, 2001; Hahne and Friederici, 2001; Weber-Fox and Neville, 1996; Moreno and Kutas, 2005).

Age of acquisition appears to have a more pronounced effect on grammatical processing than on semantic processing (Weber-Fox and Neville, 1996). Weber-Fox and Neville (Weber-Fox and Neville, 1996) compared syntactic and semantic anomalies in an ERP study with Chinese-English bilinguals. They divided their participants into five AoA groups (participants were not selected on the basis of their proficiency). Results showed that, whereas for the semantically incorrect sentences all participants who had arrived before the age of eleven performed like native speakers, there was a linear decrease across AoA groups for the syntactically incorrect sentences in the behavioral data. For the semantic condition, the N400 was delayed for participants with AoA later than 16. All other groups had a normal N400 pattern. For the syntactic condition, the ELAN found for monolinguals was absent in all learners. The P600 effect was delayed for the AoA 11-13 group and absent for the oldest learners.

Pallier et al. (Pallier et al., 2003) addressed the issue of brain plasticity and the role of the L1 by looking at adults who were adopted as children and who reported having completely forgotten their first language. Specifically, they tested Korean participants who were adopted by French speaking families between the ages of 3 and 8. Participants had to listen to French, Korean, Japanese and Polish sentences and fragments and decide whether a fragment had appeared in the sentences. The control group consisted of French monolingual participants. The fMRI data showed no significant differences between the Korean and French participants. In the individual analyses, none of the Korean participants showed any Korean specific activation. These results suggest that when L1 input is no longer available for a long period of time the L2 seems to be able to take over the role of the L1.

These studies and others, including Johnson and Newport's from 1989, suggest that in late SLA, grammar is more difficult to learn than lexical knowledge. Ullman considered that the results from the previous fMRI and ERP's studies supported the declarative/procedural model (Ullman, 2001c;Ullman, 2001a). In this model, lexical entries are stored in declarative memory (explicit memory), while other grammatical processes (including syntax, morphology, non-lexical semantics and phonology) depend on procedural memory (implicit memory). Under the declarative/procedural model, it is assumed that the processing of lexicon and grammar are affected differently by age of acquisition in SLA (Ullman, 2001b; Ullman, 2004). At later ages, the grammatical/procedural system is less available than lexical/declarative memory (Ullman, 2001b). Initially, grammatical representations that may be computed by the grammatical/procedural system in L1 tend to depend on lexical/declarative memory in L2. However, data suggest that at least some grammatical abilities that depend on the grammatical/procedural system in L1 can be learned and used by this system in high-proficiency L2 learners. In sum, the model posits that at least certain complex representations that may be computed by the grammatical/procedural system in L1 tend to be similarly computed in high-proficiency L2 learners, but stored in lexical/declarative memory in low-proficiency L2 learners.

Taken together, all of the results from neuroimaging studies seem to show that a second language is initially stored in different brain areas and processed differently than the L1. However, with increasing proficiency, the storage and processing of the L2 seems to become more similar to that of the L1, especially in domains such as semantics.

1.2.1.5. An alternative explanation for the age effects on SLA: The Less is More Hypothesis

An important explanatory alternative to the Critical Period Hypothesis can be found in the "Less is More" hypothesis (Newport, 1990; Newport, 1988). This hypothesis proposes that age effects in language acquisition result from changes in working memory with maturation. These changes are biologically determined, but not specific to language. The "Less is More" hypothesis claims that the decrease in language learning ability with age is due to an increase in working memory capacity. Having a small working memory capacity force one to process small units at once and this helps children focus on details, such as specific morphemes. Adults, on the other hand, have a larger working memory capacity and try to analyze large parts at once. Due to the complexity of these larger units, low-level components of language, like specific morphemes, are overlooked.

Kersten and Earles (Kersten and Earles, 2001) found an advantage in learning word meaning and morphology in a simple artificial language for adults starting with simple input over adults starting with complex sentences. In their experiment, adults were exposed to an artificial language consisting of both auditory nonsense sentences and visual, animated events. Some of the participants received the input in a staged fashion with three phases: first, single words were presented along with the animated events, then came sentences composed of two words, and finally three-word sentences were presented. These participants performed better on comprehension tests than those participants who were exposed to a non-staged input presentation. Elman (Elman, 1993) demonstrated that a model learns the grammar of a language better when the model at first processes only small segments of language and later graduates to incrementally longer language segments. These results show that there are benefits from processing limitations in the acquisition of a language.

Rohde and Plaut (Rohde and Plaut, 1999) tested the "Less is More" hypothesis by making a simple recurrent network learn English. They found that a connectionist network learned a language better when it was presented with the full complexity of the language. Although Rohde and Plaut were not able to reproduce Elman's findings, their results question the proposal that staged input or limited cognitive resources are necessary or advantageous for language learning.

In general, all the SLA studies reviewed in this section suggest that further work is needed to explain the range of relevant findings. For example, the fact that vocabulary is more easily acquired than morphology or syntax, and that within syntax some rules are mastered differently among second language learners must be more closely scrutinized (Johnson and Newport, 1989). Furthermore, there are many factors that may play a role in second language acquisition that are presumably different for adults than for children and should be considered, for example anxiety, intelligence, motivation, and attitudes toward a new country, culture and language (see e.g. Bialystok and Hakuta, 1994). One must take into account the fact that early learners might receive more and better L2 input in the same number of years as do late learners. Another problem in comparing late learners with early learners is the interaction between the use of the L1 and the use of the L2. When children start acquiring a language at a very early age, their L1 has not fully developed yet and is not as embedded as it is for older learners; by the time an older learner arrives in a foreign country and begins learning a second language, the more established his/her native language is. Because of this, there is probably less interference from the L1 for early learners and, as a consequence, it is easier for them to reach a high level of proficiency in the L2. In addition, children who live in a foreign country receive their primary education in the language of that country, whereas adults may receive relatively little formal instruction in their second language unless they take classes. In studies on syntax, the typological distance between L1 and

L2 might also account for part of the variation in proficiency sometimes observed in groups of early learners.

1.2.2. Models of bilingual lexicon

The structure and representation of more than one language in memory has been a topic of investigation by bilingual researchers for quite some time. One question central to the research field is whether bilingual speakers have two separate lexicons, one for each language, or one large lexicon that includes both. This question and others, such as what the underlying mechanisms that allow language lexical access and lexical selection are, have not yet received conclusive answers. However, evidence from cross-language semantic priming supports the view of a single conceptual store. Therefore, a general agreement has been reached that conceptual and lexical levels should be handled separately, with the conceptual level being shared by both languages and lexical representations remaining specific to each.

This conceptual and lexical separation is the basis for three hierarchical models, including the Word Association, the Concept Mediation and the Revised Hierarchical models. All of these models share a common structure, which consists of two separate lexical stores and one common conceptual store. The type of hierarchical model is determined by the location and weighting of the links between the L1 and the L2 lexical stores and the conceptual store. Although the two lexicons can interact to various degrees in these types of models, they are nonetheless separate.

The Word Association model (Potter et al., 1984) assumes that there is a direct link between a bilingual's L1 and L2 (see Figure 1.5a). The L1 is directly linked to the conceptual store. Thus, a bilingual speaker might access the meaning of a second language word by first translating that word into L1 at the lexical level and then retrieving its meaning from the conceptual store. The Concept Mediation model (Potter et al., 1984) assumes that there are no direct links between languages at the lexical level, but that both lexicons are connected to a common semantic representation (see Figure 1.5b). In consequence, translation across languages is accomplished by directly accessing the meaning of the L2 word.

In a classic study, Potter et al. (Potter et al., 1984) tested whether translation from one language to another is conceptually mediated as suggested by the Concept

Mediation model. The researchers compared translating words from L1 to L2 with picture naming in L2. Picture naming requires conceptual processing, therefore if translation requires it as well, then performance on both tasks should resemble each other. The Word Association model predicts that L2 picture naming should take longer than translation, as it requires first the retrieval of the concept and, second, the retrieval of the L1 word. In contrast, the Concept Mediation model predicts both tasks will take approximately the same amount of time because they involve similar processes. The results from the study showed that L2 picture naming took about the same amount of time as L1 to L2 translation, and therefore favored the Concept Mediation model.

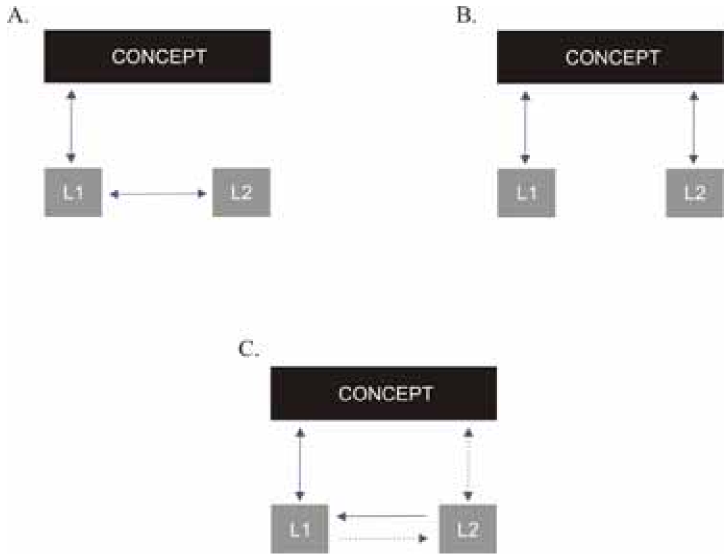

Figure 1.5. A. Word Association Model. B. Concept Mediation Model. C. Revised Hierarchical Model.

In a study by Kroll and Curley (Kroll and Curley, 1988), a group of expert bilinguals and a group of novices each performed translations from L1 to L2 and picture naming in L2. Similar to the results reported by Potter et al. (1984), response times for the more proficient group of bilinguals were equal for both tasks. In contrast, the data from the novice group favored the Word Association model, as picture naming in L2 took the participants longer to perform than translating from L1 to L2. Overall, the results from these studies suggest that beginning and advanced bilinguals may access their two languages differently and a developmental shift can be observed as a function of proficiency in language processing.

To account for this developmental shift, Kroll and Stewart (Kroll and Steward, 1994) proposed the Revised Hierarchical model (see Figure 1.5c). This model proposes two separate but interconnected lexical stores, one for each language. The most critical assumptions of the Revised Hierarchical model are that the lexical links differ in strength, words in each language are linked to a general conceptual store and to each other, and that the links between the lexicons and the conceptual store are bidirectional. The L2 lexical store is connected to the L1 lexical store by strong links and the L1 is connected to the L2 lexicon by weak links. Presumably, these links reflect the manner in which the L2 was learned. For instance, in learning their second language, L2 learners usually associate the new word to their L1 thus creating a direct and strong association to the meaning of their L1 (Kroll and Steward, 1994). In addition to the connections between the two lexical stores, both are connected to one conceptual store. However, the connections between the L1 lexicon and the conceptual store are strong, while the connections between the L2 lexicon and the conceptual store are weak. Because the link between the L2 and L1 stores is stronger and faster than the link between the L2 and the conceptual store, the bilingual is most likely to utilize this link (L2 to L1) to access the conceptual store. The model predicts that on a translation task, bilinguals will be faster to translate from L2 to L1 than L1 to L2, because the stores from L2 to L1 are more strongly associated. This prediction has been empirically supported by studies showing that L2 to L1 translations are faster than L1 to L2 translations (Kroll and Steward, 1994; Kroll and Curley, 1988; Dufour and Kroll, 1995). The model also proposes that during the early stages of L2 acquisition, the learner relies on L1 word to concept connections when ascertaining the meanings of new words in L2. As learners become more proficient in L2, they develop the ability to conceptually process L2 words in a more direct fashion, although the connections between words and concepts are assumed to remain stronger for L1 than for L2 (except for the most balanced bilinguals).

1.2.3. Studies of word learning in adults

For few decades research on language processing has provided us with valuable insights into the processing of different types of linguistic information, such as phonologic, syntactic, semantic, pragmatic and prosodic. A large number of studies have contributed to the understanding of the nature, time course and localization of the subsystems underlying language processing. Nevertheless, the question of how a first language is processed has not yet been completely clarified, thus even less is known about how a second language is processed. One of the critical challenges in second language acquisition research is to elucidate how two or more languages are processed in respect to each other or to the L1. One possibility is that the L2 is supported by a separate system and different processing mechanism than L1. However, it could be the case that L1 and L2 rely on the same (or partially the same) systems and processing mechanisms. As mentioned in the section on the Critical Period Hypothesis, different studies comparing L1 and L2 processing have yielded evidence regarding the similarities and dissimilarities between first and second language processing, emphasizing the influence of various factors, including proficiency, age of acquisition, typological distance between languages, and others. Furthermore, these studies have shown that, while in the lexico-semantic domain, L2 speakers usually attain a native-like level; that is not the case for the syntactic and phonological domain (Oyama, 1976; Johnson and Newport, 1989; Weber-Fox and Neville, 1996; Newport, 2002).

Neurophysiological methods, such as electroencephalography (EEG), magnetoencephalography (MEG), positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), which provide us with a measure of the neural activity in the brain during language processing, make it possible to look at the underlying structures and mechanisms of L2 processing. Despite this advantage, fMRI and PET studies have yielded contradictory results regarding the processing of L2. For instance, some studies point to overlapping regions of the brain that are activated for the processing of L1 and L2 in early learners (Kim et al., 1997; Perani et al., 1998), while reporting differences for late learners (Kim et al., 1997; Perani et al., 1996; Dehaene et al., 1997). Certain studies have shown no differences between natives and late bilinguals (Chee et al., 1999), while others show differences in early learners compared to native speakers (Dehaene et al., 1997). Furthermore, Perani et al. 1998 did not find differences between early and late high-proficiency L2 learners. Rüschemeyer et al. (Ruschemeyer et al., 2005) found a more similar pattern of activation between native and non-native speakers for semantic than for syntactic processing. Evidence provided by other techniques, for instance EEG, have not clarified the question much either. Mainly, studies show that while lexico-semantic information does not differ between native and L2 learners (Ardal et al., 1990; Hahne, 2001; Hahne and Friederici, 2001; Weber-Fox and Neville, 1996; Moreno and Kutas, 2005) grammatical processing does (Weber-Fox and Neville, 1996; Hahne, 2001).

The study of word learning and meaning acquisition in L2 has not received much attention, and the few that have attempted it have used an associative paradigm wherein a new word is paired to a known word (its meaning). However, in the literature that is available, many more studies can be found in which artificial grammar is created and taught to participants. For instance, a study investigating the processing of an artificially miniature language (Brocanto) showed that word category violations elicited an early anterior negativity (similar to the ELAN component) and a P600 in trained participants, whereas untrained participants did not show any ERP effect (Friederici et al., 2002). Moreover, learning related changes, as reflected by an increased proficiency level in the artificial language, were associated with decreased left hippocampal activity and increased recruitment of the left inferior frontal gyrus (pars opercularis, BA 44) (Opitz and Friederici, 2003). However, as this dissertation focuses on vocabulary learning and meaning acquisition (from contextual information), only studies regarding lexico-semantic information learning shall be considered.

Before focusing on the electrophysiological and hemodynamic correlates of the learning of word meanings, it is worth mentioning two studies from Chaffin et al. (Chaffin, 1997; Chaffin et al., 2001), which directly approach the matter of learning new word meanings from sentential context. In the first study, Chaffin (1997) investigated the role of contextual information on the processing of words varying in familiarity. Participants were presented with context sentences including high- and low-, familiar and novel words as targets. Participants were required to first read the context sentences and then perform five tasks, which included: (1) sentence generation (write a new sentence describing an imaginary event using the target word); (2) free association (context words were listed and participants had to write down for each one the first word that came to mind); (3) explanation of the associative relation; (4) superordinate production (participants were asked which kind of thing each of the target words referred to); and, (5) sentence recall (recall the sentence for each target word). Results showed that while associations to low-familiarity and novel words were more likely to be categorical (e.g., persimmon-fruit), associations to high-familiarity words tended to be thematically related (e.g., bumblebee-sting). Although the participants could only rely on the information provided by the context in order to figure out what the new word referred to, participants inferred what type of thing the novel word referred to (definitional information), thus, reporting category responses. Different types of information seem to be stored in memory for familiar and unfamiliar words, and definitional information, or information about category membership, is stored first. Once category membership is understood, attention may shift to different types of relationships (thematic relationships) as the word is encountered in various contexts and, therefore, as familiarity with the word increases. In the study, when a novel word was encountered, subjects tried to determine what kind of thing the novel word referred to; this could be an effective strategy for learning the meaning of novel words because it allows the preexisting lexical information to assist in determining the meaning of the unfamiliar word.

In the next study, Chaffin et al. (2001) studied the ability of participants to use relevant contextual information to develop meanings for novel words. They monitored readers' eye movements while reading pairs of sentences containing a target word, context, and a word related to the target word. The target word varied in familiarity (high, low, or novel) and the context in informativeness about the meaning of the target word (informative or neutral). Participants were required to read a two-sentence passage, in which the target word was embedded in the first sentence (e.g., Joe picked up the **guitar/zither/asdor** and *began to strum a tune*), while the second sentence contained a word that was either a synonym or a category superordinate to the target word (He played the *instrument* to relax). In the first sentence, the target word (in bold) was followed by an informative context (italics) that allowed the reader to infer what kind of thing the target word referred to. The second sentence provided the reader with a definitional associate (italics). Results showed that readers spent more total processing time in the informative context following the novel word than that following the low- or high- familiar ones. Participants also reread the novel target words more frequently and spent a longer total processing time on them. Finally, participants made more regressions out of the context region back to novel target words than back to low-familiar words. The processing of the definitional associate in the second sentence was unaffected by the familiarity of the target word. Therefore, participants inferred on-line during the reading of the first sentence the definitional associates of novel words. In a second experiment, Chaffin et al. manipulated the informativeness of the first sentence context. A new condition was added in which it was replaced with a neutral context that did not indicate the category membership of the target (e.g., Joe picked up the asdor and began to walk home). The second sentence remained the same as in the previous experiment. Thus, only the definitional associate in the second sentence provided information directly related to the meaning of the target word. The results showed that participants spent less initial processing time and less total time on the context regions in this condition as compared to the original condition, in which the first sentence was informative about the meaning of the novel word. Participants were sensitive to whether or not the contextual information was relevant to the task of inferring the meaning of a novel word, thus, taken together the results from both experiments show that participants inferred a meaning for the novel word from contextual information provided in the first sentence in those conditions in which that context was informative. For these conditions, the definitional associate in the second sentence was processed as quickly for novel words as for more familiar words, probably due to the fact that its lexical entry was already activated. In contrast, when the first sentence context was neutral about the meaning of the novel word, readers spent more time on the associate in sentence two and made more regressions back to the first sentence. This shows that participants used the information in the second sentence to establish a meaning for the novel word in sentence one.

The studies from Chaffin et al. demonstrate that readers infer the meaning of novel words on-line using contextual information, and that the initially-generated meaning includes definitional information (about the synonyms or words superordinate to the novel word). This first grasp of the meaning of a novel word helps to place it in semantic space by indicating its similarity to already existing and established lexical entries.

From a different research perspective, Gaskell et al. (Gaskell and Dumay, 2003) addressed the influence of newly-learned words on the processing of existing lexical items. The authors' hypothesis was that "if people learn a new word such as *chatheruke*, the presence of this new word in the mental lexicon should delay the recognition of similar existing words such as cathedral through lexical competition (Gaskell et al., 2003, pp.108)." In the first experiment, participants were familiarized with pseudowords derived from real words (e.g. *cathedruke*, from cathedral). The effects of the newly-familiarized words on the processing of similar-sounding existing words was assessed by measuring the response latencies to the existing items in a lexical decision task. The results showed that existing words were responded to more quickly when a sound-overlapping competitor had been learned in contrast to the condition without the competitor. The immediate effect of the exposure was facilitatory, suggesting that the novel words had activated the representation of the closest real word rather than developing their own lexical representations. Because in the first experiment the authors failed to find learning effects immediately after exposure (assessed by lexical competition inhibitory effects), a second experiment was performed in which participants were repeatedly exposed to and tested on the pseudowords over the course of 5 days. In this second experiment, a new condition was introduced (initial-deviation prime; e.g., *yothedral*), in addition to final-deviation prime (*cathedurke*). The results showed that effects of lexical competition started to emerge on the fourth day and remained on day five, but only for the final-deviation items. Throughout the week, the novel items were gradually developing lexical representations, which were able to join in lexical competition during word recognition.

From these results, Gaskell et al. suggested that the integration of a novel word into the mental lexicon is an extended process in which phonological information is learned quite fast, but full integration with existing items develops at a slower rate. However, in their study they did not investigate the association of form and meaning, which is a critical aspect of lexicalization.

1.2.3.1. Electrophysiological studies of word learning

The most studied ERP component directly linked to lexico-semantic processing is the N400. Kutas and Hillyard (Kutas and Hillyard, 1980) first reported a centro-parietal negativity between 300 and 600 ms poststimulus in response to semantically anomalous words in otherwise meaningful sentences. This component has also been observed for semantically correct words with a low cloze probability as a measure of the expectancy of a specific word at a certain position in a sentence (Kutas and Hillyard, 1984). Semantic priming has also been observed to correlate with the N400 component; a reduction of the amplitude of the N400 is observed for semantically-related words compared to unrelated words (Bentin et al., 1985). Moreover, presentation of non-words leads to an increased N400 (Holcomb and Neville, 1990). Generally, the N400 increases as a function of predictability of a word within its semantic context, ranging from a single word to more general world knowledge (for a review, see Kutas and Federmeier, 2000). Therefore, the N400 has been used as a tool for investigating the nature and time course of semantic processing mechanisms.

McLaughlin et al. (McLaughlin et al., 2004) studied L2 word learning in a group of native English speakers who were learning French as a foreign language. The aim of the study was to account for changes in the ERP components as a consequence of further experience with the L2. The researchers investigated the effects of L2 exposure on the participants' discrimination between L2 words and L2 pseudowords. A group of students who were enrolled in a one-year, introductory French course was evaluated. The group was tested at three different points, one after two weeks of instruction (a mean duration of 14 contact hours), at the middle of the course (a mean of 63 hours) and at the end of it (a mean of 138 hours). Participants were required to perform a lexical decision task on semantically related pairs, semantically unrelated pairs and word-pseudoword pairs. After 14 hours of L2 instruction, McLaughlin et al. found that behaviorally there were no differences between real French words and pseudowords; the participants were not able to report whether or not the targets presented were actual French words. However, although participants seemed to be unable to outwardly differentiate actual French words from French-looking pseudowords, the ERPs for the two types of words showed a different pattern. Interestingly, for all three sessions the N400 showed an increase in amplitude for pseudowords as compared to actual words. Furthermore, the authors found a high correlation between hours of instruction and the amplitude of the N400. When McLaughlin et al. explored the semantically-related and unrelated pairs, they found in session two and afterward a reduction of the N400 for related pairs, that is, even when participants performed poorly behaviorally, an N400 priming effect was present. By session 3, participants' ERP responses were qualitatively similar to native speakers' responses. The control group, which had never studied or been exposed to French, did not show any of these effects.

An important finding of this study is that the inability of participants' to distinguish differences between actual and artificial words in behavioral measures does not necessarily mean that the underlying neural processing mechanisms will find the same results. The results show how neurophysiological measures can add valuable information about the timing and degree of the activation of neural networks, even when physiological correlates are not found behaviorally. The authors suggest that exposure to L2 more rapidly impacts the learning of a second language and its neural representation than traditionally thought.

Similarly, Perfetti et al. (Perfetti et al., 2005) investigated the effects of new word learning. In their experiment, participants first learned the meaning of new words (rare English words) by being presented with the rare word and a brief definition of it. Following this familiarization process, participants made meaning judgments about pairs of words. In the meaning judgment task, a word was first presented that could either be a newly-learned rare word, a rare word that was not taught to the participant, or a familiar word. After the presentation of the first word, a second word that was either semantically-related or unrelated to the first word was shown to the participants, and they had to indicate whether the two words were related in meaning. In total, participants were taught 60 rare words, and after 45 minutes of learning they underwent an EEG session in which they performed the meaning judgment task. The results showed N400 priming effects for both familiar and trained words, but not for untrained words. This provides further evidence on how rapidly the meaning of words may be learned and embedded into the lexico-semantic network.

1.2.3.2. Hemodynamic studies of word learning

Neuroimaging methods have been used increasingly in recent years to investigate language processing. However, a complete neuroanatomical model comprising the many dimensions of language processing has not yet sprouted from the evidence collected from many different language domains. Even so, some consistent brain activations have been reported for various specific aspects of language processing.

For several decades the important role of perisylvian areas in language processing has been clear. Recent neuroimaging techniques have allowed researchers to go beyond lesion and electrocortical stimulation studies and have opened the possibility of studying the brain in vivo, helping to identify correlations between specific brain areas and linguistic processes (Price, 2000). Specifically, the left angular gyrus and left temporal lobe (middle and superior gyri) have been postulated to be involved in the long-term storage of semantic information (Price, 2000). The left inferior frontal cortex has been shown to support the selection, retrieval and integration of semantic information (Bookheimer, 2002). Within the left inferior frontal cortex it has been suggested that anterior portions (Brodmann's area (BA) 45/47) are engaged in semantic processing, whereas posterior portions (BA 44/45) are responsible for the processing of syntax (Dapretto and Bookheimer, 1999; Bookheimer, 2002). Direct intracranial recordings provide a manner in which to solve the lack of clear localization from scalp recordings by successfully localizing cortical activity, which modulates scalp-recorded N400 amplitude. Studies comparing congruous and incongruous sentence completion (McCarthy et al., 1995), related and unrelated word pairs (Nobre et al., 1994; Nobre and McCarthy, 1995), and content and function words (Nobre and McCarthy, 1995) have converged to suggest an N400 generator on the AMTL (anterior-medial temporal lobe).

Breitenstein et al. (Breitenstein et al., 2005) investigated the neural network involved in the acquisition of novel vocabulary. For that purpose they employed an associative word-learning paradigm (Breitenstein and Knecht, 2002) in which pictures of objects were paired with the auditory presentation of pseudowords. Word learning was accomplished through simple statistical association without the participant's awareness of the strategy underlying correct and incorrect pairing. Participants underwent 5 training sessions in which they were presented with both correct and incorrect picture-pseudoword pairs, with correct pairs occurring more often than incorrect pairs. Participants had to decide if the pairing was correct or incorrect, but no feedback was provided to them until at the end of the session when participants were informed about their percentage of correct responses. Thus, participants incidentally learned the novel words by noticing the higher co-occurrence of correct picture-pseudoword pairings. Results from the study reported that participants successfully learned the novel words as shown by a lineal increase of correct responses from block 1 to block 5. Furthermore, the researchers found that left hippocampus and fusiform gyrus activity decreased as a function of block session number, while activation increased in the left inferior parietal cortex (coordinates: -33, -42, 39) from session 1 to session 5. Of these regions, only the left hippocampus correlated with measures of vocabulary learning success and general semantic knowledge. The authors proposed that the hippocampus is involved in an initial binding of information from different sensory modalities, thus contributing to the initial stages of language acquisition; once more advanced stages of semantic expertise are achieved, retrieval of those associations may be mediated by other regions (Squire and Zola-Morgan, 1991). The fusiform gyrus may be also involved in initial integration of cross-modal information, as activity reductions might be a reflection of association strength of visual and phonological information due to practice. On the other hand, a left inferior parietal lobe increase in activation has been connected with the storage of novel phonological associations, thus binding phonological and semantic information. In line with these results, a recent magnetoencephalography (MEG) study provided evidence of left inferior parietal lobe involvement in training-induced picture naming improvements in aphasic chronic patients suffering from anomia (Cornelissen et al., 2003).

Cornelissen et al. (Cornelissen et al., 2004) employed MEG to explore naming-related cortical activity in adults before, during, and after learning new names for new objects. The new objects consisted of ancient domestic tools unknown to the participants. During training, the new objects were associated with phonological and/or semantic information. The participants' task was to learn the name of those objects for which a name was provided. The participants were trained every day until reaching the criterion level (at least 98% of names acquired). Behaviorally, new names were learned equally well when the participants were solely provided phonological information on the objects, or when both phonological and semantic information was provided. However, learning of the new words was successfully attained only for those conditions providing phonological information, as surprisingly no learning occurred when only semantic information was taught. The lack of semantic learning effects might be due to the irrelevance of the semantic information for the naming task. Participants were trained and tested on new names for new objects, thus, semantic information was just additional information. It is likely that the participants obviated the semantic information as the experiment per se focused only on picture-new word learning. The MEG results showed that learning-induced changes emerged within the same regions that were active during the naming of familiar items. In three out of five participants, the learning-related changes were observed in the left inferior parietal cortex. The authors suggested that the left inferior parietal cortex plays an essential role in new word learning, reflecting phonological storage of the learned words, which probably occurs because of the engagement of this region in phonological working memory.

Agreeing with the role of the inferior parietal cortex in the storage of phonological information in verbal short term memory, Golestani and colleagues (Golestani et al., 2002; Golestani et al., 2007) showed a relationship between parietal lobe anatomy and nonnative speech sound learning. In their experiment, participants were trained to perceive nonnative speech sounds. Using voxel-based morphometry, the results showed that faster learners had greater asymmetry (left > right) in parietal lobe white matter volumes and larger white matter volumes of left Heschl's gyrus than slower learners. Furthermore in another study, in which participants were trained to produce nonnative speech sounds, voxel-based morphometry results showed that those participants who more accurately pronounced the foreign speech sounds had higher white matter density in the left insula/prefrontal cortex and in the inferior parietal cortices bilaterally than less accurate participants (Golestani and Pallier, 2007). The results from these studies further support the role of inferior parietal cortex in phonological working memory.

In a PET study employing the same paradigm as Cornelissen et al. 2004, Grönholm et al. (Gronholm et al., 2005) explored the neural correlates of retrieving the names of newly-learned objects. As in the previous experiment, participants had successfully learned the names for the new objects by the last (5^{th}) session. The naming of newly-learned object yielded larger activation in the left inferior prefrontal cortex, anterior temporal areas and cerebellum when compared to the naming of familiar objects. The left lateralized fronto-temporal network is typically engaged in language processing tasks, with the frontal regions more involved with semantic retrieval and integration, and the temporal regions with long-term memory storage. This pattern of activation was interpreted as integration (at least partially) of the newly-learned words into the existing lexico-semantic network. Notwithstanding the fact that the Grönholm et al. study resembled that of Cornelissen et al. (2004), the former failed to find inferior parietal activation related to trained objects naming. The Grönholm et al. study slightly differed from that of Cornelissen et al. in the sense that the latter employed a delayed naming paradigm. Thus, participants had to retain their response in working memory longer than in the former study, which might have enhanced phonological working memory reflected in inferior parietal activation.

In another study, Raboyeau et al. (Raboyeau et al., 2004) taught French speakers 50 names of familiar objects in English over a 1-month period. Two PET sessions were performed, one before and one immediately after the training, in which participants had to name French and English objects. In the first session, participants were shown black and white pictures of animals and man-made tools and their task was to overtly name the objects (two scans of naming in French and two in English). After this first session, participants underwent a computer-assisted lexical learning program for 4 weeks, 5 days a week. In order to facilitate learning, phonological and graphemic information was provided for each object. After the training, participants were scanned again following the same procedure as used in the first PET session. The authors reported a neural network associated with successful learning involving the anterior cingulate and frontal motor cortex bilaterally, cerebellar areas, left insular cortex and right collateral sulcus. Furthermore, participants were behaviorally tested 2 months after the second PET session. Participants who showed strong differences in the number of hit responses between the second and third session were considered bad reminders, while the ones showing small differences were considered as having consolidated the memory traces of the items they had learned, and hence, considered good reminders. For good reminders, increases in activation in the left superior temporal sulcus and left middle temporal cortex were reported and interpreted as reflecting efficient semantic storage of the learned words in semantic memory.

In a recent fMRI study by James and Gauthier (James and Gauthier, 2004), participants were trained to associate semantic information with novel objects. The purpose of the study was to determine which regions supported recent associations of semantic information with novel objects. The type of information associated with the novel objects could be either a semantic feature (such as fast) and a proper name (e.g., Michael) or just a proper name. In this way, all objects were equally familiar to the participants and had a name associated with them, but only some objects had additional semantic information associated with them. After training, the participants were scanned while performing a visual matching task. The authors hypothesized that because semantic association influences visual judgments, the inferior frontal cortex would be involved in the processing of objects associated with semantic features but not for those objects associated only with a proper name. The results confirmed the authors' hypothesis; larger activation of the inferior frontal cortex and the parietal cortex was shown for novel objects associated with semantic features than for either novel objects associated only with a name or for non-trained novel objects.

Brodmann Area	Region	Reference papers
BA 40	Left inferior parietal cortex	1, 2
	Left hippocampus	1
BA 37	Left fusiform gyrus	1
BA 44	Right inferior frontal gyrus	1
BA 44	Left inferior frontal gyrus	3, 5
BA 22/38	Left anterior temporal cortex	3
	Cerebellum	3, 4
BA 24	Bilateral anterior cingulate cortex	4
BA 4/6	Bilateral frontal motor cortex	4
	Left insular cortex	4
BA 20	Right collateral sulcus	4
BA 21	Left superior temporal sulcus/middle termporal cortex[a]	4
BA 2	Left posterior parietal cortex	5

Table 1.1. Main results of the word learning hemodynamic studies. (1) Breitenstein et al. (2005); (2) Cornelissen et al. (2004); (3) Grönholm et al. (2005); (4) Raboyeau et al. (2004); (5) James and Gauthier (2004).

[a]Region found more highly activated only for good reminders.

The few available neuroimaging studies about word learning do not provide enough congruent evidence (see Table 1.1) to enable an initial draft of the network involved in the acquisition of new words. Nevertheless, one has to take in account that the oldest experiment is only three years old, and that the different tasks and approaches employed influence the pattern of results obtained.

1.2.4. The human simulation approach to language learning

In order to simulate how a person's learning machinery is engaged in acquiring new words, Gillette et al. (Gillette et al., 1999) have used the human simulation word-learning paradigm. It was developed with the aim of emulating vocabulary learning in a person acquiring the meaning of new words. Adults or children are exposed to different sources of information (linguistic and extralinguistic), which are used to create the meaning of a new or hidden item. The human simulation paradigm in adults provides a model for the frequent problem of learning a new language with the advantage that conceptual and cognitive growth factors are controlled.

The human simulation paradigm was developed to test the hypothesis that the changes observed in children's vocabularies (from nominal categories to predicate categories, and with increasing abstractness) are due to linguistic-informational developments rather than cognitive developments. To simulate the effects of linguistic development in the absence of cognitive limitations, Gleitman and her colleagues asked adults to identify words from partial information about the contexts in which they occurred or were used (Gillette et al., 1999; Snedeker and Gleitman, 2004). When the adults were limited to the information provided by observation, or situational cues, they could only identify the concrete nouns; like infants when learning their first words, these adults ended up with a vocabulary dominated by nouns. But when given information about the linguistic context, they were able to learn the verbs as well. Specifically, adults viewed a series of silent videotapes of mothers interacting with their children. The adults' task was to identify simple words (frequent nouns and verbs) under varying informational circumstances. A beep or nonsense word occurred at the same instant as the mother uttered the target noun or verb. The results were quite dramatic, only 45% of the nouns and 15% of the verbs were correctly identified when the information provided was limited to observation. In fact, a third of the verbs were never correctly identified, and when considering mental verb identifications, none were correctly guessed. The videotapes provided solely observational information representing one of the first of an infant's information sources for word learning. So as to simulate the vocabulary acquisition process, additional or alternative information was provided to the adults. The authors proposed that after the first stage, in which learners are limited to observation, many concrete nouns are learned and, thus, the frequent words that accompany observable facts become an additional source of information. By the same logic, syntax provides clues to the syntactic category of words. Thus, as language experience grows, each stage shows improvement and complements the next. As mentioned before, adults showed a learning pattern similar to that observed in infants at the onset of language acquisition, when observation is the only source of information; adults identified mostly concrete nouns, reproducing the noun-dominance of infants' first vocabularies (Gentner, 1982). From this sole source of information, verbs were harder to identify for the adult subjects. When these contexts were added to the information provided by the scenes, accurate identification rose for both nouns and verbs, although action verbs were more accurately identified than mental verbs. Although all types of verbs identification dramatically improved when syntactic frame information was added, the syntactic information had a stronger effect on mental verbs, which were as efficiently identified as action verbs.

These human simulation studies revealed two important facts about infants' language learning. First, Gillette et al. (1999) showed that children's difficulties in learning verbs are not due to the grammatical categories of verb or noun, but to imageability. Gillette et al. (1999) found a strong correlation between imageability and noun/verb distinction, as the least imageable items (whether nouns or verbs) were the most difficult to identify. Once imageability was controlled, this difficulty disappeared. Second, it demonstrated that words that label more perceptually accessible concepts are learned first while those that are more abstract or relational require additional support from linguistic contexts and, thus, are learned later. The findings of these studies, which employed human simulations, demonstrate that changes in vocabulary composition are not necessarily attributable to changes in the learner's conceptual capacities. Furthermore, the human simulation studies provide an estimate of the potential of various cues to word meaning acquisition that are available in real learning situations.

The human simulation paradigm provides a way of studying vocabulary acquisition under varying conditions of information availability. This paradigm is especially important because it allows the possibility of removing conceptual changes as an explanation for the findings, which is certainly important when testing only adults. Thus, the problem of vocabulary learning is reduced to mapping (the meaning of a word form). Furthermore, the level of successful learning and the types of items learned can be attributed to the effects of available (or changing) information.

1.3. Working memory and new word learning

In 1974, Baddeley and Hitch (Baddeley and Hitch, 1974) proposed a working memory model composed of three main components; the *central executive* which acts as a supervisory system and controls the flow of information to and from its slave systems, the *phonological loop,* and the *visuo-spatial sketchpad*. The slave systems are short-term storage systems dedicated to a content domain (verbal-acoustic and visuo-spatial, respectively). Later, Baddeley (Baddeley, 2000) added a third slave system to his model: the *episodic buffer*.

The *central executive* is assumed to be responsible for the control and regulation of cognitive processes. Its functions include the regulation of information within working memory, the control of information flow between other parts of the cognitive system, the retrieval of information from long-term memory, the processing and storage of information and the coordination of the slave systems (Gathercole and Baddeley, 1993). It is a fractionable control system that is limited in capacity and relies mostly on the brain's frontal lobes (Baddeley, 2000). The *visuo-spatial sketchpad* is one of the subsystems of working memory that deals with the integration of spatial, visual, and possibly kinesthetic information into a unified representation that may be temporarily stored for manipulation (Baddeley and Hitch, 1974; Gathercole and Baddeley, 1993; Baddeley, 2003). This slave system is reportedly allocated within the right hemisphere (Baddeley, 2000; Baddeley, 2003). The *episodic buffer* is dedicated to linking information across domains to form integrated units of visual, spatial, and verbal information and to chronologically ordering these units (Baddeley, 2000; Baddeley, 2003). It is assumed to be a limited capacity system dependent on executive processing, and is principally devoted to information storage (Baddeley, 2003). The main motivation for Baddeley's introduction of this component was the observation that some patients with amnesia, who presumably had no ability to encode new information in long-term memory, nevertheless had good short-term recall of stories, recalling much more information than could be held in the phonological loop (Baddeley and Wilson, 2002). The *phonological loop* is the most studied subcomponent of the working memory model and, thus, the one that has the most backing evidence. Importantly, this subsystem has been demonstrated to be directly involved in vocabulary learning (Baddeley et al., 1998).

The *phonological loop* is specialized for the storage of verbal material and it is comprised of two components – the phonological store and an articulatory rehearsal process. Any auditory verbal information that a human takes in is assumed to enter automatically into the phonological store, while visually-presented information can be transformed into phonological code by silent articulation and thereby encoded into the phonological store (Gathercole and Baddeley, 1993). As the information in the phonological store decays with time, the process of articulatory rehearsal serves to refresh the decaying representations and to thusly maintain the items in memory (Gathercole and Baddeley, 1993; Baddeley et al., 1998). Evidence for the articulatory rehearsal process is provided by the word length and articulatory suppression effects. The word length effect refers to Baddeley's observation that lists of short words are remembered better than lists of long words (Baddeley, 1975). This is explained by the fact that short words can be articulated faster, so that more words can be silently articulated before they decay. The word length effect can be abolished under conditions of articulatory suppression in which participants are asked to repeatedly say aloud an irrelevant word or phrase. Memory of verbal material is impaired when participants are engaged in articulatory suppression. Articulatory suppression is thought to block the articulatory rehearsal process, thereby promoting the decay of memory traces in the phonological store (Baddeley, 1975; Gathercole and Baddeley, 1993). Evidence for the phonological store is provided by phonological similarity and irrelevant speech effects. Conrad and Hull (Conrad and Hull, 1964) reported that lists of items that sounded similar were more difficult to remember than items that sounded different, whereas visual or semantic similarity had comparatively little effect (Conrad and Hull, 1964; Gathercole and Baddeley, 1993). This effect supports the assumption that verbal information is coded largely phonologically in working memory. The effect of irrelevant speech is evidenced by the observation that playing speech sounds, even in a foreign language, disrupts the formation of memory for verbal material (Colle and Welsh, 1976). The explanation for this phenomenon is that speech sounds enter the phonological store automatically and interfere with memory traces of the list to be remembered (Gathercole and Baddeley, 1993).

The phonological loop plays a key role in the acquisition of vocabulary. Evidence for this is provided by a number of neuropsychological, developmental and experimental studies. Baddeley et al. (Baddeley et al., 1988) studied the involvement of the phonological loop in new word learning in a patient with severe impairment of phonological working memory. The patient (PV) was required to learn pairs of word-nonword (the nonword being a Russian word) and word-word (unrelated words in her native language). The results showed that while word-word pairs were learned as rapidly as normal subjects, PV failed to learn any of the word-nonword pairs. The involvement of the phonological loop in learning new words was further supported by the observation that PV could learn the pairs by semantic mediation (word-word) and orthographic information (the patient learned some of the word-nonword pairs when visually presented).

Research on children has demonstrated that the ability to learn new words is greatly affected by working memory span (Gathercole and Baddeley, 1990b; Gathercole and Baddeley, 1993; Baddeley et al., 1998). Service (Service, 1992) studied the nonword repetition abilities of a group of Finnish children learning English as a second language. The results showed a high correlation between repetition scores and the acquisition of English language vocabulary. Gathercole and Baddeley (1990a) studied the ability of 5-year-old children with high and low phonological memory skills to learn new words. Phonological memory skills were assessed by means of nonword repetition ability, as this provides a good measure of phonological loop capacity and it also influences the learning of new words (Gathercole and Baddeley, 1989; Gathercole et al., 1992). Children attempted to learn new names of toy animals. The toys were given either familiar names such as Peter or phonologically unfamiliar names such as Meeton. The children with low nonword repetition scores were significantly poorer at learning the unfamiliar names than children with high scores. In contrast, no differences were found in learning the familiar names between the two groups. Similarly, Gathercole et al. (Gathercole et al., 1997) tested the ability of 5-year-old children to learn word-word and word-nonword pairs. The main finding of their study was that phonological memory was highly associated with the rate of learning of word-nonword pairs, but not with that of word-word pairs. Moreover, children with disordered language (characterized by poor vocabulary development) are dramatically impaired in their abilities to repeat unfamiliar phonological forms (Gathercole and Baddeley, 1990a). Similar results have been shown in adults. For instance, Papagno et al. (Papagno et al., 1991) studied vocabulary learning in adults who were simultaneously engaged in articulatory suppression. The reasoning for this condition was that if the phonological loop mediates word learning, then a task that it is known to affect it would hamper the learning of new words. As predicted, the learning of phonologically unfamiliar material was more impaired by articulatory suppression than was the learning of familiar material. Further evidence was provided in a subsequent study from Papagno and Vallar (Papagno and Vallar, 1992). In this study, the researchers manipulated the degree of phonological similarity and word length of the items to be learned. They found that neither of these variables influenced word-word pair learning possibly because it is mediated by semantic coding. However, slower learning of word-nonword pairs was observed when the new words were either of a high degree of phonological similarity or of substantial length.

The findings of these various studies support the phonological loop's direct involvement in new word learning. According to the working memory model, the phonological loop is primarily involved in the storage of unfamiliar sound patterns of words until more stable (long-term) representations can be established. Hence, the quality of the temporary memory trace in the phonological loop is critical for the construction of more permanent phonological structures that are stored in the mental lexicon. Contrastingly, the learning of familiar lexical items is mediated by semantic information, that is, existing knowledge of a native language, and has little to no reliance on the phonological loop (Baddeley et al., 1998).

The phonological loop has been demonstrated to be critical for new word learning, however only if new word learning is defined as long-term learning of new phonological forms. Although the learning of phonological forms is important for language learning, it is worth mentioning that semantic and visual representations are just as important. Furthermore, other variables seem to play a crucial role in new word acquisition. Duyck et al. (Duyck et al., 2003) found that word imageability played an important role in associative word learning in adults and children. They reported that articulatory suppression disrupted not only word-nonword learning, but also word-word pairs when the target was a low imageable word (either a low imageable content word or a function word). Furthermore, when participants, previous to the main experiment, were presented with nonwords associated with visual images, the learning of the word-nonword pairs was not affected by articulatory suppression. The authors suggested that although verbal working memory is important in word learning, it is limited to phonological representations; word associations can be learned by other means such as visual working memory (Duyck et al., 2003).

1.4. Research Aims

The series of studies that comprise this dissertation are aimed at simulating vocabulary learning and meaning acquisition of different types of words, namely words which differ in imageability[1]. For this purpose, the human simulation paradigm is the best option to approach the question of how the meanings of words are learned, omitting infants as experimental subjects. It also offers the advantage of using electrophysiological and hemodynamic techniques to explore the underlying processes and neural regions that sustain on-line word learning and that, with the use of infants, would have been difficult or impossible to study.

In order to study the meaning acquisition of new words, the human simulation paradigm was adopted (Gillette et al., 1999). In the first series of experiments (Chapters 2 and 3), adults were provided with congruent and incongruent semantic contexts from which they had to derive the meanings of new words. This strategy was further applied in order to understand the neural mechanisms involved in learning concrete and abstract words (Chapters 4 and 5).

More specifically, Chapter 2 analyzes the interaction of semantic information congruency and meaning resolution using ERP (experiments 1 and 3). A different experiment explores the effects of context congruence on lexical acquisition using a self-paced reading paradigm (experiment 2). Chapter 3 examines the localization of cortical areas of successful meaning acquisition with fMRI, and investigates the neural network for lexical learning (experiment 4). In Chapter 4, the self-paced reading paradigm is used to study meaning acquisition of concrete and abstract words. First, a reanalysis of experiment 2 is presented (experiment 2b). Experiment 5 investigates abstract word learning from congruent and incongruent sentential contexts. Afterward, a comparison between experiments 2b and 5 is presented. In experiment 6, the simultaneous acquisition of concrete and abstract words is studied using the self-paced paradigm. Finally, Chapter 5 examines the localization of cortical areas differently involved in meaning acquisition of concrete and abstract words using fMRI (experiment 7).

[1] Several studies have reported that imageability and concreteness are highly correlated (e.g., Paivio, 1971). In this regard we are using both terms interchangeably throughout the present dissertation.

Chapter 2[†]

Experiment 1, 2 and 3: Watching the brain during meaning acquisition

2.1. Introduction

"To make children understand what the names of simple ideas or substances stand for, people ordinarily show them the thing whereof they would have them have the idea and then repeat to them the name that stands for it." This is how the British Empiricist Locke envisioned the word learning process in 1690 (Locke, 1964). Indeed, the link between word form and meaning is at the core of human language, and the explosive growth in the vocabulary of children has attracted the interest of scholars from St. Augustine in the fourth century (Augustinus, 398) to Quine (Quine, 1960) and Pinker (Pinker, 1984). The acquisition of word meaning involves, at its most basic level, the process of mapping concepts onto specific sounds or signs. This mapping is arbitrary, that is, the same pattern of sounds could correspond to different meanings in different languages. We are constantly encountering new words during all the stages of development and it has been estimated that between the age of 2 and 20 years, the number of words learned per day ranges between 6 and 25 words (Nagy and Anderson, 1984; Landauer, 1986). The estimates of the size of vocabulary of high-school graduates and college students range from 40.000 to 100.000 words (Nagy et al., 1987; Sternberg, 1987). Most of these words are learned in high school, simply from contextual reading and without explicit instruction. This remarkable word-learning ability is crucial if we consider that new or novel words are constantly created in each language (e.g., slang words, technical words, etc.) and that most people are faced with the challenge of

[†] This chapter corresponds to:
Mestres-Missé, A.; Rodiguez-Fornells, A. & Münte, T.F. (2006) Watching the Brain during Meaning Acquisition. Cerebral Cortex. In press.

learning at least one new language during their life. The aim of this project is to understand how the meaning of a new word is created in a specific linguistic context.

In the very first stages of word learning, infants have to glean the link between a word and its corresponding object from extralinguistic information with current evidence suggesting that they use sophisticated pragmatic strategies to infer the referential intentions of the speaker in the mapping process in addition to mere statistical association between a word and an object or action (Tomasello and Akhtar, 1995; Baldwin et al., 1996; Bloom, 2002). Simple word-to-world pairings do not suffice to learn "hard words" such as verbs, however, because these often do not correspond to concrete basic-level concepts (Gillette et al., 1999; Gleitman et al., 2005). When word learning begins, the only source of information available to the child is the observation of intentional acts of the speakers in conjunction with the heard word (word-to-world mapping). The majority of a child's first words are thus concrete nouns. These provide the basis upon which language will be built. As the child accumulates linguistic experience, less concrete words such as verbs, adjectives, adverbs, and conjunctions are learned. A number of experiments have demonstrated that children in this stage are sensitive to the linguistic context in which a new word appears and that they use the information provided by this context to determine its meaning (Hall and Graham, 1999; Subrahmanyam et al., 1999; Cain et al., 2003; Hall and Belanger, 2005; Fernald and Hurtado, 2006). Moreover, an extensive corpus analysis of child-directed speech (CDS) showed that only a 7% of CDS utterances were comprised of single words. Rather, short simple frames (such as "Look at the…") combined with different content words made up 50% of CDS (Cameron-Faulkner et al., 2003). Therefore, once a certain vocabulary and syntax has accrued, linguistic information can and must be used as an additional source in the word-learning process, thus adding a structure-to-world mapping strategy to the earlier available processes. This more advanced word learning strategy is similar to the one employed by adult learners of a second language (Singleton, 1999; Groot, 2000) and will be explored in the present investigation.

Word learning has been studied using the human simulation paradigm (Gillette et al., 1999): adults are exposed to a novel word and the available linguistic or extralinguistic information that can be used to infer its meaning is systematically varied. Unsurprisingly, in one recent study (Gillette et al., 1999) correct identification of novel verbs jumped from 8% in an observation condition entailing silenced video of mother-child interaction to 90% in a condition, which provided the entire utterance (minus the target word) plus the video of the conversation situation.

The aim of the present investigation is to get a first glimpse at the neural correlates of word-learning in a variant of the human simulation paradigm that provided linguistic context information. Specifically, young adult native speakers of Spanish were required to silently read triplets of sentences in order to derive the meaning of a novel word that appeared in the terminal position of each of these sentences (see Table 2.1). Novel words respected the phonotactic rules of Spanish and were thus pronounceable (see Appendix A for the complete list). In all cases, the hidden "target" word (like "car" for "lankey" in Table 2.1) was a concrete Spanish noun of medium frequency (mean 58.1 per one million words) (Sebastian-Gallés et al., 2000). For each target word, 3 sentences were constructed (in total 585), in which an increasing degree of contextual constraint was created. Contextual constraint was measured in an independent paper-and-pencil test in different participants that had to fill in the missing last word of each sentence (see Methods). Increasing contextual constraint across the triplet ensured that participants could gradually narrow down the meaning of the new word. A second behavioral pretest in 15 young volunteers (195 new words in sentence triplets) yielded a correct identification of the meaning in 91.12 % of the cases.

The main event-related brain potential (ERP) (Münte et al., 2001) experiment featured 2 further conditions in addition to the condition in which participants could derive the meaning of the novel word (henceforth meaning condition, M+). In the non-meaning (M-) condition, participants could not assign meaning to the novel word, because unrelated sentences were used. In the third real-word (R) condition, existing Spanish words were presented in the terminal position of the sentences for comparison.

To rule out the possibility that the observed ERP pattern is due to participants "giving up" in the M- condition, a self-paced reading experiment was conducted in a different group of volunteers, providing a measure of the time needed to process each word of the sentence (Mitchell, 1984).

M+ condition
Mario always forgets where he leaves the lankey
It was expensive the repair of the lankey
I punctured again the wheel of the lankey
M- condition
I have bought the tickets for the garty
On the construction site you must wear a garty
Everyday I buy two loaves of fresh garty
R condition
She likes people with nice and clean teeth
In a fight Mary had broken two teeth
After a meal you should brush your teeth

Table 2.1. Word-learning task. Participants were required to discover the meaning of a novel word at the end of each of three successively presented sentences (each 8 words in length). In the M+ condition, the meaning of the novel word was readily apparent, whereas in the M- condition, no meaning could be mapped to the novel word, as the three sentences each required a different terminal word. To control for the repetition effects across sentences, real words were used at the end of the sentences in the R condition. Upon the completion of the three sentences (word by word presentation, word duration 200 ms; stimulus onset asynchrony 500 ms), a prompt was shown requiring the participants to report the "hidden" word in the M+ and M- conditions or to produce a synonym or a semantic related word in the R condition. Guessing was encouraged. Participants were to say "don't know", if no meaning came to mind (note: English translation of Spanish materials, keeping the Spanish word order).

Finally, to test whether the association between the novel word and its meaning generalizes to other contexts, an additional study employing the same word-learning ERP design in a new group of participants was used. This time, however, an additional test was conducted in-between the different learning blocks (i.e., every 24 trials). Novel words from the M+ condition were presented either before their real-word counterpart (e.g., in Table 2.1 "lankey" – "car"; stimulus duration, 200 ms; onset asynchrony between words, 500 ms; see Methods for further details) or preceding a different unrelated real word ("lankey" – "house"). A control condition contrasting semantically related (e.g., money – coin) and unrelated (e.g., money – horse) pairs of real words was also used. Participants had to indicate by a button press, whether or not the 2 words were semantically related. The N400 component of the ERP was used as an index of the amount of facilitation of the processing of the second word (Kutas and Hillyard, 1989; Holcomb, 1993; Swaab et al., 2002). We hypothesized that learning of the novel words should lead to a reduced amplitude of the N400 for immediately following real-word counterparts.

2.2. Methods

2.2.1. Pretests

Suitable sentences were selected after a pretest in 165 students of the University of Barcelona, all native speakers of Spanish. In this pretest, each sentence was presented in isolation with the final word missing and participants were required to complete the sentence with the first word that came to their mind and that fit well with the sentence. For each intended final word, 3 sentences were selected that differed regarding their contextual strength and thus gave a low, medium, and high rate of completions with the intended word (first sentence mean cloze probability for intended word was 6.1 ± 10.3% standard deviation [SD]; second sentence 28.5 ± 18.9%; third sentence 76.0 ± 17.7%). The materials generated from the pretest and used in the main experiment are given in Appendix A.

2.2.2. Experiment 1: ERP learning experiment

Twenty-four right-handed healthy native speakers of Spanish (mean age 21.7 ± 3.2 SD years; 18 women) participated after giving informed consent.

Sentence contexts were presented in random order with 65 triplets in each condition. Sentence contexts were rotated systematically over all conditions such that across the group of participants each sentence occurred equally often in each condition.

ERPs were recorded with tin electrodes mounted in an elastic cap and located at 29 standard positions (Fp1/2, F7/8, F5/6, F3/4, C3/4, C5/6, T7/8, Fpz, Fz, Cz, Pz, Cp3/4, Cp5/6, Tp7/8, P3/4, P7/8, O1/2). Electroencephalographic signals were re-referenced off-line to the mean of the activity at the 2 mastoid processes. Vertical eye movements were monitored with an electrode placed below the right eye referenced to the outer canthi of the right eye. The electrophysiological signals were filtered with a bandpass of 0.01-50 Hz (half-amplitude cutoffs) and digitized at a rate of 250 Hz. Trials on which base-to-peak electrooculogram (EOG) amplitude exceeded 50 µV, amplifier saturation occurred or the baseline shift exceeded 200 µV/s were automatically rejected off-line. The mean percentage of rejections was M = 17.7% (SD = 9.1).

ERPs were obtained for the terminal word separately for conditions and sentence position within a triplet (length 1024 ms, prestimulus baseline 100 ms). For illustrations, ERPs were low-pass filtered (cutoff frequency 8 Hz). Brain potentials were quantified by a mean amplitude measure (time-window 300-500 ms) at different electrode locations. First, data were subjected to an omnibus repeated measures analysis of variance (ANOVA) with factors condition (R, M+, M-), sentence position (first, second, third), and electrode site (15 selected electrode locations: midline positions Fz, Cz, Pz plus F7, F3, F4, F8, T3, C3, C4, T4, T5, P3, P4, T6). Second, additional pairwise ANOVAs were carried out to assess differences between conditions in the midline positions, where amplitude differences were maximal. Third, in order to further analyze significant interactions that appeared in the omnibus ANOVA between the experimental factors (condition and sentence position) and electrode, 12 of the 15 electrodes were used for topographical analysis. The 12 selected electrodes (F7, F3, F4, F8, T3, C3, C4, T4, T5, P3, P4, T6) were divided to yield 3 factors: anteriority (anterior, central, posterior), laterality (parasagittal and temporal) and hemisphere (right and left). For all statistical effects involving two or more degrees of freedom in the numerator, the Greenhouse-Geisser epsilon was used to correct possible violations of the sphericity assumption. Each exact *P* value after correction will be reported in conjunction with the original degrees of freedom. Tests involving electrode x condition interactions were carried out on data subjected to a vector normalization procedure (McCarthy and Wood, 1985). Topographical maps were created using spherical spline interpolation and current source density (CSD).

2.2.3. Experiment 2: Self-paced reading experiment

Eighteen volunteers (mean age 20.9 ± 1.8 years; 14 women) that did not partake in any of the other studies viewed 12 sentence triplets per experimental condition (R, M+, M-) in a randomized order and rotated across participants as in the first ERP experiment. The target words were 36 new words (see Appendix A for a list of target words and sentences used). All of them were frequent words in Spanish (mean frequency of 63.2 per million occurrences. Mean cloze probability was: first sentence (low constraint) 6.3% (SD = 10.8), second sentence (medium constraint) 38.8% (SD = 19) and third sentence (high constraint) 84.8% (SD = 11.2). The probability of meaning resolution after reading sequentially the two sentences was 98.04%. The entire sentence was presented on the video screen with each letter replaced by the letter X. By pressing a key, the first word was revealed and could be read. Upon the next key press, this word was replaced by Xs again and the next word was rendered readable. Thus, reading times for each word were logged.

The use of this noncumulative moving-window methodology (Mitchell, 1984) ensures that the participants read each word carefully in order to understand the meaning of the sentence. After the presentation of each context, a prompt was shown requiring the participants to write the “hidden” word in the M+ and M- conditions when possible and to produce a synonym or a semantic related word in the R condition.

2.2.4. Experiment 3: ERP generalization experiment

Twenty new right-handed healthy native speakers of Spanish (mean age 21.5 ± 2.1 years; 16 women) participated.

Materials from the first experiment were used. Now, each stimulus list was divided into 8 sublists comprising 8 trials per condition (R, M+, M-) and 8 filler trials. Filler word sentences were included to equate the probability of real word and novel words at the end of the sentences. Filler sentences had the same structure as R conditions (3 sentences and ascending cloze probability). This condition was not included in the analysis because it was not rotated across the different scenarios.

After each learning block, the generalization experiment was presented. ”Related” and “unrelated” word pairs were created for the novel words (only M+ condition) as well as for the real words from the R condition. Novel words from the M- condition were not presented. Novel words from the preceding block were presented twice, once prior to their real word counterpart (related) and once prior to a real word that corresponded to a different novel item (unrelated). Trial order was counter-balanced across participants, such that half of them were first exposed to the related pair of a particular novel word, whereas the other half first saw the unrelated pair. For the real-word condition, the same logic was applied, but in this case, the second words of each pair were either synonyms or close semantic associates. Stimulus duration was 200 ms, and the stimulus onset asynchrony between the prime and target word was 500 ms. The intertrial interval between word pairs was varied randomly between 1 and 2 s.

Participants pressed one button for related second words and another button for unrelated second words (see Table 2.2 for examples).

Condition	Novel-word learning		Real word	
	Prime (new-word)	Target (hidden word)	Prime (word)	Target (semantic relation)
Related	ateloso	tomate (*tomato*)	autobús (*bus*)	tranvía (*tram*)
	vatesa	nevera (*fridge*)	cuchillo (*knife*)	navaja (*clasp knife*)
Unrelated	ateloso	nevera	autobús	navaja
	vatesa	tomate	cuchillo	tranvía

Table 2.2. An example of the experimental conditions used in the second ERP experiment.

Amplifier settings and data processing was carried out as in the first ERP experiment. The relatedness effect was assessed by a mean amplitude measures at 2 different time windows (300-500 ms and 500-700 ms) at 15 electrode locations (Fz, Cz, Pz plus F7, F3, F4, F8, T3, C3, C4, T4, T5, P3, P4, T6). These data were subjected to a repeated measures ANOVA including trial type (real-word vs. novel-word decisions), relatedness (related vs. unrelated) and electrode site (15 levels) as factors. To further analyze the significant interactions between experimental factors (trial type and relatedness) and electrode which appeared in this ANOVA, an additional analysis using the 12 lateral sites (F7, F3, F4, F8, T3, C3, C4, T4, T5, P3, P4, T6) assigned to 3 topographical factors and employing vector normalization was conducted (see Methods of the first ERP experiment for details). In addition, pairwise comparisions between ERPs from related and unrelated trials were carried out separately for the novel- and real-word conditions in time intervals 300-500 and 500-700 ms. The unrelated minus related difference waveforms were subjected to a digital high-pass filter (1 Hz half amplitude cutoff) to neutralize slow drifts.

2.3. Results

2.3.1. Experiment 1: ERP learning study

Brain potentials to the terminal words of the first sentence of a triplet showed a larger negativity at posterior sites for real words from the R condition compared with both M+ and M- novel-word conditions (Figure 2.1 and 2.2, upper part). This negativity is an instance of the N400 component of the ERP that is thought to index the semantic integration of a word within the current context (Kutas and Hillyard, 1984; Brown and Hagoort, 1993; Kutas and Federmeier, 2000). The scalp distribution of this component (see Figure 2.2, left maps) showed a posterior distribution (difference waveform, R minus M+ or R minus M-). For the second sentence, brain potentials to novel words in the M+ condition were different from those presented in the M- condition between 250 and 550 ms. At the end of the third sentence, the ERPs from M+ and R conditions were indistinguishable and both were clearly different from M-, in particular at central and posterior locations.

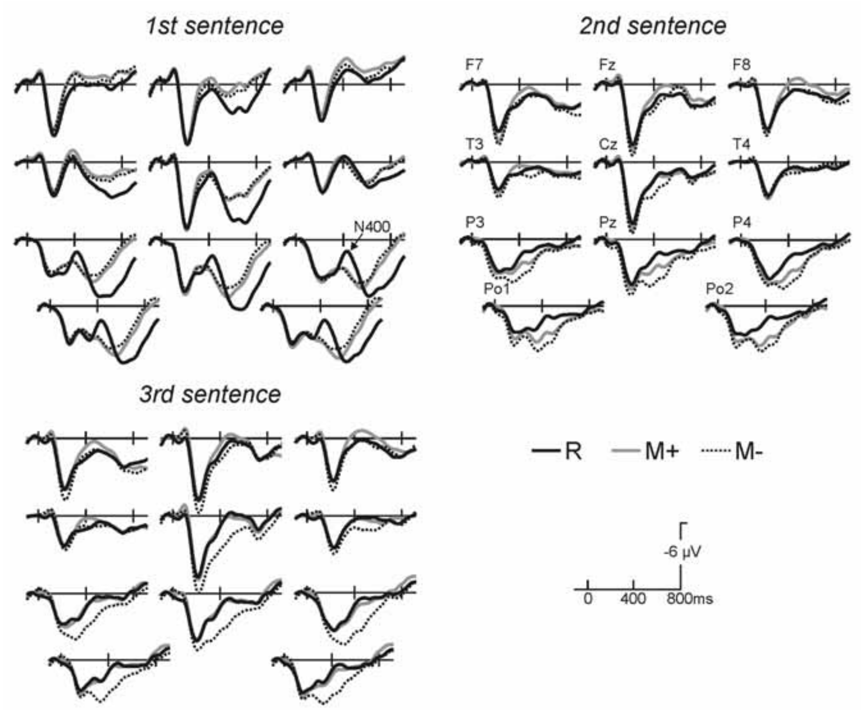

Figure 2.1. Group average ERPs to the terminal word show marked differences between conditions. For the first sentences, terminal words from the R condition were associated with a phasic negativity (N400) over posterior sites, indexing semantic integration. This is not seen in the M+ and M- conditions. For the second sentence, the brain potentials clearly differentiated between the three conditions with the M+ condition lying in-between R and M-. For the third sentence, M+ and R conditions are virtually indistinguishable.

The results of the omnibus ANOVA (mean amplitude 300-500 ms, 15 electrode locations) revealed a main effect of condition ($F_{2,46}$ = 10.71, P < 0.001), sentence position ($F_{2,46}$ = 3.5, P < 0.05), and a significant condition by sentence interaction ($F_{4,92}$ = 2.9, P < 0.025). All the remaining interactions were significant (condition by electrode, $F_{28,644}$ = 10.7, P < 0.001; sentence position by electrode $F_{28,644}$ = 5.8, P < 0.001; condition x sentence x electrode $F_{56,1288}$ = 1.6, P < 0.01). The main effects observed in the omnibus ANOVA were followed up by pairwise comparisons at midline locations (Fz, Cz and Pz) of the conditions for each sentence. The results are summarized in Table 2.3 (see also Figure 2.2, upper part) and corroborate the viual inspection of the ERPs. When novel words in the M+ condition where contrasted with M-, a significant difference appeared already at the second sentence with the M+/M- difference increasing further for the third sentence. Notice that the topography of the difference waveform comparing M+ minus M- at the end of the third sentence (see Figure 2.2, right maps) shows also a standard N400 posterior right central distribution. No differences between R and M+ were present for the sentence.

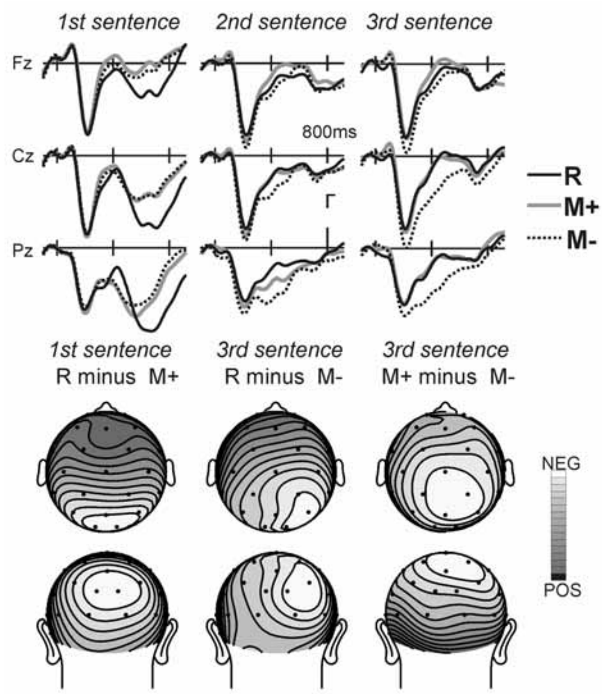

Figure 2.2. Grand average ERPs to the terminal words of the first experiment (midline locations, Fz, Cz, Pz). The topographic isovoltage maps (spherical spline interpolation) show the scalp distribution of the differences between conditions. Maps depict the mean amplitude in a 50-ms time window centered upon the peak waveforms computed subtracting the different conditions. Maps depict the mean amplitude in a 50 ms time window centered upon the peak of the difference waveform (in all cases 425 ms; relative scaling is used): R minus M+ comparison, minimum/maximum values, -1.85/0.66µV; R minus M-, -1.8/0.55µV; M+ minus M-, -2.79/0.48µV.

In order to decompose the condition x sentence x electrode interaction observed in the omnibus ANOVA, a topographical analysis using vector-normalized data was carried out as specified in Methods. Main effects of condition ($F_{2,46} = 10.7$, $P < 0.001$) and sentence position ($F_{2,46} = 4.9$, $P < 0.023$) as well as the interaction between condition and sentence position ($F_{4,92} = 2.7$, $P < 0.05$) were preserved. A significant interaction between condition and hemisphere was observed ($F_{2,46} = 5.8$, $P < 0.005$), which reflected the larger negativity over the left hemisphere for R words when compared with M+ and M- conditions (see also pairwise comparisons in Table 2.4). The significant condition x anteriority interaction ($F_{4,92} = 22.8$, $P < 0.001$) was due to the fact that R words showed a different distribution than both M+ and M- words (see Table

4; mean amplitude in μV at frontal, central, and parietal locations, M+: 0.28, 0.83, 1.92; M-: 1.1, 1.6, 2.7; R: 1.1, 1.04, 1.3). Finally, there was also a condition x laterality interaction ($F_{2,46} = 9.05$, $P < 0.001$).

300-500 ms		1st sentence	2nd sentence	3rd sentence
M+ versus M-	Condition	n.s.	7.5**	33.3***
	Cond x E	n.s.	n.s.	n.s.
M+ versus R	Condition	n.s.	n.s.	n.s.
	Cond x E	4.5*	6.6**	n.s.
M- versus R	Condition	n.s.	6.5*	12.3*
	Cond x E	n.s.	5.8**	4.9*

Table 2.3. ERP learning experiment: *F*-values from pairwise ANOVAs comparing the different conditions at the midline electrode locations (Fz, Cz and Pz). Degrees of freedom: condition (cond, 1,23) and interaction condition x electrode (cond x E, 2,46). n.s., not significant. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

We also observed interactions between sentence position and anteriority ($F_{4,92} = 22.8$, $P < 0.001$; see also Table 2.4) as well as condition x sentence position x laterality ($F_{4,92} = 2.9$, $P < 0.031$) and condition x sentence position x laterality x anteriority interactions ($F_{8,184} = 2.4$, $P < 0.041$; see also Table 2.4).

		R versus M+		M + versus M-		M- versus R+	
	d.f.	*F =*	*P <*	*F =*	*P <*	*F =*	*P <*
Condition (C)	1,23			28.9	0.001	10.4	0.004
Sentence position (S)	2.46			7.1	0.005	4.7	0.014
C x S	2,46			4.5	0.018	3.6	0.04
C x lat	1,23			19.05	0.001	14.1	0.001
C x S x lat	2,46			6.5	0.004		
C x hem	1,23	5.4	0.029			11.4	0.003
C x ant	2,46	28.7	0.001			2.5	0.001
S x ant	4,92	4.92	0.001	8.6	0.001	9.6	0.001
C x S x lat x ant	4,92					3.8	0.007

Table 2.4. ERP learning experiment: pairwise ANOVAs comparing the different conditions and including topographical factors: laterality, hemisphere, anteriority. Laterality, lat; hemisphere, hem; anteriority, ant; df, degrees of freedom.

2.3.2. Experiment 2: Reading time study

For M+ condition, responses were considered correct when subjects reported the exact target word intended by the experimenters or a very closely related word. The overall meaning extraction in this experiment was 91.2% in the M+ condition with the majority of the responses being intended target words. In the case of R condition, subjects were asked to produce a synonym or a semantically related word. Responses would have been considered "incorrect", if the response did not have a semantic relation with the final word. Such responses did not occur. On average, the 18 subjects used 2.8 different answers for each word in the R condition. The pattern of reading times illustrated in Figure 2.3 suggests that participants attempted to extract a possible meaning in the M- condition even for the third sentence. In the first sentence, reading times for the terminal word were shortest in the R condition (see Table 2.5), whereas M+ and M- conditions did not differ. Novel-word conditions showed marked differences for the second and third sentences with reading times for terminal words in the M- condition showing a linear increase (sentence position main effect, $F_{2,17} = 18.5$, $P < 0.001$). Such an increase was not present in the other 2 conditions (M+: $F = 1.17$; R: $F = 1.5$). These results suggest that 1) in the M+ condition, the meaning of the novel words had been inferred using contextual learning and that 2) volunteers did not "give up" in the M- condition.

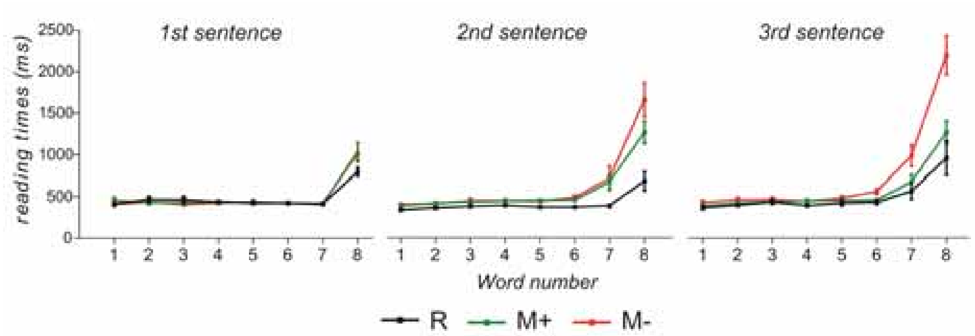

Figure 2.3. Mean self-paced reading times ± standard error of mean in the self-paced reading experiment for different word positions and sentences. New words were presented at the end of each sentence in the new-word conditions. Notice that new words in the M+ (meaning) and M- (non-meaning) conditions began to differ from the R condition along the second sentence. In the third sentence, a clear differentiation between new-word conditions can be observed.

	1st sentence	2nd sentence	3rd sentence
M+ versus M-	NS	-2.7*	-3.3**
M+ versus R	3.1**	3.3**	NS
M- versus R	2.8*	3.7**	3.7**

Table 2.5. Self-paced reading experiment: pairwise *t*-tests comparisons of the reading times for the terminal words (n = 18). Degrees of freedom for the *t*-tests 17. NS, not significant. *$P < 0.05$; **$P < 0.01$.

2.3.3. Experiment 3: ERP generalization experiment

Button press responses for word pairs from the M+ learning conditions were correct in 69 ± 11.1% (SD) for related and 67 ± 14.1% for unrelated pairs. Thus, a moderate degree of word learning took place in the present experiment. Expectedly, a larger percentage of correct responses was obtained for related (90 ± 5.1%) and unrelated (95 ± 3.8%) pairs in the real-word condition ($F_{1,19}$ = 200, P < 0.001). Decisions in the real-word condition were faster (827 ± 124 vs. 989 ± 130 ms; $F_{1,19}$ = 120, P < 0.001). Decisions for related pairs were slower in both conditions (novel word: related 997 ± 129, unrelated 981 ± 132 ms; real word: related 839 ± 124, unrelated 815 ± 126 ms, $F_{1,19}$ = 4.02, P < 0.055). There was no interaction between relatedness and condition (F < 1).

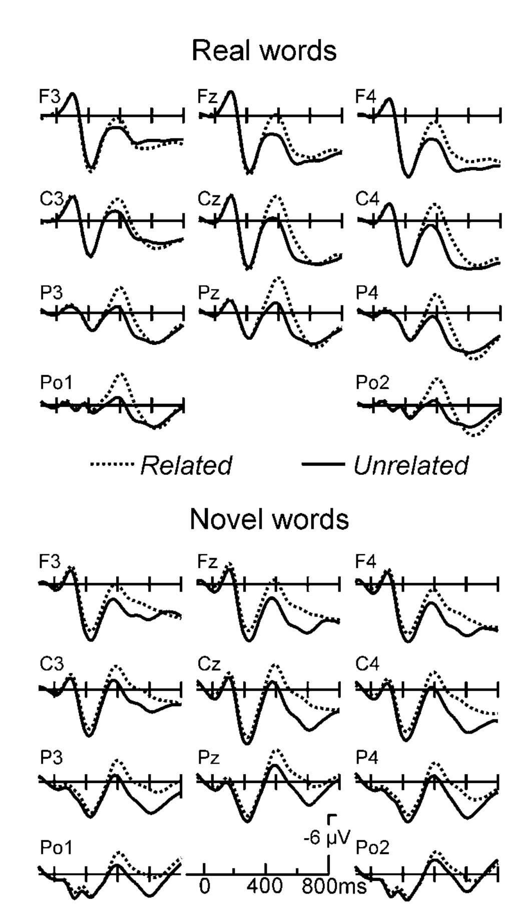

Figure 2.4. Grand average brain potentials for target words in the generalization experiment. Brain potentials to the second word of a pair varied as a function of their relation to the first word (semantically related or unrelated). Unrelated words showed a more negative course from 250 ms onwards in both the novel-word and the real-word conditions.

Inspection of the ERPs (Figure 2.4) shows that the N400 component was reduced for second words of related pairs not only in the real-word condition but also in the novel-word condition. Thus, novel words from the M+ condition facilitated semantic processing of their corresponding real word counterparts. Statistically, a relatedness effect was seen between 300-500 ms and 500-700 ms ($F_{1,19}$ = 17.3, P < 0.001 and F = 5.9, P < 0.025, respectively). Pairwise comparisons showed that this effect was significant only during the first time window for real words and in both time windows for the novel words (see Table 2.6). A condition main effect was only observed in the second time window ($F_{1,19}$ = 5.17, P < 0.034) and no interaction between condition and relatedness was found.

Topographic mapping of the N400 effect (Figure 2.5B) showed a typical right posterior central maximum for the real-word control condition, which has been reported previously (Kutas and Hillyard, 1989; Kutas and Federmeier, 2000). This distribution has been related to neural generators in the left middle temporal and inferior frontal regions that support the integration of meaning using multiple sensory modalities and knowledge domains (Halgren et al., 2002). Indeed, CSD mapping (Figure 2.5C, bottom left) revealed a temporal source-sink configuration. By contrast, the relatedness effect in the novel-word condition showed a frontocentral distribution and the CDS map revealed a frontal source-sink configuration (Figure 5C, bottom right). Statistically, a second set of ANOVAs, using vector-normalized data, showed that the scalp distribution of the relatedness effect was different for real and novel words in the 300- to 500-ms time window (condition x relatedness x hemisphere, $F_{1,19}$ = 10.8, P < 0.0004). In addition, significant interactions were found for relatedness x hemisphere ($F_{1,14}$ = 15.8, P < 0.001), relatedness by laterality ($F_{1,19}$ = 23.7, P < 0.001), relatedness x hemisphere x anteriority ($F_{2,38}$ = 3.6, P < 0.016). These interactions reflected the fact that the priming effect was largest at the right parasagittal and central posterior locations. Further, condition x hemisphere x anteriority ($F_{2,38}$ = 7.04, P < 0.0028) interactions reflected different scalp distributions of the ERPs in the novel- and real-word conditions. A very similar pattern of topographical effects was observed for the second time window evaluated (500-700 ms).

	300-500 ms	500-700 ms
Relatedness effect		
New words	**7.03****	**13.7****
Real words	**23.9*****	0.09
Priming x electrode		
New words	**3.00****	**3.67****
Real words	**7.15*****	**2.54****

Table 2.6. Results of the pairwise comparison of unrelated versus related target words (mean amplitudes in the corresponding intervals at 15 electrode locations) at two different time-windows. Bold numbers underscore significant effects. Degrees of freedom: relatedness (1,19) and the interaction between priming and electrode (14, 266). Interaction values have been previously vector normalized. *P < 0.05, **P < 0.01, ***P < 0.001.

It is important to note that the peak latency of the N400, determined in the unrelated minus related difference waveforms, was delayed by 152 ms in the novel-word condition (Figure 2.5A; peak latency in time window 300-900 ms; $F_{1,19} = 15.1$, $P < 0.001$). This latency difference paralleled the differences observed in mean reaction time for real-word and novel-word target decisions (827 ± 124 (SD) vs. 989 ± 130 ms respectively; $F_{1,19} = 120$, $P < 0.001$).

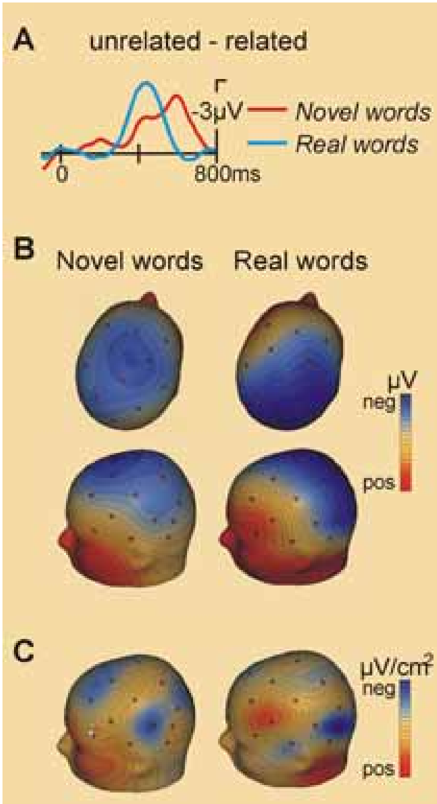

Figure 2.5. A. Unrelated minus related difference waveforms (right central parietal location, Cp2) show a negativity for both real-word and novel-word conditions. B. The scalp distribution of the relatedness (difference waveform) effect at the peak value shows a right parietal maximum in the real-word condition, whereas the peak activity is observed over frontocentral brain regions in the novel word-condition. Isovoltage maps were created using spherical spline interpolation. C. Current source density (CSD) maps at the same time points and for both conditions.

2.4. Discussion

To our knowledge, this is the first ERP study addressing the process of meaning acquisition from context in real time. Using the contextual constraints of the sentences, a meaning is mapped onto the novel word. The change of the brain potential signature for novel words from the M+ condition towards that of the real words over the sentence triplets qualifies as a neural correlate of the online acquisition of the meaning of a novel word extracted from a context. Importantly, participants were able to discern what semantic concept the new word was referring to using only 3 sentences that included the new word at the end of each sentence.

Moreover, as shown by the second ERP generalization experiment, learned words as well as real words lead to reductions of ERP amplitude to immediately following matching real words. This amplitude reduction might signal either the activation of the concept associated to the (learned) novel word at his learning stage or the activation of the associated (hidden) word. This latter possibility is corroborated by behavioral investigations addressing the learning of words in a second language (Kroll and Steward, 1994), which suggest that in the initial learning phases the link between a novel word and the corresponding word in the first language is stronger than the link between the novel word and the concept it denotes. With the repeated use of the new word, the conceptual link might be reinforced and speakers might be able to use this path freely in order to comprehend and produce words without having to rely on the lexical association between the novel word and the word in the first language. Further studies are needed in order to understand the neural mechanisms involved in the consolidation of the lexical and semantic links of the novel words and their brain representations.

Closer inspection of the effect in the generalization experiment reveals that it is both delayed and associated with a different scalp topography in the novel-word compared with real-word condition. Whereas the relatedness effect can be ascribed to a temporal source-sink configuration in the real-word condition, a frontal source-sink ensemble was seen in the novel-word condition most probably suggesting the involvement of prefrontal regions. This corresponds nicely to recent neuroimaging studies of semantic priming which have shown suppressed activity in the inferior frontal gyrus and in the middle temporal regions for semantically related words (Kotz et al., 2002; Matsumoto et al., 2005).

Although ERPs allow localizing their neural sources only with some uncertainty, topographical differences as the ones evidenced here permit to conclude that a different neural network is recruited in the real-word and novel-word conditions. One of the explanations for the topographical differences observed in the generalization experiment between novel and real words is that in the former the preexisting associative relations are still weaker and, therefore, an increase in cognitive control might be required in order to guide semantic knowledge retrieval and selection. This finding would predict that second language learning will require the involvement of cognitive control mechanisms that regulate the differential strengths and levels of activation of the different representations during the learning process (Rodriguez-Fornells et al., 2006) . In contrast, stable associative links exist in the real-word condition, which should render retrieval attempts more automatic and less dependent on cognitive control processes. Thus, we propose that retrieval of the meaning of a novel word enlists a prefrontal network driven by retrieval effort and monitoring demands. It remains to be shown whether consolidation of the novel words via further practice and use in multiple contexts and the resulting direct access of the novel word to its concept would abolish the brain potential differences between novel and real words.

To what extent can these findings be generalized to more natural situations, for example, adults acquiring a second language or children learning their first (Bloom, 2000)? A previous study found that native speakers of English, after only 14 h of exposure to a new language (French), showed an N400 effect in the second language even when performance was still at chance level in a word/nonword decision task (McLaughlin et al., 2004). Also, an N400 increase has been observed when adults tried to segment words from artificial language streams (Sanders et al., 2002; Cunillera et al., 2006). Clearly, the current experiment greatly restricted the information available to the learner. Learning in the real world often entails some sophisticated mind reading of the speaker's intentions (Tomasello and Akhtar, 1995; Bloom, 2000; Bloom, 2002) in addition to linguistic input to aid word-to-meaning mapping. Ultimately, these different information types may engage very similar learning processes, and the current experimental paradigm seems suited to study word learning in different populations and with different kinds of information used for the assignment of words to meaning.

Chapter 3[‡]

Experiment 4: Functional neuroanatomy of meaning acquisition from context

3.1. Introduction

The acquisition of word meaning involves establishing a correspondence between concepts and specific sounds or signs. This mapping is arbitrary, for example, different patterns of sound correspond to the same concept in different languages. It has been estimated that between the age of 2 and 20 years, the amount of words learned everyday ranges between 6 and 25 words and high school graduates and college students are in the possession of vocabularies between 40.000 to 100.000 words (Nagy and Anderson, 1984; Landauer, 1986). Most of these words are learned during high school by exposure to appropriate contexts and without explicit instruction (Nagy et al., 1987; Sternberg, 1987). How this is achieved and what brain processes support meaning acquisition from context is largely unknown. In light of the fact that novel words are constantly created in each language (e.g., slang words, technical words, etc.) and that most people are faced with the challenge of learning at least one foreign language during their life an understanding of word learning at the brain level is of great importance. Behavioral research in language learning, summarized by Bloom (2000), suggests that several cognitive mechanisms are called upon to create word-to-meaning mappings, including memory processes, an appreciation of the categories and individuals that make up the external world, syntactic processing and the ability to understand the beliefs and intentions of the others.

[‡] This chapter corresponds to:
Mestres-Missé, A.; Camara, E.; Rodriguez-Fornells, A.; Rotte, M. & Münte, T.F. (submitted). Functional neuroanatomy of meaning acquisition from context.

While word learning in adults and children may be different in several aspects, it still seems useful to briefly consider what is known with respect to word acquisition in children: Children grasp the meaning of new words on the basis of a few incidental exposures, without any explicit training or feedback (Carey and Barlett, 1978; Dollaghan, 1985; Heibeck and Markman, 1987; Rice and Woodsmall, 1988; Waxman et al., 1999), a process known as “fast mapping”. Children, as well as adults, possess an object bias, i.e. a preference to interpret a novel word as referring to a real world object (Macnamara, 1972; Markman, 1989; Gillette et al., 1999; Bloom, 2000). The first words can be learned through the observation of the world and attention to the intentional acts of word users. This strategy works for concrete nouns and action verbs. For closed class words (e.g., determiners or conjunctions) and abstract nouns, for example, this strategy does not work and has to be supplemented by other language processes as for example, syntactic processing (Gillette et al., 1999). Although several studies have focused on the influence of syntactic cues in word learning, little is known about learning from semantic context. The present chapter is devoted to this issue by examining word-to-meaning mappings constructed via contextual learning.

People do not typically use words in isolation but in the context of sentences. Thus, while associative word learning might occur in special circumstances (e.g., rote memorizing of the vocabulary of a second language in school) and has been targeted by neuroscientific investigations (for example,Breitenstein and Knecht, 2002; Breitenstein et al., 2005), the present study rather tries to study word learning in a more natural fashion. To simulate natural word learning, we use a variant of the so-called human simulation paradigm (Gillette et al., 1999). In such studies adults or children are exposed to different sources of information (linguistic and extralinguistic), which have to be used to determine the meaning of a novel word. Specifically, the present investigation tries to identify the brain regions that mediate meaning acquisition of novel words during contextual learning. The same word learning task as in the previous experiments was used (see Chapter 2, also Table 2.1). The word learning task allowed adult participants to derive the meaning of new words presented within three successive sentences. Functional magnetic resonance imaging (fMRI) was used to evaluate the brain regions involved in this process.

Previous imaging studies suggest that candidate brain regions likely involved in word learning and meaning construction might include (i) left inferior prefrontal cortex, which has been associated to control of semantic retrieval (Wagner et al., 2001; Badre and Wagner, 2002), and (ii) left lateral temporal regions, in particular the middle temporal gyrus (BA21), which have been related to the storage of long-term conceptual knowledge (Petersen et al., 1988; Martin and Chao, 2001), to lexical-semantic processes (Damasio et al., 1996; Ferstl and von Cramon, 2001; Keller et al., 2001; Baumgaertner et al., 2002; Indefrey and Levelt, 2004), and the activation of visual forms and word meanings (Howard et al., 1992; Pugh et al., 1996; Hagoort et al., 1999). The activation of other prefrontal regions involved in executive control, performance monitoring and working memory aspects of the word learning task is also expected.

3.2. Methods

3.2.1. Participants

Twelve native Spanish volunteers were financially compensated for their participation in the study (mean age 24.5 years; range 19-32; 6 women). All participants were right-handed and gave written informed consent. The protocol had been approved by the ethical committee of the University of Magdeburg.

3.2.2. Task and stimulus materials

Participants silently read groups of three sentences, each ending in the same novel word, and had to discover the meaning of this word. In addition to a condition in which all three sentences were consistently licensing one meaning for the terminal novel word (henceforth M+ condition); in a second (M-), the novel word was not associated with a consistent meaning across the sentence triplet. In a third control condition (R) sentences closed with a real word (see Chapter 2, also Table 2 for examples). Sentences were systematically rotated between the three critical conditions across subjects by creating different scenarios. Fifty sentence triplets were presented in each condition. The scenarios were created such that the mean frequency of the appropriate terminal words was the same for each condition (between 50.08 and 50.43 Freq/million, Sebastián-Gallés et al., 2000). Sentences uniformly had a length of 8 words. Novel words respected the phonotactic rules of Spanish and were created changing one or two letters of an existing word.

For each target word three sentences differing in their contextual constraint were built, with the most highly constrained sentence always presented last (see Appendix A for the complete list of target words and sentences). In this way, the meaning of the novel word could be derived progressively. Target words and sentences were chosen from the previous EEG experiments. Mean cloze probability for the final pool of 450 sentences (150 groups of three sentences) was: first sentence (low constraint) 6.45% (SD = 10.41), second sentence (medium constraint) 29.43% (SD = 18.20) and third sentence (high constraint) 79.40% (SD = 15.08). The percentage of meaning resolution after reading sequentially each triplet was 92.8% (SD = 9.1).

For the M- condition sentences from different triplets were mixed resulting in a different combination of sentences 1, 2, and 3. Thus, no meaning could be assigned to the novel word but the relative position of a sentence within a triplet was preserved. For the R condition, the sentences were presented with the appropriate real word in the terminal position. Each list of 150 triplets was divided into 5 runs comprising 10 triplets of each condition as well as 10 additional fixation trials of 4 seconds.

Each run started with a fixation asterisk lasting for 8 seconds to allow time for T1 equilibration effects. Each trial began with a fixation cross of 500 ms duration; then sentences were presented word by word in the center of the screen (word duration, 200 ms; stimulus onset asynchrony 500 ms). The last (8^{th}) word or novel word was presented in red for 500 ms. After each triplet, a prompt was presented for 2 seconds requiring the subjects to think covertly about the hidden word. Fixation trials and triplets from the M+, M-, and R conditions were presented in a pseudorandom order. Stimulus presentation was controlled by Presentation 0.60 Software (Neurobehavioral Systems) and synchronized with MRI data acquisition with an accuracy of 1 ms. Stimuli were projected onto a screen and could be viewed by the subject through a mirror system mounted on to the head-coil.

Prior to the scanning session, participants were carefully trained outside the scanner using test trials to ensure that they fully understood the task. Scanning began with a 15-min structural scan followed by the 5 functional runs, each lasting about 10 minutes. A short rest was given between the runs.

As the fMRI design did not allow testing for the correct meaning assignment immediately after each trial, a short behavioral test was carried out after each run. In this test the terminal novel words from the previous sentences (M+ and M- conditions) were either paired with their correct meaning or with an unrelated word. In the M-related condition, novel words were paired with the meaning on the last sentence of the triplet. The two words of a pair were presented simultaneously in the center of the screen. Participants indicated if the novel word and the second word of a pair were synonymous or not by pressing one of two buttons (10 trials after each block; random stimuli onset asynchrony between 1000 and 2000 ms). To ensure that words from the R condition were processed as well, an additional test ("did you see this word in the previous block?") comprising the presentation of 10 words from the R condition and 10 novel real words in pseudorandom order was conducted requiring an old/new decision for each stimulus.

3.2.3. MRI scanning methods

Imaging was performed with a neuro-optimized GE Medical Systems 1.5 Tesla Signa Neurovascular MR scanner with standard quadrature head coil. A MR-compatible response box was used containing two response keys (middle finger and forefinger of the right hand). Conventional high-resolution structural images (3D FSPGR sequence, 60 slice sagittal, 2.8 mm thickness) were followed by functional images sensitive to blood oxygenation level-dependent (BOLD) contrast (echo planar T_2*-weighted gradient echo sequence, TR/TE/flip angle = 2000ms/40ms/80°). Each functional run consisted of 310 sequential whole-brain volumes comprising 23 axial slices aligned to the plane intersecting the anterior and posterior commissures, 3.125 mm in-plane resolution, 5 mm thickness, 1 mm gap between slices, positioned to cover all the brain. The four first volumes were discarded due to T1 equilibration effects.

3.2.3.1.Preprocessing

Different preprocessing steps were implemented using statistical parametric mapping (SPM99, Friston et al., 1995; Friston et al., 1998). First, for each subject, functional volumes were phase-shifted in time with reference to the first slice to minimize purely acquisition-dependent signal-variations across slices. Head-movement artifacts were corrected based on an affine rigid body transformation with reference to the first image of the first run. Functional data was then averaged and mean functional image was normalized using the EPI-derived MNI template (ICBM 152, Montreal Neurological Institute) provided by SPM. After an initial 12-parameter affine transformation, an iterative non-linear normalization was applied using discrete cosine basis functions by which brain warps are expanded in SPM (Ashburner and Friston, 1999). Resulting normalization parameters derived for the mean image were applied to the whole functional set. Finally, functional EPI volumes were resampled into 4 mm cubic voxels and then spatially smoothed with an 8 mm full-width half-maximum (FWHM) isotropic Gaussian Kernel to minimize effects of inter-subject anatomical differences.

3.2.3.2.Data analysis

The statistical evaluation was based on a least-square estimation using the general linear model by modeling the different conditions with a regressor waveform convolved with a canonical hemodynamic response function. Confounding effects in global mean were removed by proportional scaling, and signal-correlated motion effects were eliminated by including the estimated movement parameters. Contrast images were calculated for each subject. The individual contrast images were entered into a second-level analysis using a one-sample t test. Unless mentioned otherwise, contrasts were threshold at $P < 0.001$ (uncorrected) with a cluster extend of 20 contiguous voxels, and only clusters at a $P < 0.05$ (corrected for multiple comparisons) were considered significant (Worsley and Friston, 1995). The maxima of suprathreshold regions were localized by rendering them onto normalized T1 structural images of the MNI reference brain (Cocosco et al., 1997). Maxima and all coordinates are reported in MNI coordinates, as used by SPM99 and labeled following the Talairach atlas.

To investigate the possible correlations between individual subject behavioral performance and the activation changes of those areas that have been found to be modulated by meaning acquisition, the contrast images (from the contrast M+ > M-) were entered into a random effects correlation analysis in SPM99 that highlighted the voxels showing a significant correlation between the correct meaning extraction (expressed as the percentage of correct responses on the word-pair task) and the intensity of task-related BOLD activity. In order to restrict the correlation analysis to those regions active only by M+ when compared to M-, an explicit mask ($P < 0.05$, uncorrected) created from the contrast M+ > M- was applied to the random effects correlation analysis. For this analysis, activation clusters at a significance level of $P <$ 0.05 corrected for multiple comparisons within the region of interest were interpreted.

Maps of parameter estimates (β values) were computed from the generalized linear model to assess the magnitude of activation during each stage of the task. The mean parameter estimate of each regressor was then calculated at the activation maximum. Statistical analyses with planned comparisons (two-sided, paired-sample *t* tests) were used to test differences ($P < 0.05$) between the parameter estimates from the different conditions. As an illustration of the different involvement of certain regions on the M+ and M- conditions, three regions of interest (ROIs) were studied. ROIs were defined and corresponding average values were assessed using the toolbox provided by R. Poldrack (http://spm-toolbox.sourceforge.net/toolboxes.html, version 1.7). Selective averaging was performed using a finite impulse response (FIR) model. Each ROI had a radius of 8 mm. Two functionally defined ROIs were derived from the contrast M+ minus M-: left thalamus (dorsomedial nucleus; coordinates: -4, -16, 4) and left anterior parahippocampal gyrus (BA 35, coordinates: -20, -24, -16). Because the right anterior cingulate gyrus showed increased activity for M-, a ROI was defined (BA 32/6, coordinates: 12, 8, 40) to further explore this activation.

ROIs, used for within region comparison, were created by selecting voxels with overlap between the group full second level analysis. Data averaged time series were collected from intersecting voxels and baseline correction was performed for every participant using the mean value between -4 and 0 seconds before the appearance of the stimuli. The corrected baseline values were used for the corresponding figures. These ROIs were created to illustrate further the differential pattern of activation in regions candidates to be related with vocabulary learning. However, all statistical analyses throughout the text refer to the parameter estimates.

3.3. Results

3.3.1. Behavioral performance

In the word pair task following each functional run, words from the M+ condition yielded 69 ± 13% (SD) correct responses for related and 44 ± 18% correct rejection for the unrelated pairs (d’ = 0.728). As expected, the performance in the M- conditions did not differ between related and unrelated pairs (42 ± 18% related, 46 ±

23%; d’ = 0.270). The percentage of correct responses was larger in the M+ condition ($t_{11} = 4.2$, $P < 0.001$).

Regarding reaction times, significant differences were found for M+ words between related and unrelated pairs ($t_{11} = -3.8$, $P < 0.003$; related: 1444 ± 188 ms; unrelated: 1728 ± 285 ms). No significant differences between both conditions where encountered in the M- condition ($t < 1$). Thus, the present results show a moderate degree of meaning acquisition for the novel words in the M+.

In the old/new judgment task the percentage of hits was 78.8% (SD = 10.6) and the percentage of false alarms 9.3% (SD = 8.2; d’ = 2.12).

3.3.2. fMRI results

Figure 3.1a and Table 3.1 show the comparisons between each condition and rest. The contrast between M+ and rest led to differences in activation in left inferior frontal gyrus (LIFG, BA 45), left middle temporal gyrus (LMTG, BA 21), left putamen, right posterior parahippocampal gyrus (BA 19) and left posterior parahippocampal gyrus (BA 19) among other regions. M- vs. rest showed activations in left inferior frontal gyrus (BA 45), left middle temporal gyrus (BA 21), right posterior parahippocampal gyrus (BA 31), left posterior parahippocampal gyrus (BA 19) and left putamen among other regions. For the R condition, activity in left middle temporal gyrus (BA 21), left inferior frontal gyrus (BA 45) and left precentral gyrus (BA 4) was seen.

The comparison between M+ versus M- (see Figure 3.1b and Table 3.2) showed increased activation for M+ in the left anterior parahippocampal gyrus (BA 35), left precuneus (BA 31) and left thalamus (dorsomedial nucleus). The reverse comparison, M- minus M+, showed increased activation in the right insula (BA 13) and right anterior cingulate gyrus/pre-suplementary motor area (ACC/pre-SMA, BA 32/6) (see Figure 3.1b and Table 3.3).

			Stereotactic coordinates			
Brain region	**~BA**	**x**	**y**	**z**	***z* score**	***P***
M+ > Rest						
L IFG	45	-56	24	12	5.38	0.001
L MTG	21	-60	-36	-12	4.73	0.001
R postcentral gyrus	2	52	-28	56	4.54	0.001
L Fusiform Gyrus	19	-44	-72	-20	4.11	0.001
L Putamen		-24	-12	8	3.94	0.007
R Cerebellum		4	-56	-44	3.90	0.009
L Lingual Gyrus	19	-32	-64	0	3.85	0.007
R Posterior Parahippocampal Gyrus	19	28	-48	0	3.82	0.001
L SFG	6	-8	-8	68	3.81	0.006
L Posterior Parahippocampal Gyrus	19	-24	-56	-4	3.51	0.007
M- > Rest						
L IFG	45	-56	20	20	4.97	0.001
L Fusiform gyrus	19	-36	-76	-20	4.79	0.001
L MTG	21	-56	-36	-4	4.75	0.001
L Putamen		-24	-12	8	4.61	0.001
L Posterior Parahippocampal Gyrus	19	-28	-52	0	4.51	0.001
R Precentral gyrus	4	36	-28	68	4.29	0.001
R Insula		44	-16	16	4.07	0.001
R Posterior Parahippocampal Gyrus	30	28	-48	4	4.00	0.001
L Cerebellum		-44	-56	-24	3.81	0.010
R > Rest						
L MTG	21	-56	-32	-12	4.57	0.001
L Precentral Gyrus	4	-52	-8	44	4.07	0.001
L IFG	45	-56	20	16	3.91	0.003

Table 3.1. Brain regions showing changes in activity for each condition, comparing type of word and rest. MNI coordinates and *z* scores for the peak location in a particular identified anatomical cluster ($P < 0.001$ uncorrected; 20 voxels spatial extent) for the statistically significant differences of the corresponding activated regions. Note that only the clusters that were significant on a cluster level of $P < 0.05$ (corrected for multiple comparisons) are listed. BA = approximate Brodmann's area; R = Right hemisphere; L = Left hemisphere; IFG = inferior frontal gyrus; SFG = superior frontal gyrus; MTG = middle temporal gyrus.

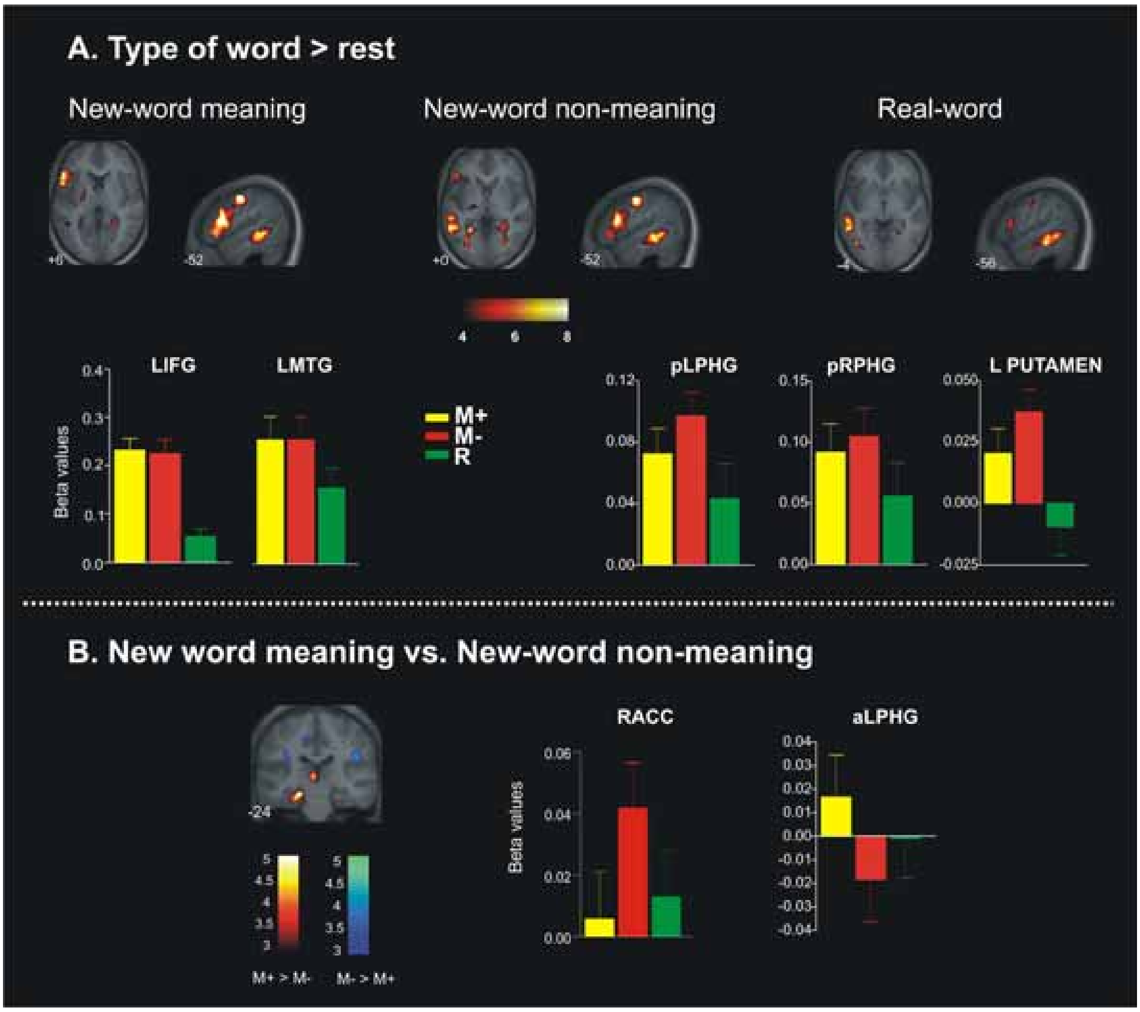

Figure 3.1. A. Axial and sagital views in standard stereotactic space of the group average comparisons between word type and rest. Notice the differential recruitment of the inferior frontal gyrus and middle temporal gyrus, as well as hippocampal regions and other subcortical regions, in each condition. All the views presented were superimposed on the mean anatomical image formed averaging for all 12 subjects T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *T* values of the corresponding contrast. Group-average beta values for M+, M- and R conditions in the left IFG (BA 45, coordinates of the activation maximum: -56, 24, 12) , left MTG (BA 21, coordinates -60, -36, -8), left posterior parahippocampal gyrus (BA 19, coordinates -28, -52, 0), right posterior parahippocampal gyrus (BA 30, coordinates 28, -48, 4) and left putamen (coordinates -24, -12, 8). Error bars indicate standard error of the mean. B. Coronal view in standard stereotactic space of the group average comparisons between M+ and M- (depicted in red colors) and M- versus M+ (depicted in blue colors). Notice the larger activation of left anterior parahippocampal gyrus and left thalamus (dorsomedial nucleus) in M+, and larger activation in ACC in M-. View presented was superimposed on the mean anatomical image formed averaging for all 12 subjects T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *T* values of the corresponding contrast. Group-average beta values for M+, M- and R conditions in left anterior parahippocampal gyrus (BA 35, coordinates -20, -24, -16) and right anterior cingulate gyrus/pre-SMA (BA 32/6, coordinates 12, 8, 40). Error bars indicate standard error of the mean. Hemodynamic time courses and percentage of signal change in left anterior parahippocampal gyrus (BA 35) and right anterior cingulate gyrus (BA 32/6). Represented in grey bars the three sentences within each condition.

	Stereotactic coordinates					
Brain region	**~BA**	**x**	**y**	**z**	***z* score**	***P***
M+ > M-						
L Precuneus	31	-4	-68	20	3.87	0.015
L anterior Parahippocampal Gyrus	35	-20	-24	-16	4.14	0.049[a]
L Thalamus (dorsomedial)		-4	-16	4	3.80	0.0001[a]
M- > M+						
R Insula	13	36	-8	28	4.42	0.0001
R ACC/pre-SMA	32/6	12	8	40	3.01	0.013[a]

Table 3.2. Brain regions showing changes in activity for new-word conditions, comparing meaning and non-meaning conditions. MNI coordinates and z score for the peak location in a particular identified anatomical cluster ($P < 0.001$ uncorrected; 20 voxels spatial extent; [a] $P < 0.01$; 20 voxels) for the statistically significant differences of the corresponding activated regions. Note that only the clusters that were significant on a cluster level of $P < 0.05$ (corrected for multiple comparisons) are listed. BA = approximate Brodmann's area; R = Right hemisphere; L = Left hemisphere; ACC/pre-SMA = anterior cingulate gyrus/pre-supplementary motor area.

For the comparison between M+ and R (see Figure 3.2a) significant differences in activation were observed in the left inferior frontal gyrus (BA 45), the right caudate head, right and left caudate body, right and left inferior frontal gyrus (BA 47), left thalamus (dorsomedial nucleus) and left precentral gyrus (BA 6) (see Figure 3.2a and Table 3.3). The reverse comparison showed activation in the right posterior cingulate gyrus (BA 31), right inferior parietal lobe (BA 40) and left middle frontal gyrus (BA 10) due to the deactivation of these regions in the M+ condition (see Figure 3.2c and Table 3.3). When comparing M- to R, left inferior frontal gyrus (BA 45), right superior frontal gyrus/ACC (BA 8/32), right posterior parahippocampal gyrus (BA 30), right and left caudate body, right inferior frontal gyrus (BA 47), left middle temporal gyrus (BA 21), left posterior parahippocampal gyrus (BA 19) and right precentral gyrus (BA 4) were found activated (see Figure 3.2a and Table 3.3). The reverse contrast showed activations in right precuneus (BA 31), left middle frontal gyrus (BA 10), right superior frontal gyrus/inferior parietal lobe (BA 39) and right inferior parietal lobe (BA 40) (see Figure 3.2c and Table 3.3).

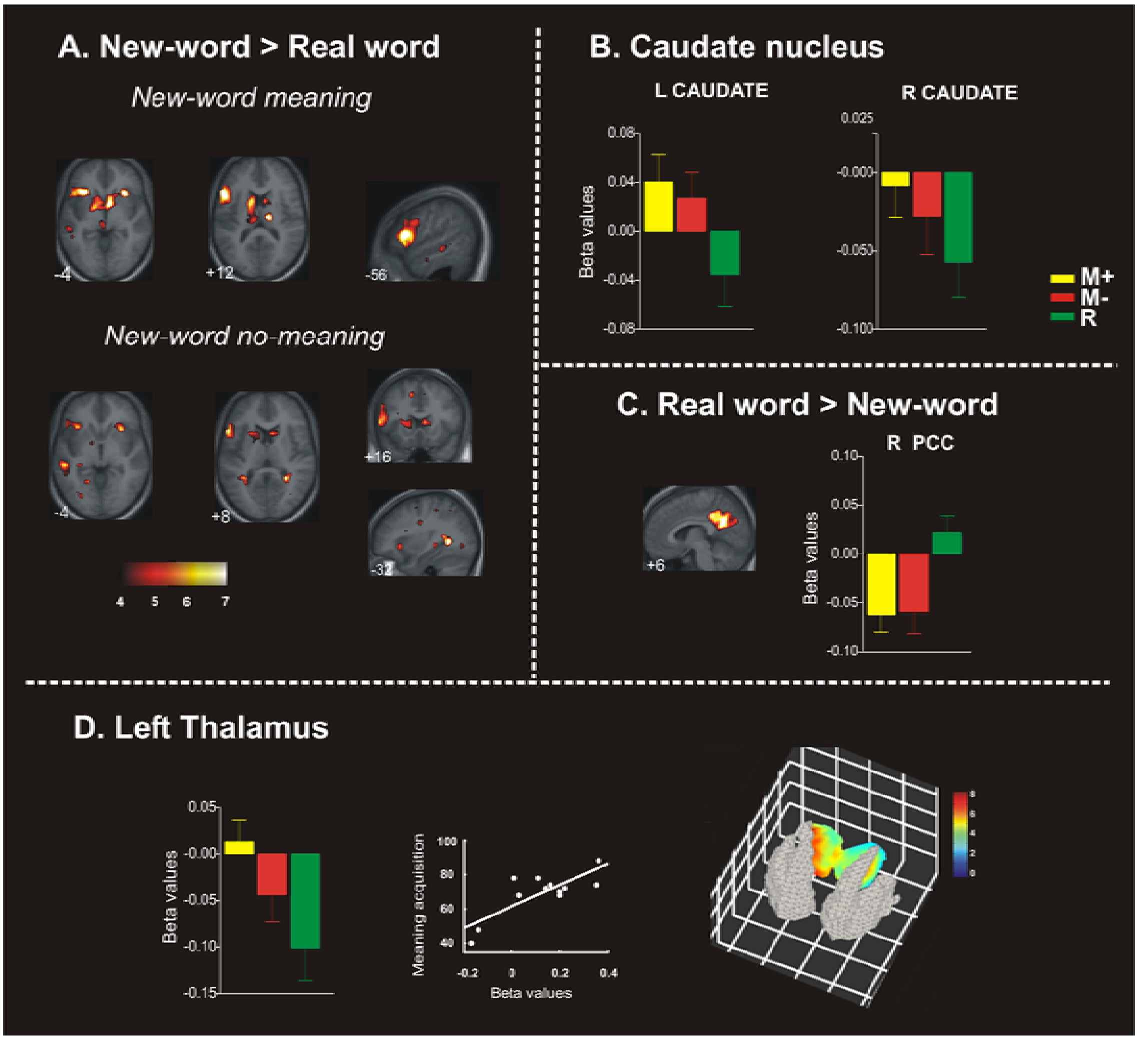

Figure 3.2. A. Axial, sagital and coronal views in standard stereotactic space of the group average comparison between new-word conditions versus word. Notice the differential recruitment of subcortical structures in both hemispheres. Sagital view of the reversed comparison word minus new-word non-meaning condition. All the views presented were superimposed on the mean anatomical image formed averaging for all 12 subjects T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *t* values of the corresponding contrast. B. Group-average beta values for M+, M- and R conditions in the left caudate nucleus (coordinates of the activation maximum: -12, 8, 16) and right caudate nucleus (coordinates 8, 20, 0). C. Group-average beta values for M+, M- and R conditions in the right posterior cingulate gyrus (BA31, coordinates 8, -36, 36). Error bars indicate standard error of the mean. D. Left top: hemodynamic time course and percentage of signal change in the left thalamus (dorsomedial nucleus, coordinates -4, -16, 4). Represented in grey bars the three sentences within each condition. Left bottom: group-average beta values for M+, M- and R conditions in the left thalamus. Error bars indicate standard error of the mean. Right top: tri-dimensional view of the thalamus based on MARSBAR toolbox (http://marsbar.sourceforge.net/) included templates. Activity maps were constructed by reslicing the original T-value map (M+ vs. M-) to (1 x 1 x 1 mm) and surface-projected to the thalamus derived template. Radiological convention. Right bottom: Scatterplot of the beta values against the efficiency of meaning acquisition (corrected recognition rate for M+) at the left thalamus (coordinates -8, -28, 8).

		Stereotactic coordinates				
Brain region	**~BA**	**x**	**y**	**z**	***z* score**	***P***
<u>M+ > R</u>						
L IFG	45	-56	20	12	4.75	0.001 [a]
R Caudate Head		8	20	0	4.32	0.001 [a]
L Caudate Body		-12	8	12	4.21	0.001 [a]
R IFG	47	32	24	-4	4.78	0.001
L IFG	47	-36	24	-8	4.70	0.001
R Caudate Body		8	8	12	3.84	0.001
L Thalamus (dorsomedial)		-8	-20	12	3.72	0.001
L Precentral Gyrus	6	-52	-4	52	3.55	0.001
<u>M- > R</u>						
L IFG	45	-60	24	12	5.06	0.001
R SFG/Anterior Cingulate	8	4	28	44	4.76	0.001
R Posterior Parahippocampal Gyrus	30	28	-48	4	4.73	0.004
R IFG	47	32	20	-4	4.21	0.002
L MTG	21	-56	-32	-4	4.12	0.001
R Caudate Body		8	12	12	4.08	0.001
L Posterior Parahippocampal Gyrus	19	-20	-56	-4	3.98	0.001
R Precentral Gyrus	4	36	-20	56	3.81	0.001
L Caudate Body		-12	8	16	3.66	0.001
<u>R > M+</u>						
R Cingulate gyrus	31	8	-36	36	4.81	0.001
R PLi	40	56	-36	28	4.46	0.001
L MFG	10	-8	48	12	4.31	0.001
<u>R > M-</u>						
R Precuneus	31	12	-60	28	5.19	0.001
L MFG	10	-4	56	4	4.63	0.001
R STG/ PLi	39	52	-56	24	4.27	0.020
R PLi	40	60	-36	36	4.11	0.009

Table 3.3. Brain regions showing changes in activity for each condition comparing New-word and Real-word. MNI coordinates and *z* score for the peak location in a particular identified anatomical cluster ($P < 0.001$ uncorrected; 20 voxels spatial extent; [a] $P < 0.0001$; 20 voxels) for the statistically significant differences of the corresponding activated regions. Note that only the clusters that were significant on a cluster level of $P < 0.05$ (corrected for multiple comparisons) are listed. BA = approximate Brodmann's area; L = Left hemisphere, R = Right hemisphere, IFG = inferior frontal gyrus; SFG = superior frontal gyrus; MTG = middle temporal gyurs; STG = superior temporal gyrus; PLi = inferior parietal lobule.

3.3.3. Parameter estimates analysis

The parameter estimates (beta values) analysis showed that the level of activity for M+ did not differ significantly from M- for the left inferior frontal gyrus (IFG), left middle temporal gyrus (MTG), left putamen, right posterior parahippocampal gyrus (see figure 3.1a) and left and right caudate (see figure 3.2b). The lowest BOLD activity was observed in all of these regions for R condition. By contrast, the right posterior cingulate gyrus showed a reduction of activity of M+ and M- relative to R (see figure 3.2c).

Of particular interest in the present study are those regions that differentiate M+ and M-. Only four regions showed such a pattern: in the left thalamus (dorsomedial nucleus), the M+ condition showed greater activity than both, M- ($t_{11} = 5.4$, $P < 0.001$ and R condition ($t_{11} = 4.3$, $P < 0.001$). The M- condition showed also larger activity than R ($t_{11} = 2.3$, $P < 0.03$). Moreover, a significant positive correlation was found between the percentage of correct responses in the word-pair task for M+ (which was taken as an index of meaning acquisition) and the intensity of BOLD response in the thalamus (coordinates of the peak of the cluster, –8, –28, 8; Pearson r = 0.799; $P < 0.002$, two-tailed) (see figure 3.2d). In the left anterior parahippocampal gyrus a higher level of activation was found for M+ when compared to M- ($t_{11} = 5.97$, $P < 0.001$) (see figure 3.1b), whereas the reverse pattern was found in the left posterior parahippocampal gyrus. M- response was greater than both M+ ($t_{11} = -2.1$, $P < 0.05$) and R ($t_{11} = 5.4$, $P < 0.001$), no differences were found between M+ and R (see figure 3.1A). The right anterior cingulate gyrus again showed a higher level of activation for M- than M+ ($t_{11} = -3.6$, $P < 0.004$) (see figure 3.1b).

In order to asses if the thalamic and anterior parahippocampal activity observed in M+ when compared to M- was due to meaning acquisition and not to previous differences between those conditions, data was further analyzed. Each sentence was modeled separately as a block of 4 seconds. The first sentence did not show any processing difference between M+ and M-. The second and third sentences were modeled together per each condition. When M+ and M- were compared the different regions mentioned before were activated [left thalamus (coordinates, -8, -20, 4; $z = 3.94$, $P < 0.0001$), left anterior parahippocampal gyrus (BA 35, -20, -24, -16; $z = 3.63$, $P < 0.0001$), left precuneus (BA 31, coordinates, -4, -64, 8; $z = 3.55$, $P < 0.002$)]. The same occurred for the comparison M- and M+ [right insula (coordinates, 40, 0, 8; $z = 5.37$, $P < 0.0001$), right anterior cingulate gyrus (ACC/pre-SMA) (BA 32/6, coordinates, 12, 20, 48; $z = 3.98$, $P < 0.005$)]. Thus, in the first sentence participants did not know if they could or not learn the meaning of the novel word and, therefore, no differences were observed between both conditions. However, on the second and third sentences only in congruent conditions meaning could be learned, thus, differences in processing arose when comparing these conditions.

In sum, parameter estimates analysis yielded the following pattern: (i) greater activation was observed in the left thalamus and left anterior parahippocampal gyrus for M+ compared to M-, (ii) M- trials showed greater activation than M+ in the left posterior parahippocampal gyrus and right anterior cingulate gyrus. In addition, (iii) a positive correlation across subjects between brain activity in the left thalamus and the efficiency of meaning acquisition for novel words was observed.

3.4. Discussion

Using functional magnetic resonance imaging, the mapping of novel words to meaning derived from sentential context was studied in young adults. The performance in the word pair task conducted after each functional run indicated that participants were able to acquire the meaning for those novel words that had been read in a set of coherent sentences (M+ condition) (Chaffin et al., 2001). While performance on that task was far from perfect, it has to be kept in mind that participants were exposed to multiple novel words over a short period of time and further practice would have likely yielded a stronger word-meaning link (Gaskell and Dumay, 2003).

The fMRI results suggest that word learning is supported by a multi-element brain network including the left inferior frontal gyrus (BA 45), the middle temporal gyrus (BA 21), the parahippocampal gyrus and several subcortical structures. We will consider the possible role of each of these structures in word learning in the following sections. First we will discuss the common regions activated when trying to discover the meaning of a new-word (M+ and M- vs. R condition). Afterward, we will discuss the implication of differential recruitment of some regions when successfully discovering the meaning of a new-word (M+ vs. M-).

3.4.1. Brain regions engaged in learning the meaning of a new word

All three conditions in the present study (M+, M- and R) showed activation in the medial temporal cortex, specifically, middle temporal gyrus (BA 21), and inferior frontal gyrus (BA 45) when compared against fixation control. However, as attested by the parameter estimates, activation was clearly greater for the two novel word conditions, which in turn did not differ.

Several neuroimaging studies suggest that greater middle temporal activation is related to increased semantic integration demands (Petersen et al., 1988; Price et al., 1996; Vandenberghe et al., 1996; Damasio et al., 1996; Just et al., 1996; Martin et al., 1996; Price, 2000; Ni et al., 2000; Martin and Chao, 2001; Baumgaertner et al., 2002). The middle temporal region is commonly active in semantic tasks independent of input modality, supporting its role in supramodal semantic processing (Vandenberghe et al., 1996; Price, 2000). Applying a semantic integration account to the current data, the fact that no differential effect was found for M+ and M- conditions might be taken to reflect attempts to integrate candidate concepts that might be represented by the novel word into the sentence context. If this account was true, we would predict that in a longer term learning study with repeated presentations of M+ words the activity in this condition should become more similar to the R condition.

Left inferior frontal regions have been implicated in executive aspects during language tasks (Just et al., 1996; Thompson-Schill et al., 1997; Gabrieli et al., 1998; Dapretto and Bookheimer, 1999; Wagner et al., 2001; Baumgaertner et al., 2002). Thus, with an increase in the difficulty of contextual integration a modulation of the activity in the inferior frontal gyrus is predicted. In fact the anterior region of the left IFG (BA 45) was found more active in both novel word conditions. The IFG is neither morphologically (Amunts et al., 1999) nor functionally homogeneous. While, the posterior and dorsal part of left IFG (BA 44) has been implicated in interference resolution (Thompson-Schill et al., 1997), phonological control (Fiez et al., 1996; Fiez, 1997; Gold and Buckner, 2002) and syntactic processing (Dapretto and Bookheimer, 1999; Friederici et al., 2000; Friederici et al., 2003), its anterior and ventral regions (BA 47/45) have been associated with semantic control (Fiez, 1997; Poldrack et al., 1999; Wagner et al., 2001; Bokde et al., 2001).

The results from the present experiment are consistent with previous neuroimaging studies, as anterior left IFG (pars triangularis, BA 45 and pars orbitalis, BA 47) showed increased activation for those conditions requiring more elaborate semantic processing (Petersen et al., 1988; Kapur et al., 1994; Demb et al., 1995;

Warburton et al., 1996). While involvement of the IFG in semantic processing was initially unexpected as damage to this region of the brain is not associated to semantic deficits, neuroimaging studies suggest that it is involved in the control of semantic information retrieval (Kapur et al., 1994; Buckner et al., 1995; Fiez, 1997). Another proposal states that the IFG is required for semantic tasks that require selection from competing semantic features (Thompson-Schill et al., 1997).

The current findings are certainly consistent with these proposals, as in the novel word conditions a set of initial candidate words that fit the low cloze probability first sentence has to be narrowed down during the second and third sentences. This necessitates controlled retrieval of semantic knowledge and selection of the best fitting candidate concept. With regard to the specific role of the anterior IFG, controlled retrieval vs. selection from competing alternatives, one might lean towards the former interpretation, as one should have encountered greater left IFG activation in the M-condition under the competing alternatives account, because more alternatives compete for selection in this condition. The present result of increased cognitive control when learning the meaning of a new word emphasizes the importance of considering the role of these processes in the early stages of learning a language which has been neglected in previous models of bilingual learning (e.g., Kroll and Steward, 1994). Increased cognitive control in the early stages of learning might be especially relevant in order to be able to consolidate the new memory trace and its conceptual links and to regulate the strength of the activation and inhibition of the new lexical representation within the lexicons (Rodriguez-Fornells et al., 2006).

Right and left caudate nucleuses, as well as left putamen, were found more activated for novel-word conditions (with no differences between M+ and M-) than for real-word conditions. The role of these subcortical in word learning will be discussed in the next section as they are part of a neural loop which is important for meaning acquisition.

Finally, activity decreases occurred in the posterior cingulate and temporoparietal regions for the M+ and M- condition relative to the R condition. Such differential deactivation has been found previously in language tasks (e.g., Kuperberg et al., 2003). Raichle (2001) has hypothesized that these medial parietal regions are responsible for the continuous gathering of incoming sensory information at rest.

Consequently, the differential deactivation of this region in association with various tasks (including language tasks) should reflect differential attention demands incurred by such tasks. Thus, the higher the attentional demands of a given task the greater the degree of deactivation in parietal regions. This should also imply that less processing resources are available for other tasks.

3.4.2. Brain regions differentially activated for successful meaning acquisition

A number of subcortical structures showed differential activation depending on the experimental condition and thus appear to be involved in word learning. The *left thalamus* (dorsomedial nucleus) showed greater activation in the M+ condition compared to M- and R conditions; in addition, this region also showed a positive correlation with the efficiency of meaning acquisition. The *left and right caudate nucleus* showed enhanced activity in both novel word conditions compared to the real-word control sentences. Similarly, the activation of the *left putamen* was greater in both novel word conditions compared to the R condition.

The basal ganglia and the thalamus have been shown to play a role in language and cognitive processing. However, in spite of recent advances in our knowledge about their internal organization and input-output connections (Middleton and Strick, 2000), the exact computations supported by these structures are still unknown. Recent fMRI studies have implicated the left thalamus in object recall and lexical retrieval (Crosson et al., 1999; Kraut et al., 2002; Crosson et al., 2003). In an experiment by Kraut et al. (Kraut et al., 2002) participants were required to decide whether two presented object features were related to a specific object (e.g., “desert” and “humps” should activate the concept “camel”). There was thalamic activation when the features elicited object recall in semantic memory, but no activation when the features were merely semantically associated. Further evidence for a role of the left thalamus in language processing comes from patients with isolated anterior thalamic infarcts who have consistently been shown to have word finding difficulties (Ghika-Schmid and Bogousslavsky, 2000; Segal et al., 2003).

With regard to the role of the basal ganglia in language processing activation of the caudate nucleus or the putamen in language tasks has been inconsistent. Similarly, human lesion data do not provide support for a direct role of either the caudate or the putamen in language (Nadeau and Crosson, 1997). These structures have been shown to be part of several parallel loops involving distinct regions of prefrontal and, to a lesser extent, temporal and parietal cortex (Middleton and Strick, 2000). Via its participation in these functional loop, the striatum has been related to a number of cognitive and executive processes in addition to the modulation of movements, such as learning, reinforcement (Schultz, 2006) and response selection (Desmond et al., 1998). In particular it seems to play an important role in learning arbitrary associations (Laubach, 2005). In a recent study Crosson et al. (Crosson et al., 2003) found activation of the left pre-SMA-left dorsal caudate-left ventral anterior thalamic loop in tasks involving retrieval of pre-existing lexical items, whether based on semantic or phonological processes.

Several regions of this loop have also been found in the present study. The left thalamus showed greatest activation in the M+ condition (see figure 3.2d). Whereas the ACC showed greatest activation in M- (see figure 3.1b). Right and left caudate did not show differences in activation between M+ and M-, but differences were observed when comparing both novel word conditions to real word control sentences (see figure 3.2b). These structures appear to facilitate retrieval of lexical items from pre-existing stores during language generation and might induce and maintain a processing bias long enough to impact controlled cognitive processes, including working memory (Crosson et al., 2003). We propose that this pattern is consistent with a role of this loop in meaning extraction in the congruent context. Because the thalamus receives inhibition from the globus pallidus, this loop could maintain a bias toward the retrieval of one lexical item versus competing alternatives. Once the most appropriate lexical alternative is selected, inhibition of the thalamus by the globus pallidus might be released via excitation of the caudate nucleus (which increases inhibition of the globus pallidus) and would then lead to thalamic excitation of the frontal cortex (Crosson et al., 1997). Consistent with this hypothesis, ACC shows greater activation in the condition in which meaning could not be extracted (see figure 3.1b). The role of the left thalamus in meaning acquisition is further substantiated by a positive correlation between its activity and the efficiency of meaning acquisition (see figure 3.2d). To summarize, in the condition in which meaning could be extracted the bias maintained by the loop discussed above may be overridden, allowing further processing of the selected item by frontal structures.

Moreover, differences in activation between M+ and M- were found in the medial temporal lobe (MTL). The right and left posterior parahippocampal gyrus showed enhanced activation of the two novel word conditions compared to the R condition. Prior studies have demonstrated that medial temporal lobe structures have a central role in associative learning, episodic memory and the acquisition of new lexical information. For example, H.M., a patient characterized with anterograde amnesia following bilateral medial temporal lobe excision, was impaired in the acquisition of new lexical information (Gabrieli et al., 1988; Postle and Corkin, 1998), but not in lexical and grammatical processing tasks (Kensinger et al., 2001). Importantly, H.M. was not able to learn new words ("xerox", which he had not acquired premorbidly) (Gabrieli et al., 1988). Consequently, he also did not show stem completion priming for words that entered the language after the time of his surgery, although normal priming was observed for words that were learned preoperatively (Postle and Corkin, 1998). This dissociation suggests a role of the medial temporal lobe in the acquisition of new lexical knowledge (see Ullman, 2001c).

Important for the present results, several imaging studies have reported activation of hippocampal and surrounding parahippocampal regions in tasks that required linking the meaning of a target word with context information which provides knowledge about the world (Henke et al., 1999; Bartha et al., 2003; Hoenig and Scheef, 2005). In the present study, *posterior* parahippocampal gyrus, mostly left, showed greater activation in M- items than M+ (see Figure 3.1a). We suggest that the differences observed might reflect semantic associative processing rather than encoding of a retrieved meaning which should be most pronounced in M-. Because of multiple competing candidates in the M- condition, the additional activation in this condition can be explained.

Interestingly, the *anterior* left parahippocampal gyrus displayed greater activation for M+ items than for M- or R ones (see Figure 3.1b). This dissociation between posterior and anterior portions of the parahippocampal cortex is consistent with the proposal that anterior regions within the MTL are predominantly involved in encoding, while the posterior regions subserve retrieval (Lepage et al., 1998). This account has received support from several fMRI studies (Saykin et al., 1999; Pihlajamaki et al., 2003; Prince et al., 2005), and the present set of data would certainly be consistent with this proposal as well (anterior: M+ > M- → encoding; posterior M- > M+ → retrieval).

3.5. Conclusions

The present study showed a number of brain areas, including subcortical structures, involved in the meaning assignment to novel words. By studying conditions, that did or did not allow meaning assignment, we could tentatively identify the role of these brain areas in the retrieval, selection and encoding of the meaning. Obviously, the present study provides only a first glimpse at the neural machinery of word learning. Further manipulations, including, for example, (a) an increased number of exposures to a novel word, (b) a more natural, incidental learning environment, or (c) the learning of novel words denoting novel concepts, are needed to come to a deeper understanding of the identified network.

Chapter 4[§]

Experiment 5 and 6: Acquiring the meaning of concrete and abstract concepts from verbal contexts

4.1. Introduction

Over many years, studies about concrete and abstract word processing have shown that indeed these two types of words are processed in different ways. In contrast to abstract concepts, the concept to which concrete words refer can be easily perceived through sensory experiences. For example, *cake* is a highly perceivable word, and its meaning is associated with many sensory properties (taste, shape, etc.). In contrast, the meaning of an abstract word (e.g., *truth*) is very difficult to be perceived or imagined. It is not tangible and it is hard to describe because our senses cannot explore what makes "truth" the word *truth*. In fact, in order to describe an abstract word we need other abstract concepts and the context and situations which are associated with that word. Typically, the superiority for concrete words over abstract words has been demonstrated, as usually the former show a processing advantage over the latter. For example, the processing of abstract words presented in isolation is slower than the processing of concrete words (Kroll and Merves, 1986; Schwanenflugel and Shoben, 1983). Concrete paired associates are usually remembered better than abstract paired associates (Paivio, 1971). Moreover, abstract word naming is slower than concrete word naming when words are presented without a supportive context (Schwanenflugel and Stowe, 1989), and participants also typically take longer to read sentences constructed of abstract words (Schwanenflugel and Shoben, 1983).

[§] This chapter corresponds to:
Mestres-Missé, A.; Münte, T.F. & Rodriguez-Fornells, A. (submitted). Acquiring the meaning of concrete and abstract concepts from verbal contexts.

4.1.1. Different theoretical accounts of the concreteness effect

Schwanenflugel et al. (Schwanenflugel and Shoben, 1983) found similar lexical decision times for abstract and concrete words when they were presented as the last word of a sentence. This result led the authors to propose the context availability theory, which argues that the difference between concrete and abstract words is only quantitative. This theoretical account states that concrete words have a larger amount of contextual information in semantic memory (Schwanenflugel and Shoben, 1983; Schwanenflugel and Stowe, 1989). Abstract words are comprehended more slowly when presented in isolation because they are less associated with relevant contextual knowledge in semantic memory than concrete words. When abstract words are provided with an external context, such as a supportive sentence stem, then they are processed as efficiently as concrete words. The reason that there is a difficulty in recruiting the context of abstract words is based on the idea that these types of words tend to appear normally in a wider range of different contexts (Schwanenflugel and Shoben, 1983). Considering a spreading activation model of semantic memory (Collins and Loftus, 1975), if the amount of information connected to a concept is very large, the recruitment of a specific piece of information will be more difficult ("fan effect", Anderson, 1983; Schwanenflugel and Shoben, 1983). This is the reason why a supporting context helps in the activation of the specific context information. Therefore, the authors proposed that abstract words are characterized by a large number of context-dependent properties. In contrast, concrete words have more context-independent properties (Barsalou, 1982) that are more easily accessed when the words occur in isolation. Considering this interpretation, concrete words do not benefit as much from an external context because they already have strong built-in contexts or stable core meanings (Schwanenflugel and Shoben, 1983; Schwanenflugel and Stowe, 1989) (see also Saffran et al., 1980). According to Kieras (Kieras, 1978), another explanation of this contextual advantage of concrete words might be that these words are more familiar and therefore they are associated with more propositions in memory, which easily facilitates the assignment of a context to the specific word. Another possibility is that the representations of concrete words might be closely tied to perceptual propositions that activate perceptual contexts in which the concept has appeared, facilitating the assignment of a context.

Another quantitative alternative account of the concreteness effect postulates that the differences are due to concrete words being supported by more semantic features than abstract words (Plaut and Shallice, 1993). This hypothesis was proposed in order to explain the strong concreteness effect observed in deep dyslexia patients (Coltheart et al., 1980). In agreement with this hypothesis, Jones (Jones, 1985) demonstrated that people tend to produce more predicates for concrete than abstract words. In addition, in a free association task, de Groot (de Groot, 1989) also found that participants were able to generate more associates for concrete than abstract words. In the connectionist model of reading developed by Plaut and Shallice (1993), concrete words are endowed with more semantic features than abstract words, and therefore when the word-processing system is damaged, it makes it more difficult to retrieve abstract words because they have less semantic features. Interestingly, the model was able to explain the reverse pattern, abstract word processing advantages observed in various neurophyschological patients (Warrington, 1981; see also Breedin et al., 1994).

In contrast to the previous approaches, which emphasize quantitative differences between concrete and abstract words, other models have been proposed that postulate qualitative differences between concrete and abstract words. The best-known account is probably Paivio's dual coding theory (Paivio, 1971; Paivio, 1986), which attributes the concrete words' superiority to abstract words lacking the direct sensory referents of concrete words (Paivio, 1971). The theory assumes that there are two cognitive subsystems, one specialized for the representation and processing of nonverbal objects/events (i.e., imagery), and the other specialized for dealing with language, a verbal system. According to this account, the difference between concrete and abstract words is due to image representations stored only for concrete words. In this sense concrete and abstract words are qualitative different, as each system is supposed to be functionally distinct, although some connectivity exists between them. Both verbal semantic information and nonverbal imagistic information are stored for concrete words, while abstract words are associated mainly with information stored in the verbal system. Abstract words predominantly activate linguistic semantic representations. Processing concrete words activates linguistic semantic information as well as imagistic information. Therefore, faster processing is expected for these words because more information is activated.

In agreement with the existence of a qualititative difference between concrete and abstract words, recently, Crutch et al. (2005) showed neuropsychological evidence that concrete and abstract words have qualitatively different principles of organization: the organizational principle of abstract words is associative, while concrete words show a categorical organization (Crutch and Warrington, 2005). The authors studied a patient with semantic refractory access dysphasia. In this type of phenomenon, temporal factors influence the performance of a cognitive task. The performance on these patients is facilitated if the delay between each response and the presentation of the next stimulus is increased. So refractoriness can be observed between related concepts because the activation of one representation leads to the partial activation of other representations that share neural space. In this frame, the authors tested semantic similarity and semantic association as competing principles of organization of abstract and concrete word semantics. Interestingly, they did not detect semantic relatedness effects among synonymous abstract words, while in contrast this effect was observed for concrete word stimuli. They showed larger refractoriness effects among associated than synonymous abstract words, suggesting that abstract words were represented in an associative neural network, while for concrete words the pattern was the reverse, having a much more categorical organization (Crutch and Warrington, 2005).

All these different theories demonstrate a common difference between concrete and abstract words, in the sense that all of them postulate that the representation of concrete words includes an additional component or mechanism that facilitates its access, activation, and further remembering: (i) an additional nonverbal (imaginal) representation linked to sensorimotor information, (ii) an increased amount of semantic features, (iii) larger familiarity of concrete words or additional perceptual components that facilitate the assignment of a context, (iv) categorical vs. associative organization.

A different and probably more parsimonious explanation is the one that considers that concrete words have “intrinsic” properties whereas abstract words have “extrinsic” properties. An “apple” can be described by its color, its taste, its shape, its smell, and so on, but the word “truth”, for example, cannot be defined by any perceptual characteristic, and it can neither be sensed with the five senses. Therefore, which are the basic features of the meaning of the word? There are several interesting studies investigating the nature of the difference between abstract and concrete words.

Logically, these differences are in the meaning itself of these words, in the basic features that define them. Wiemer-Hastings et al. (Wiemer-Hastings and Xu, 2005) studied those differences and found that abstract concepts are relational concepts characterized by their links to external concepts rather than to intrinsic properties. As these relational concepts vary widely across situations, their properties are quite unspecific, linked more to personal experiences, interactions, and situations which make them more subjective and unspecific, and therefore, less imaginable. On the contrary, concrete concepts represent objects along with all their attributes, functions, parts, actions, relations to other objects, and so on (see also Barsalou and Wiemer-Hastings, 2005). Interestingly, psycholinguistic models of the organization of the semantic system in bilinguals have proposed that more abstract concepts might not share exactly the same meaning representation across languages, which is probably due to their dependence on extrinsic features (see van Hell and de Groot, 1998b; Kroll and Tokowicz, 2001; Dong et al., 2005).

In a similar vein, Breedin et al. (Breedin et al., 1994) argued that in order to account for the reversal of the concreteness effect observed in some patients, it is fundamental to assume that the essential distinction between abstract and concrete words is the difference with respect to perceptual properties, which are essential to the meanings of concrete words but not abstract ones. These authors showed that the patient they studied was more impaired on the perceptual aspects of word meaning than on the non-perceptual features. Thus, if the perceptual nature of concrete words is supposed to be responsible for concrete words' superiority, then the loss of these perceptual features might be responsible for the reversal of the concreteness effect, where abstract words are more preserved compared to concrete ones (Breedin et al., 1994).

4.1.2. Language acquisition of concrete and abstract words

The different theories reviewed in this chapter emphasize that the main difference between concrete and abstract concepts is that concrete concepts' representations entail additional information which makes them easier to access, learn, and remember. These differences in the representations of concrete and abstract words might reflect the way these words have been learned. In fact, concrete and abstract words show large learning differences, and young children learn concrete and abstract words at different rates. Children's first vocabularies are formed mostly of concrete words, as they are restricted to the information that is accessible through observation of the material world (extralinguistic information), that is, to the world-to-word pairing (Bloom, 2000; Gillette et al., 1999). Specifically, Gillette et al. (1999) considered that only a small and limited stock of nouns can be identified only from inspection of extralinguistic information, while learning of other types of words (such as verbs or conjunctions) requires, in addition, the information provided by their linguistic contexts of use (sentence-to-world pairing). In order to test this idea, Gillette et al. investigated word learning (nouns versus verbs) from several information sources. As their aim was to evaluate the effect of information change independent of conceptual change, the paradigm used was the human simulation approach. Adult participants had to identify simple words (masked by a beep or a nonsense word) under varying informational circumstances; words were chosen among the most frequently encountered by the average English-learning child during the first 2 years of life. Gillette et al. (1999) observed that nouns were acquired more efficiently than verbs and concrete verbs more efficiently than abstract verbs, if the information provided to participants was limited to extralinguistic observation (videotaped recordings of mother-infant interactions). To be more precise, even though Gillette et al.'s experiment was aimed at studying the learning of nouns vs. verbs, the results showed that the variable imageability was what better explained the results. Therefore, adults learned the observable objects and events better than the non-observable ones. The authors performed a second experiment for which imageability was controlled. They found that concrete items were learned better than abstract items. The authors concluded that in the first stages of life an infant is limited to the information provided by the environment, that is, observable information, and thus the words labeling concrete concepts (the majority being nouns but also some concrete verbs, such as *throw*) should be easier to acquire. In summary, the concreteness effect in first language acquisition might be due to the tangible presence of the referents of concrete words which support the learning of them, while abstract words lack those perceptual referents. Abstract words cannot be learned until a certain representational capacity is reached that permits the utilization of linguistic contexts in order to unravel the meaning of these words (Bloom, 2000).

Effects of word concreteness have been also shown in second or foreign language acquisition (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000). It is important to bear in mind that second-language learners (compared to infants) do not begin the learning process from scratch, because they already have in memory a specific label and a concept for most of the corresponding concrete and abstract new-words that they will be learning. In adults, concrete words have been found to be easier to learn than abstract words, recalled better and faster, and learned and remembered better (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000; de Groot, 2006). These effects of word concreteness found in novice learners of a second or foreign language have been also observed in fluent bilinguals, showing that concrete words are translated faster and more accurately than are abstract words (de Groot and Poot, 1997; van Hell and de Groot, 1998b; van Hell and de Groot, 1998a). Van Hell et al. (van Hell and de Groot, 1998b), employing a bilingual variant of the word association task (bilingual participants associated a series of words, once in the language of the stimulus, and once in the other language), found that bilinguals were faster at generating word associations to concrete words than abstract words. In addition, the associations reported for concrete words were more often translations than those for abstract words. De Groot and Keijzer (de Groot and Keijzer, 2000) suggested that the differences between the memory representations of concrete and abstract words may be the cause of the concreteness effect. The memory representation of concrete words is supposed to contain more semantic features than that of abstract words (Plaut and Shallice, 1993); hence, concrete word translation pairs may share larger parts of the conceptual representation than abstract translation pairs (van Hell and de Groot, 1998b). Notice that the difference between concrete and abstract words is assumed to be *quantitative*, not qualitative. In contrast, the meanings of abstract words tend to be less consistent and more dependent on the linguistic context of use (Breedin et al., 1994). Abstract meanings differ across contexts and cultures, and concrete words are more likely to share meaning across language and cultures, as the perceptual objects they refer to are the same or similar. Hence, the meanings of abstract words may be more language-specific than concrete word meanings, resulting in fewer common elements for abstract translation pairs than for concrete translation pairs (van Hell and de Groot, 1998a).

Based on these observations and results from novice and fluent bilinguals, De Groot and colleagues (van Hell and de Groot, 1998b; de Groot, 1992) proposed a model of bilingual semantics called The Distributed Feature model, which assumes that meaning is represented in memory as a set of semantic features. The semantic system is assumed to be shared across the two languages of the bilingual. As mentioned before, representations for concrete words are assumed to be quite similar across languages, while those for abstract words are assumed to be more different. Thus, concrete word translations pairs share more semantic features (meaning) than abstract ones (Tokowicz et al., 2002). The model predicts than when a bilingual individual translates an abstract word, only some semantic features for that language will overlap with the semantic features of the other language; thus, the time it takes will be longer than for concrete word translations. In a series of experiments, those predictions were confirmed, showing that the time to recognize and produce translation equivalents was faster when the word pairs were concrete than when abstract (de Groot, 1992; de Groot and Poot, 1997; van Hell and de Groot, 1998b; van Hell and de Groot, 1998a).

4.1.3. Objectives

In the present experiment a new word-learning task was created where adults were engaged in developing the meaning of new words presented repetitively across some sentences. The meaning of the new-words had to be inferred using only contextual information. Using self-paced reading, the present study evaluated the on-line meaning acquisition of concrete and abstract words and its differences when controlling for conceptual, cognitive, and/or linguistic capacity and the information provided by the context of the sentences.

The present investigation can be conceived as a human simulation of the acquisition of the meaning of concrete and abstract concepts from verbal contexts. This human simulation learning approach has been successfully used in adults in order to understand the “noun bias effect” observed in infants when learning a language (Gillette et al., 1999). Although a huge number of studies have been devoted to studying the advantages of processing concrete vs. abstract words, no study has previously investigated which are the differences in learning concrete and abstract concepts in adults using verbal contextual information. It is supposed that contextual learning of new-words is a powerful mechanism that permits the discovery of the meaning of new-words across all of life. Children need to learn thousands of new words, and it is supposed that most of them are learned through contextual information. It has been estimated that students in the middle grades might encounter between 16,000 and 24,000 new words (Nagy et al., 1987) in the approximately million words of text they might be exposed annually (Nagy et al., 1985). This means that a typical seventh grader has to learn the meaning of app. 10 to 15 new words per day. Interestingly, it is supposed that a huge amount of this learning process takes place using contextual information acquired during reading, because (i) the majority of English words are used only in print and not in normal speech, (ii) most of the words usually used in normal speech have already been acquired, and (iii) children learn to use less than one word by direct instruction (Durkin, 1979). However, these estimations seem to be overestimating the real amount of contextual learning (see for a clarifying exposition Landauer and Dumais, 1997). Some studies have reported that children do not discover more than one new meaning every twenty paragraphs. As children normally read an average of 50 paragraphs per day (Carver, 1990), no more than 2.5 words per day could be learned from context. Some authors have even stated that most likely, word meaning might not be learned from ordinary reading (Carver and Leibert, 1995). This conclusion was drawn because no evidence was encountered that students who read relatively easy library books during six weeks increased their reading level, vocabulary, rate, or efficiency.

Some authors have proposed that in order to solve this puzzle of how word meanings are acquired by reading, it is necessary to suppose that either the way in which the different studies evaluated the degree of learning of new words is not well measured (and they are hiding the real vocabulary learning rate) or that children accrue only partial semantic knowledge for the new-words that will be filled and completed with additional exposures (see Landauer and Dumais, 1997; McGregor et al., 2002). In fact, it has been proposed that a "slow mapping" process occurs in children between several new-words and their corresponding referents and meanings. Although this idea apparently disagrees with the well-know fast mapping process (the acquisition of a new-word meaning from one or a very small number of incidental exposures, (Carey, 1978), it can be considered that a slow mapping could be triggered immediately after the fast mapping process. Initially, a fragile new-word representation is created in the lexical memory and the child might begin to hypothesize about its meaning, updating this semantic representation until it perfectly maps the relationship between the word, the referent, and its related concepts. From this perspective, word learning is considering a more gradual process in which word representations are progressively developed and refined over time through multiple exposures (Bloom, 2000; McGregor et al., 2002). Interestingly, Curtis (Curtis, 1987) proposed four stages in order to describe this slow word-knowledge development process: (i) no knowledge of the new word is possible ("I never saw it before"), (ii) some emerging knowledge is possible (e.g., "I've heard this word, but I do not know what it means"), (iii) describing contextual knowledge ("I can recognize it in context …"), and (iv) referencing full knowledge ("I know it").

In order to study how word meaning is determined from reading, several studies tried to mimic this process, selecting new-words (low frequency or unknown words at that particular age) and embedding them in carefully controlled sentences or contexts (e.g., Jenkins et al., 1984; Sternberg, 1987). In our particular approach to studying the concreteness effect, we embedded concrete and abstract meanings in three-sentence contexts and evaluated the mean reading times when participants encountered the target new-words. Based on previous hypotheses related to concrete vs. abstract word processing, we predict that if the lack of perceptual properties for abstract words is the main source of difference between abstract and concrete words, then we should find the same learning differences in adults as in children even though an equally supportive linguistic context is provided for both types of words. This result would prove that the learning differences already observed in children (Bloom, 2000) remain in adulthood in spite of having a full representational and conceptual capacity. In a similar vein, children fail to learn abstract words because of a lack of external referents that support their learning and a not fully developed representational capacity which restricts them practically to world-to-word pairing (Gillette et al., 1999; Bloom, 2000). More importantly, this investigation might be of interest in the field of second-language learning and contextual learning, in order to understand how the meaning of the new abstract and concrete word is progressively mapped in the already existing conceptual and lexical first language information.

4.2. Reanalysis of experiment 2

In experiment 2 (see Chapter 2) we investigated whether a new concrete word could be learned from semantic information provided by sentence contexts. A reanalysis of experiment 2 was performed after participant's data was cleaned individually (experiment 2b). Sentences where the participant could not discover meaning of the new-word, either omissions or incorrect responses, were removed. All extreme values reading time values which were above or below the overall mean reading time +/- 2 SDs were removed from the analysis.

4.2.1. Results and discussion

Participants were able to extract correctly the meaning of the new words presented, as assessed by the high percentage of correct meaning extraction (91.6% ± 9.5%).

Reading time analysis for the target word (8th word in each sentence) was performed (Figure 4.1a, Table 4.1). A 3 x 3 ANOVA repeated measures design was conducted introducing Learning (new-word meaning vs. new-word non-meaning vs. real-word) and Sentence (1st vs. 2nd vs. 3rd). The analysis showed a main effect of Learning ($F_{2,34} = 13.9$, $P < 0.001$), a main effect of Sentence ($F_{2,34} = 9.2$, $P < 0.001$), and a significant interaction between these factors ($F_{4,68} = 5.3$, $P < 0.002$). The Learning factor was split out in order to study the reading times pattern for each condition among the three sentences. Significant differences were encountered only in the new-word non-meaning condition (Sentence effect, $F_{2,34} = 12.1$, $P < 0.001$), revealing differences in reading times for the target word among the three sentences. As sentences proceeded, reading times to the new-word non-meaning target word increased. No significant differences were found in the new-word meaning condition ($F < 1$) or in the real-word condition ($F < 1$) (see Figure 4.1a and 4.1b). When the Sentence factor was split out, significant differences were found between conditions in all three sentences [1st sentence (Learning effect, $F_{2,34} = 9.2$, $P < 0.001$), 2nd ($F_{2,34} = 10.5$, $P < 0.001$) and 3rd sentence ($F_{2,34} = 9.001$, $P < 0.001$)].

Further, pairwise comparisons showed significant differences between the reading times to the target word in the 1st sentence for each condition (new-word meaning vs. real-word, $t_{17} = 3.5$, $P < 0.002$; new-word non-meaning vs. real-word, $t_{17} = 3.09$, $P < 0.007$). Participants were faster to respond to the target word when appearing in the real-word condition (see Figure 4.1a left). As expected, in the 1st sentence, no differences were observed between new-word meaning and new-word non-meaning ($t < 1$). However, when comparing the target word reading times in the 2nd sentence, significant differences arose between all conditions (new-word meaning vs. new-word non-meaning, $t_{17} = -2.1$, $P < 0.046$; new-word meaning vs. real-word, $t_{17} = 3.6$, $P < 0.002$; new-word non-meaning vs. real-word, $t_{17} = 3.5$, $P < 0.002$) (see Figure 4.1a, middle). Participants responded faster to the target word in the real-word condition. The reading times were significantly larger in the new-word non-meaning condition when compared to the new-word meaning condition. Finally, reading times to the target word in the third sentence showed significant differences between new-word meaning and new-word non-meaning (t_{17} = -3.57, $P < 0.002$) and new-word non-meaning vs. real-word (t_{17} = 3.3, $P < 0.002$). Participants showed significantly larger reading times to the target word in the new-word non-meaning condition when compared to the other two conditions, which did not show differences between them ($t < 1$) (see Figure 4.1a right).

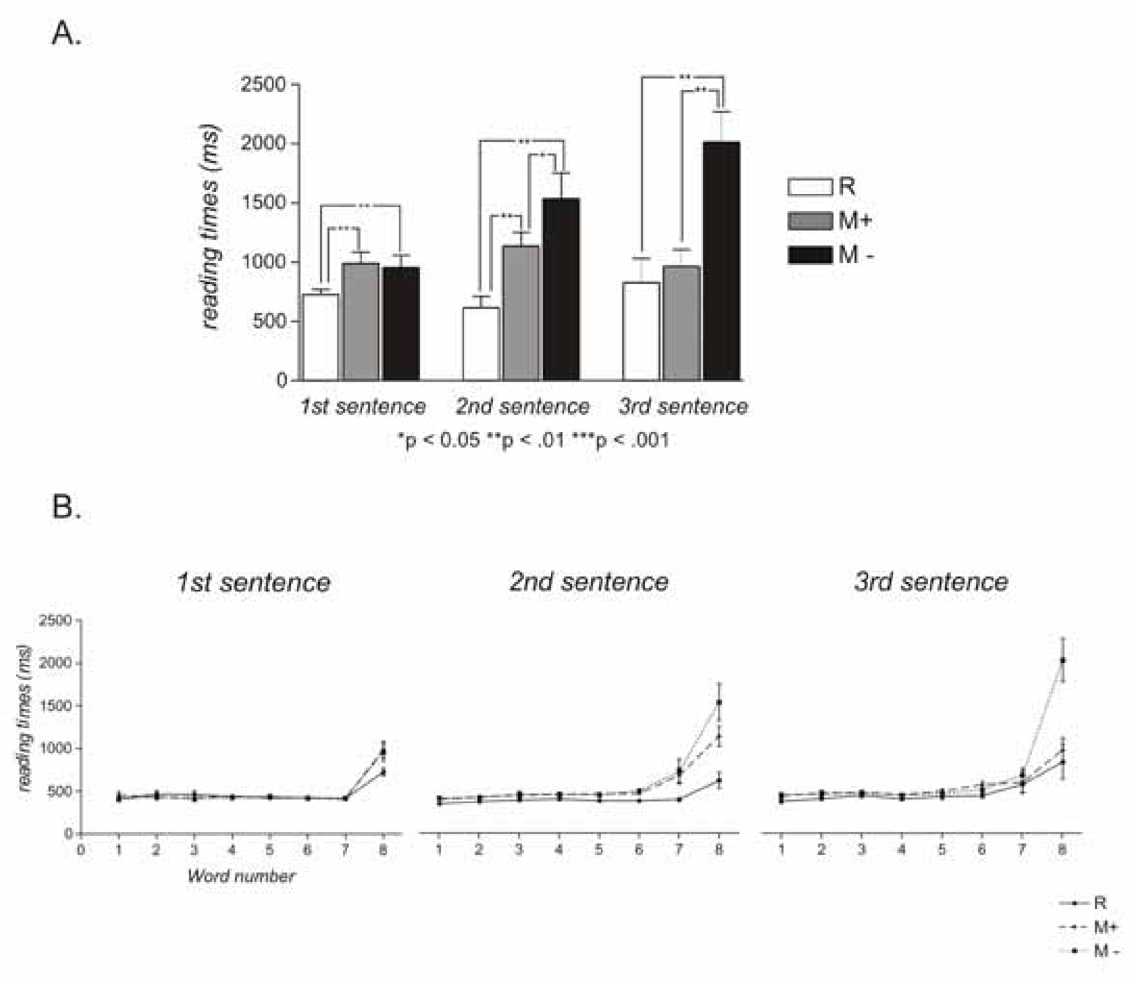

Figure 4.1. A. Mean reading times to the target concrete word (8th word) in each sentence for each condition (experiment 2b). B. Mean self-paced reading times for different word positions and sentences. New-words were presented at the end of each sentence in the new-word conditions.

The results showed differences in the processing of sentences depending on the possibility of meaning extraction across the three sentences. As sentences proceeded, reading times for the new-word embedded in an incongruent context (non-meaning condition) progressively increased. In the first sentence, no differences between new-word meaning and new-word non-meaning were found, as this first sentence context did not allow differentiating between both new-word conditions. Conversely, after the second sentence presentation, differences between new-word meaning and new-word non-meaning appeared. New-word non-meaning showed longer reading times than new-word meaning and real-word. New-word meaning also showed longer reading times than real-words. This difference disappeared at the third sentence where the new-word meaning condition was processed as quickly as real-words. New-word non-meaning continued showing differences with the other two conditions, at the same time revealing an increase in reading times compared to the second sentence. These results suggest that the meaning of a new concrete word can be progressively and successfully learned from congruent contextual information, and, hence, processed as quickly as a real concrete word at its third exposure.

4.3. Experiment 5: New abstract word learning

The previous experiment showed that the contextual self-paced learning paradigm could be used to derive the meaning of a concrete new-word. The question we asked in this second experiment was whether the learning of an abstract word from contextual information would show the same acquisition pattern (measured using reading times). The design of this experiment was identical to that of the previous one except for the words and sentences used.

4.3.1. Method

4.3.1.1.Participants

18 undergraduate students (mean age 21.2 ± 1.6 years; 12 women) at the University of Barcelona participated in this experiment for bonus credits in psychology courses.

4.3.1.2.Task and design

The same word learning task as the previous experiments was used. Thus, participants were required to read triplets of sentences in order to discover the meaning of a novel word which appeared at the end of each sentence. Two conditions were created, one in which a new word meaning could be extracted and created, or the meaningful-group:

1. “Yesterday I found out somebody stole your crint”

2. “Let’s see if it occurs to you any crint”

3. “I don’t know what to write; I don’t have any crint”;

and one condition in which the new word meaning could not be resolved across the sentences, or the non-meaningful group:

1. “You should know that this sign means lotic”

2. “I am sorry but it was not my lotic”

3. “Juan is a liar; he never tells the lotic”

Novel words respected the phonotactic rules of Spanish and were thus pronounceable. In all cases, the hidden-target word (like “idea” for “*crint*”) was an abstract Spanish noun of medium frequency. A third condition was presented in which real words were used. Sentences were systematically rotated for the three critical conditions.

Two pilot studies were carried in order to determine the “cloze probability” of each sentence. Cloze probability was studied presenting each sentence isolated to 75 first-year psychology students. Participants were required to complete the sentence with the first word that came to their mind and that fit well with the sentence. A second pilot study was conducted in order to determine the percentage of meaning extraction after reading sequentially the three sentences. The groups of three sentences were presented to 19 first-year psychology students, who were asked to report the word which fitted after reading the three sentences. These results were used to match the different experimental conditions.

4.3.1.3. Stimuli

The target words were 36 new words (abstract nouns, Appendix B). All of them were frequent words in Spanish (mean frequency of 130.5 per million occurrences). Moreover, all of the words chosen were not highly imaginable or concrete and highly familiar, as rated in a scale ranged from 1 (low) to 7 (high); (mean familiarity: 5.3; mean imageability: 3.6 and mean concreteness: 3.4). Three lists of 12 sets of three sentences were created (36 sentences per list). Each list presented to the participants was comprised of 12 meaningful groups of sentences, 12 groups of non-meaningful sentences and 12 groups of real sentences (control condition). Mean cloze probability for the abstract sentences that were used (36, 12 groups of two sentences) was: first sentence (low constraint) 5.9% (SD = 7.4), second sentence (medium constraint) 45.7% (SD = 15.7), and third sentence (high constraint) 86.7% (SD = 12.2). The probability of meaning resolution after reading sequentially the three sentences was 97.85%. The assignment of the experimental condition (meaningful new-word, non-meaningful new-word and real-word) was performed in the same way as the previous experiment.

4.3.1.4. Procedure

We used a non-cumulative moving-window methodology (Mitchell, 1984) for the present self-paced reading experiment because it ensures that the participants read carefully each word, which was crucial for understanding the meaning of the sentence. Each triplet of sentences (1^{st} sentence, 2^{nd} sentence and 3^{rd} sentence for each target word) was presented, one following the next, to the participants in a word-at-a-time window format. Thus, first appeared the first sentence for that target word then the second one and finally the third. After the presentation of the three sentences a prompt was shown requiring the participants to write the meaning of the new word or a synonym in the case of real words. Sentences were initially presented on the screen with each non space character replaced by a dash. The participants pressed the space bar to reveal the first word in the first sentence. Each subsequent button press revealed the next word and replaced the previous word with dashes. The participants read the three sentences context in this manner and then reported the meaning of the new word. One-word-at-a-time reading latencies were recorded as the time interval between successive button presses.

4.3.2. Results and discussion

Two participants were removed from the analysis because their percentage of meaning extraction was below 65%. Participants were able to extract correctly the meaning of the new words presented (85.4% ± 9.9%). Participants' data was cleaned in the same way as in the previous experiment.

Reading time analysis for the target word (8^{th} word in each sentence) was performed (Figure 4.2a, Table 4.1). A 3 x 3 ANOVA design was conducted introducing Learning (new-word meaning vs. new-word non-meaning vs. real-word) and Sentence (1^{st} vs. 2^{nd} vs. 3^{rd}).

	Reading times last word (target) (ms)		
Experiment 2b	1^{st} sentence	2^{nd} sentence	3^{rd} sentence
New-word Meaning	988 ± 404	1134 ± 500	964 ± 141
New-word Non-meaning	954 ± 433	1535 ± 919	2014 ± 1072
Real-word	725 ± 191	614 ± 407	927 ± 852

Experiment 5	1^{st} sentence	2^{nd} sentence	3^{rd} sentence
New-word Meaning	1245 ± 330	1850 ± 716	1166 ± 281
New-word Non-meaning	1442 ± 416	2264 ± 1038	4003 ± 2441
Real-word	948 ± 275	760 ± 404	1450 ± 1068

Experiment 6	1^{st} sentence	2^{nd} sentence
New-word Meaning Concrete	890 ± 391	779 ± 319
New-word Meaning Abstract	1052 ± 507	1617 ± 662
Real-word Concrete	670 ± 245	659 ± 240
Real-word Abstract	754 ± 230	892 ± 479

Table 4.1. Reading times to the target word in each sentence for the three experiments.

The analysis showed a main effect of Learning ($F_{2,30}$ = 30.2, $P < 0.001$), a main effect of Sentence ($F_{2,30}$ = 15.1, $P < 0.001$), and a significant interaction between these factors ($F_{4,60}$ = 13.82, $P < 0.001$). When splitting out the Learning factor, significant differences were encountered among the three sentences in all three conditions, new-word meaning condition ($F_{2,30}$ = 13.5, $P < 0.001$), new-word non-meaning ($F_{2,30}$ = 15.8, $P > 0.001$), and real-word ($F_{2,30}$ = 6.3, $P > 0.020$), revealing significant differences in reading times for the target word among the three sentences (see Figure 4.2a and 4.2b). For the new-word non-meaning condition, a pattern of increasing reading times was observed as sentences proceeded. New-word meaning and real-word showed a different pattern of reading times. For new-word meaning, there was an increase in reading times on the second sentence followed by a decrease on the third sentence. Contrary to what was found in the new-word meaning condition, real-words showed a decrease in reading times on the second sentence followed by an increase on the third sentence.

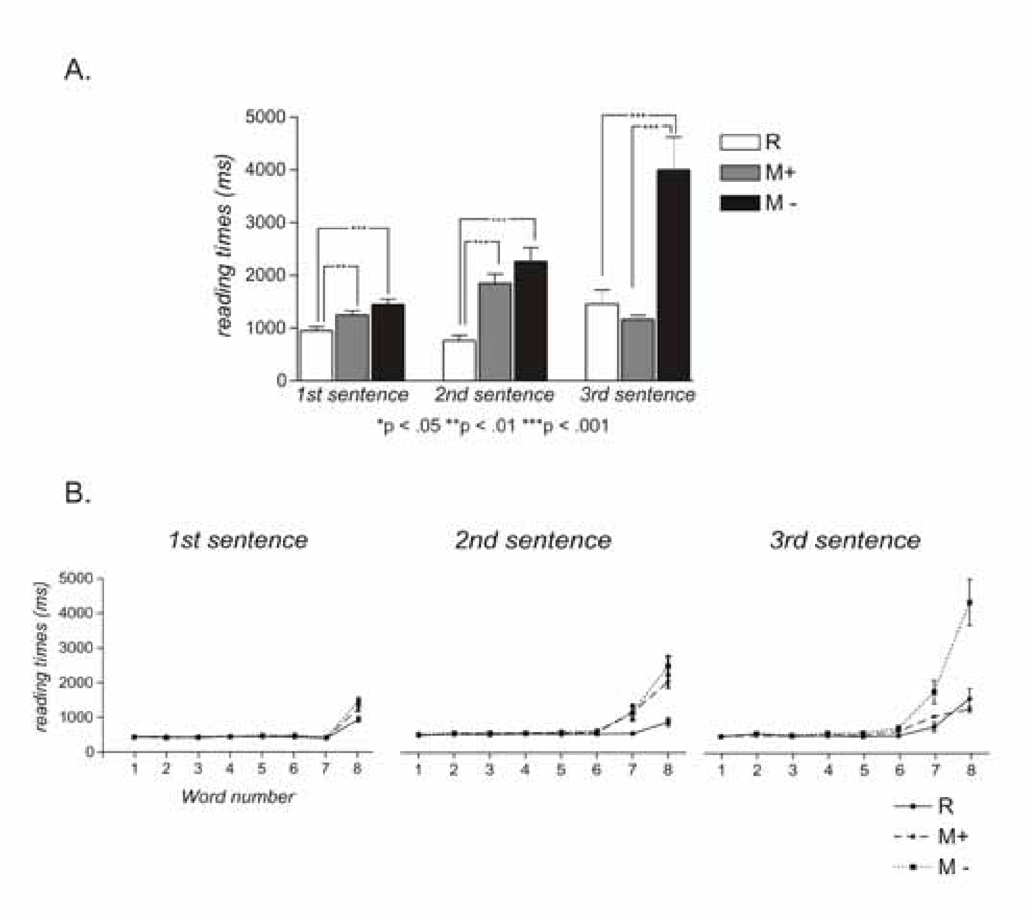

Figure 4.2. A. Mean reading times to the target abstract word (8th word) in each sentence for each condition (experiment 5). B. Mean self-paced reading times for different word positions and sentences. New-words were presented at the end of each sentence in the new-word conditions.

Significant differences were also found when comparing reading times to the target word in the 1st sentence of each condition ($F_{2,30} = 15.5$, $P < 0.001$), as well as in the 2nd ($F_{2,30} = 29.4$, $P < 0.001$) and 3rd sentence ($F_{2,30} = 19.3$, $P < 0.001$). When comparing reading times to the target word in the 1st sentence for each condition, significant differences were found between new-word conditions and real-word (new-word meaning vs. real-word, $t_{15} = 3.6$, $P < 0.002$; new-word non-meaning vs. real-word, $t_{15} = 7.08$, $P < 0.001$), but no differences were observed between new-word meaning and new-word non-meaning ($t = -1.7$, $P = 0.09$). Participants were faster to respond to the target word when appearing in the real-word condition, but there were no differences between new-word conditions in this first sentence (see Figure 4.2a left). When comparing the target word reading times in the 2nd sentence, significant differences arose between new-word meaning and real-word (t_{15} = 6.8, $P < 0.001$), new-word non-meaning and real-word, t_{15} = 6.2, $P < 0.001$), as well as between new-word meaning and new-word non-meaning (t_{15} = -2.8, P = 0.05). Participants responded faster to the target word in the real-word condition, and reading times were significantly larger in new-word conditions. New-word non-meaning was the condition that showed larger reading times for the target word (see Figure 4.2a middle). Finally, reading times to the target word in the third sentence showed significant differences between new-word meaning and new-word non-meaning (t_{15} = -4.9, $P < 0.001$) and new-word non-meaning vs. real-word (t_{15} = 4.3, $P < 0.001$). No differences were found between new-word meaning and real-word condition ($t < 1$). Participants showed significantly larger reading times to the target word in the new-word non-meaning condition when compared to the other two conditions, which did not show differences in this third sentence (see Figure 4.2a right).

The present results showed differences in the processing of sentences depending on the possibility of meaning extraction for abstract words across the three sentences. Just as we saw for concrete words, new abstract words were successfully learned from congruent contextual information and, hence, were processed as fast as real abstract words. The same pattern as the one found in the previous experiment was observed here. In the first sentence, no differences between the new-word meaning and new-word non-meaning were encountered; obviously, the first sentence context did not allow differentiating between both new-word conditions. Differences between new-word meaning and new-word non-meaning conditions appeared at the second sentence. The new-word non-meaning condition showed already longer reading times than the new-word meaning and the real-word, which replicated the pattern we observed when learning concrete words in the previous experiment. The new-word meaning condition also showed longer reading times than the real-word condition. This effect, however, seems to be larger than the corresponding increase in the second sentence observed for concrete words in the first experiment (Figure 4.1). However, this difference disappeared at the third sentence, where the new-word condition was processed as fast as the real-word. The new-word non-meaning continued to show differences with the other two conditions, at the same time showing an increase on reading times compared to the second sentence.

4.4. Reanalysis of experiment 2b and 5.

The previous results replicated the pattern of on-line learning observed for concrete words in the previous concrete word-learning experiment. However, a closer inspection of Figure 4.1a and 4.2a clearly shows that even though the reading time tendencies are similar, some differences can be observed in the magnitude of the reading times between concrete and abstract words. We tested these differences in new concrete and abstract word learning by comparing directly experiment 2b and experiment 5. Based on the previous literature (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000; de Groot, 2006), we should find that the acquisition of the meaning for abstract new-words should be slower and more effortful than learning new concrete words. In addition, when comparing the on-line reading time patterns for concrete vs. abstract real words, we should find evidence of the concreteness effect (Paivio, 1971; Schwanenflugel and Shoben, 1983; Kroll and Merves, 1986; Schwanenflugel and Stowe, 1989). The context availability theory (Schwanenflugel and Shoben, 1983; Schwanenflugel and Stowe, 1989) would predict larger reading times for abstract words on the first sentence. However, as contextual information accrues, concrete and abstract words should be processed equally fast; thus, no differences between both should be found on the second sentence.

4.4.1. Results and discussion

Participants extracted correctly both concrete and abstract new word meanings. Although abstract words had a lower percentage of meaning extraction when compared to concrete words, this difference was not significant ($t_{32} = 1.88$, $P = 0.065$).

A repeated measures ANOVA with Sentence (3 levels, 1st sentence, 2nd sentence and 3rd sentence) and Learning (new-word meaning, new-word non-meaning and real-word) as intra-subject factors and Imageability (concrete and abstract) as a between-subject factor was performed for each condition to evaluate differences in meaning acquisition between concrete and abstract words. A significant interaction was found between Sentence, Learning, and Imageability ($F_{4,128} = 4.1$, $P < 0.014$), as well as between Sentence and Imageability ($F_{2,64} = 5.1$, $P < 0.013$) and Learning and Imageability ($F_{2,64} = 5.4$, $P < 0.013$). In order to decompose these interactions, a 3 x 2 repeated measures ANOVA was performed in each sentence separately, introducing Learning and Imageability as an intra- and between-subjects factor, respectively.

For the first sentence, a significant main effect of Learning was found ($F_{2,64}$ = 23.87; $P < 0.0001$), as well as a significant interaction between Learning and Imageability ($F_{2,64}$ = 3.44; $P < 0.038$). In order to decompose this interaction, a 2 x 2 ANOVA was performed introducing Learning (new-word meaning and real-word) and Imageability. The results showed only a significant main effect of Learning ($F_{1,32}$ = 26.28; $P < 0.0001$; the interaction was not significant, $F < 1$). However, when new-word no meaning was introduced instead of new-word meaning, as well as a significant main effect of Learning ($F_{1,32}$ = 49.7; $P < 0.0001$), a significant interaction was found ($F_{1,32}$ = 6.638; $P < 0.015$). The present pattern at the first sentence suggests that new-word reading times differed from those of the real words.

The same type of analysis was performed on the second and third sentences. For the second sentence, the results showed only a main effect of Learning ($F_{2,64}$ = 37.07; $P < 0.0001$) but no interaction between Learning and Imageability (F = 2.7; P = 0.087). Both concrete and abstract words showed the same pattern of largest reading times for the new-word non-meaning condition.

For the third sentence, unlike the second, the interaction between Learning and Imageability was significant ($F_{2,64}$ = 5.29; $P < 0.012$). Also, a significant Learning effect was found ($F_{2,64}$ = 29.43; $P < 0.0001$). These statistical effects reflect a different pattern of the learning conditions in both concrete and abstract words. When we contrasted only the new-word conditions in a new ANOVA design, a significant interaction was encountered between Learning and Imageability ($F_{1,32}$ = 8.23; $P <$ 0.007; the main effect of Learning was also significant, $F_{1,32}$ = 38.95; $P < 0.0001$), which reflects the larger increase of reading time in the new-word non-meaning abstract condition (see Figure 4.2a). Interestingly, when this ANOVA was performed comparing only the new-word meaning condition and real words and concrete and abstract conditions, no differences were observed (Learning ($F < 1$); interaction Learning x Imageability (F = 1.19; P = 0.282). This result suggests that there were no differences in the third sentence for real-word conditions and the condition in which the meaning was extracted for concrete and abstract words. In contrast, when the ANOVA was performed comparing real-words and new-word non-meaning conditions, a main effect of Learning

($F_{1,32}$ = 30.88; P < 0.0001) and its corresponding interaction was encountered ($F_{1,32}$ = 4.11; P < 0.051).

Pure concreteness effects (faster reading times for concrete than abstract words) were further evaluated using direct pairwise comparisons in the target word in each sentence position. The reading time for this word in the abstract sentences was slower than in the concrete ones in the real-word condition only in the first sentence (real-word condition: 1st sentence t_{32} = -2.7, P < 0.009; 2nd sentence t = -1.04, P = 0.303; 3rd sentence t = -1.8, P = 0.068). In the new-word meaning condition, this effect was observed during the first (marginally) and the second sentences but not in the third sentence: 1st sentence t = -2.01, P = 0.053; 2nd sentence t_{32} = -3.4, P < 0.002; 3rd sentence t = -1.2, P = 0.227). In contrast, in the new-word non-meaning condition, the concreteness effect was observed across the three sentences (1st sentence t_{32} = -3.3, P < 0.002; 2nd sentence t_{32} = -2.1, P < 0.037; 3rd sentence t_{32} = -3.1, P < 0.004).

Finally, in order to evaluate the evolution across the three sentences of the reading times for each condition (real-word, new-word meaning, and new-word non-meaning) and its comparison between abstract and concrete words, we performed an ANOVA, introducing in the design the factors Sentence (1st, 2nd, and 3rd) and Imageability (concrete and abstract). For real words, no difference was observed in the evolution of concrete and abstract words (main effect of Sentence ($F_{1,32}$ = 6.71; P < 0.009; but the interaction Sentence x Imageability was not significant, F = 2.08; P = 0.153; Imageability, $F_{1,32}$ = 4.6, P < 0.04). In the new-word meaning condition, a different pattern of reading times was observed across sentences (interaction between Sentence x Imageability, ($F_{2,64}$ = 3.40; P < 0.042; Sentence, $F_{2,62}$ = 9.28; P < 0.0001; Imageability, $F_{1,32}$ = 11.4, P < 0.002). This interaction reflects that concrete new-word meaning conditions did not show reading time differences among the three sentences, while the abstract showed a differential pattern. For the new-word non-meaning condition, the reading times of both abstract and concrete conditions showed a differential pattern which was evident at the third sentence (Sentence x Imageability, ($F_{2,64}$ = 5.34; P < 0.014; Sentence, $F_{2,62}$ = 27.41; P < 0.0001; Imageability, $F_{1,32}$ = 11.7, P < 0.002).

These present results showed that both concrete and abstract word meanings can be learned from contextual information. Participants were equally successful in discovering the meaning of concrete and abstract words (new-word meaning condition). In the meaning condition, the main difference between the two word learning experiments was that abstract new-words showed larger reading times on the first (marginal effect) and second sentences. Therefore, we could conclude that more time is needed to extract and learn the meaning of an abstract word from contextual information than of a concrete word, at least during the first two sentences. However, at the third sentence, both new word meaning conditions were processed in the same amount of time.

This result would agree with the idea that at the third sentence, a richer contextual information is already available, which facilitates the later integration of the meaning of concrete and abstract new words. At the last sentence, the mean reading time required was similar for new words and real words. Notice also that for the real word-condition, the differences between abstract and concrete reading times were significant only at the first sentence. No differences were found in real words at the second and third exposures. The present result is congruent with the context availability theory, which posits that when abstract words are provided with an external supportive context, then they are processed as efficiently as concrete words (Schwanenflugel and Shoben, 1983).

Finally, it is worth mentioning the striking differences observed between the new-words embedded in incongruent abstract and concrete sentences (non-meaning conditions). In fact, in all sentences, a significant difference was encountered between the abstract and the concrete non-meaning conditions. For example, the reading time for the new-word abstract non-meaning condition at the third sentence was approximately double the reading time encountered for the concrete sentence condition (4003 ms vs. 2014 ms). Thus, participants needed twice the amount of time in order to stop finding the meaning of the new-word when an abstract verbal context was provided. We will further try to expand on the possible implications of this interesting finding (see general discussion).

4.5. Experiment 6: Concrete vs. abstract word learning

In order to study the effects of learning concrete and abstract words in the same experimental setting, a third experiment was performed in which only imageability was manipulated using an intra-subject design. As in the previous experiments, participants were asked to discover the meaning of new concrete or abstract word forms from a verbal context. Concrete and abstract contexts were randomly intermixed. In the design of this experiment we introduced some differences when compared to the two previous ones. First, as a consequence of introducing both types of words (concrete and abstract), conditions would have been multiplied by two, resulting in a very long experiment. In order to optimize the design, we decided to remove the new-word non-meaning condition from the design, as we were mainly interested in the learning differences between concrete and abstract words and its effect in a within-subject design.

Second, we only presented two sentences instead of three as in the previous experiments. The results of the previous analysis (comparison of experiments 2b and 5) clearly showed that when participants discovered the meaning of a concrete or abstract word (new-word meaning conditions) the largest concreteness effect was observed in the second sentence, but this effect disappeared at the end of the third sentence, being marginal at the first sentence. The conclusion of this analysis (although it is based on a between-subject analysis) is that the differences between extracting the meaning of concrete and abstract words are maximum at the end of the second sentence. Most likely, in many cases, participants might have discovered the meaning of the new word at the end of the second sentence, and therefore no concreteness effect arose at the end of the third sentence. Notice also that the previous effect of a larger concreteness effect in the second sentence in the new-word meaning condition cannot be explained by a larger cloze probability of the second sentences in the concrete condition. In fact, the mean cloze probability for the second concrete sentence was lower (38.8 %) than for the abstract condition (45.7%), which cannot initially favor any interpretation of facilitation of meaning extraction in the first two concrete sentences. Interestingly, when it was not possible to discover the meaning of the new word (in the incongruent or non-meaning conditions), this concreteness effect remained and was maximized until the end of the third sentence (see general discussion for a possible explanation of this interesting finding). Thus, based on the results of this analysis, we reasoned that on-line differences in learning the meaning of an abstract and concrete word could be sufficiently seized using only two sentences. Thus, we predicted for new-word conditions and following the previous results, an interaction between Imageability (concrete, abstract) and Sentence order. A large increase in the reading times should be observed for the new-word abstract condition at the end of the second sentence when compared to the concrete new-word condition.

In spite of these modifications, the task and procedure were the same as in the previous experiments.

4.5.1. Method

4.5.1.1.Participants

24 undergraduate students (mean age 21 ± 1.3 years; 16 women) at the University of Barcelona participated in this experiment for bonus credits in psychology courses.

4.5.1.2.Stimuli

The target words were 40 new words, 20 concrete words, and 20 abstract words (see Appendix B). Concrete words were frequent words in Spanish (mean frequency of 41.18 per million occurrences). Moreover, all the words chosen were highly imaginable, concrete, and familiar, as rated in a scale ranged from 1 (low) to 7 (high); (mean familiarity: 6.3; mean imageability: 6.2, and mean concreteness: 5.9). Abstract words were matched in frequency with the concrete words (mean frequency of 45 per million occurrences) ($t < 1$). The selected abstract words were highly familiar, and not very imaginable or concrete (mean familiarity: 5.8; mean imageability: 3.4 and mean concreteness: 3.4). Two lists of 40 sentences pairs were created (80 sentences per list). Each list was comprised of 10 abstract-meaningful groups of sentences, 10 groups of concrete-meaningful sentences, 10 groups of abstract-real sentences (control sentences), and 10 groups of concrete-real sentences (control condition). Concrete and abstract sentences were chosen from the previous word-learning experiments. Mean cloze probability for the concrete sentences used (40, 20 groups of two sentences) was: first sentence (low constraint) 11.9% (SD = 7) and second sentence (high constraint) 89.4% (SD = 6.2). The probability of meaning resolution after reading sequentially the two sentences was 100%. Mean cloze probability for abstract sentences used (40, 20 groups of two sentences) was: first sentence (low constraint) 11.2% (SD = 8.4) and second sentence (high constraint) 88.1% (SD = 10.3). The probability of meaning resolution after reading sequentially the two sentences was 92% (SD = 9.2).

The two lists were matched in frequency, familiarity, concreteness, and imageability for the hidden-target word, abstract words were matched with abstract words and the same for concrete words, and abstract and concrete words were also matched for frequency between them; (mean frequency abstract-group 1 was 44.5 Freq/million, mean familiarity was 5.7, mean concreteness was 3.4, and mean imageability was 3.4; group 2 abstract: mean frequency was 44.7, mean familiarity 6, mean concreteness 3.5, and mean imageability 3.4; and for the concrete words, group 1 mean frequency was 42.7, mean familiarity 6.2, mean concreteness 6.1, and mean imageability 6; group 2 concrete: mean frequency was 43.2, mean familiarity 6.5, mean concreteness 5.8, and mean imageability 6.3). Furthermore, frequency was matched between lists across all word types. The assignment of the experimental condition (meaningful new-word and real-word) was systematically rotated among the four groups of 10 sentences in the two lists created. In order to build the control condition we took the same meaningful sentences pairs and replaced the new-word for the real word.

4.5.1.3.Procedure

The same experimental procedure as in the previous experiment was used.

4.5.2. Results and discussion

Participants were able to extract correctly the meaning of the new words presented showing no significant differences between concrete and abstract words [concrete words (93.3 ± 6.4%) and abstract words (90 ± 7.8%); ($t(23) = 1.6$; $P = 0.11$)]. Participants' data was cleaned in the same way as in the previous experiments.

Reading time analysis for the target word (8th word) in each sentence was performed (Figure 4.3a, Table 4.1). A 2 x 2 x 2 repeated measures ANOVA design was applied introducing Sentence (first and second), Learning (new-word vs. real-word), and Imageability (concrete vs. abstract). The results showed a main effect of Sentence ($F_{1,23} = 7.96$; $P < 0.010$), a main effect of Learning ($F_{1,23} = 20.88$; $P < 0.0001$), and a main effect of Imageability ($F_{1,23}$ = 65.27; $P < 0.0001$). A significant interaction was found between Sentence and Imageability ($F_{1,23}$ = 37.12; $P < 0.0001$) and between Learning and Imageability ($F_{1,23}$ = 17.70; $P < 0.001$). The triple interaction between Sentence, Learning, and Imageability was also significant ($F_{1,23}$ = 9.64; $P < 0.005$). The other interaction was not significant (Sentence x Learning: F = 3.63; P = 0.069).

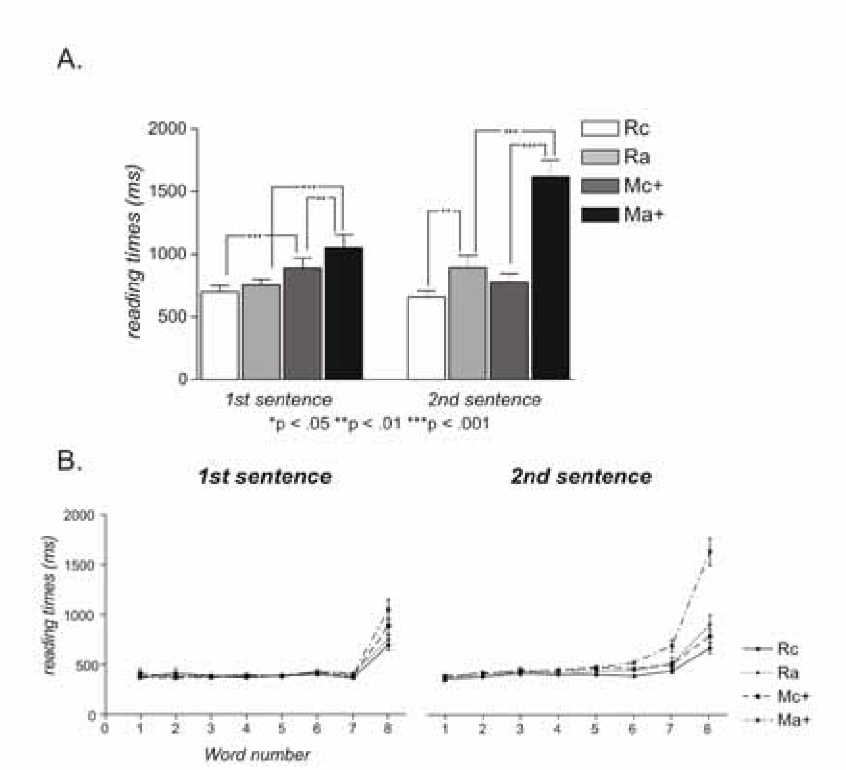

Figure 4.3. A. Mean reading times to the target word (8th word) in each sentence for each condition (experiment 6). B. Mean self-paced reading times for different word type word positions and sentences. New-words were presented at the end of each sentence in the new-word conditions.

In order to study further these effects, A 2 x 2 ANOVA design for each sentence was conducted introducing Learning (new-word vs. real-word) and Imageability (concrete vs. abstract). The analysis showed for the 8th word of the 1st sentence a main effect of Learning ($F_{1,23}$ = 20.12, $P < 0.0001$) and Imageability ($F_{1,23}$ = 8.97, $P < 0.006$), but no significant interaction (F = 3.4, P = 0.078). Real-word conditions were faster than the new-word ones, and concrete words were faster than abstract words for the 8th word of the first sentence (see Figure 4.3a and 4.3b, left). However, for the 2nd sentence, a significant interaction was found between Learning and Imageability ($F_{1,23}$ = 13.72; $P < 0.001$). Main effects of Learning ($F_{1,23}$ = 14.65; $P < 0.001$) and Imageability ($F_{1,23}$ = 68.83; $P < 0.0001$) were also found to be significant. Thus, in this second sentence, in general, concrete words were again processed faster than abstract words. New concrete words were processed as fast as real concrete words (see pairwise comparisons at Figure 4.3a); however, new abstract words showed longer reading times than real abstract words (see Figure 4.3a and 4.3b, right). This result shows that even if participants were equally successful at inferring the meaning of a new concrete and abstract word form from the context (see percentages of meaning extraction), new abstract words were not yet processed as a real abstract word. This was not the case for new concrete words, which did not show reading time differences when compared to real concrete words. Moreover, these new learned new words showed the classical concreteness effect.

Next, two 2 x 2 repeated measures ANOVAs were performed for each learning condition (new-word and real-word) introducing Sentence (first vs. second) and Imageability (concrete vs. abstract). For new-words, a main significant effect of Imageability ($F_{1,23} = 42.76$; $P < 0.0001$) and Sentence ($F_{1,23} = 11.18$; $P < 0.003$) was found. As we predicted based on the reanalysis of experiments 2b and 5, a significant interaction between these factors (Imageability x Sentence) was found ($F_{1,23} = 32.88$; $P < 0.0001$). New concrete words were in both sentences faster than new abstract words (1st sentence: $t_{23} = -2.8$; $P < 0.009$; 2nd sentence: $t_{23} = -6.7$; $P < 0.0001$). Even though for new-word conditions the information provided by the context of the first sentence was not sufficient to extract a meaning, differences were already observed between concrete and abstract new-words processing. Moreover, only new abstract words showed a drastic increase in reading times on the second sentence compared to the first one ($t_{23} = -5.01$; $P < 0.0001$) (new concrete words: $t = 1.43$; $P = 0.165$). The corresponding ANOVA analysis for real words showed only a significant main effect of Imageability ($F_{1,23} = 10.68$; $P < 0.003$) [(Sentence: $F < 1$) (Interaction Sentence x Imageability: F = 2.81; $P < 0.107$)]. While no differences between real-word conditions regarding imageability were observed in the first sentence ($t = -1.66$; $P = 0.110$), real abstract words showed larger reading times on the second sentence ($t_{23} = -2.61$; $P < 0.015$). Contrary to what we found for new-words, neither real concrete ($t < 1$) nor real abstract words ($t = -1.33$; $P = 0.196$) showed a reading time difference between the first and the second sentence.

A third analysis was performed, in which Sentence (1st vs. 2nd) and Learning (new-word and real-word) were introduced as factors in a 2 x 2 repeated measures ANOVA. For concrete items, the results showed only a significant main effect of

Learning ($F_{1,23} = 9.87$; $P < 0.005$). Neither the Sentence effect ($F = 1.33$; $P = 0.261$) nor the interaction between these factors ($F < 1$) was significant. In the first sentence, real concrete words were processed faster than new concrete words ($t_{23} = 3.65$; $P < 0.001$); however, in the second sentence, no differences were found between real and new concrete words ($t = 1.64$; $P = 0.114$) (Figure 4.3a). In contrast, abstract words showed a different pattern. A significant main effect of Learning ($F_{1,23} = 20.92$; $P < 0.0001$) and a significant main effect of Sentence was found ($F_{1,23} = 23.49$; $P < 0.0001$). The interaction between these factors was also significant ($F_{1,23} = 7.59$; $P < 0.011$). Real abstract words were processed faster than new abstract words in both the first and second sentences (1st sentence: $t_{23} = 4.24$; $P < 0.0001$; 2nd sentence: $t_{23} = 4.04$; $P < 0.001$), (Figure 4.3a and 4.3b). Contrary to concrete words, real abstract and new abstract words maintained the reading time differences observed in the first sentence; moreover, new abstract word was the only condition showing an increase in reaction times in the second sentence compared to the first.

In summary, the results of the present experiment showed that when mixing concrete and abstract words on a contextual new-word learning task, both word-types were successfully learned. As we predicted, a significant interaction was encountered between Imageability and Sentence order for the new-word conditions, which replicated the previous results from the between-subject comparison (experiments 2b and 5). The learning of the meaning of the new abstract word boosted the mean reading time in the second condition (1617 ms) when compared to the time required for the concrete new-word (779 ms) (see Figure 4.3). As we expected, the second sentence was crucial in order to differentiate the on-line learning pattern of both concrete and abstract new-words. In fact, only new abstract words showed an increase in reading times from the first to the second sentence. This result might show that the information accrued from the first sentence did not provide enough clues or contextual information for defining which concept the new word was referring to. Most likely, in the new-word abstract condition, participants may have had to gather all the information provided by both sentences in order to correctly build up the meaning of the new word. However, for concrete words no extra re-checking was probably needed when the target word came in the last sentence, which means that participants had already gathered enough information across sentence processing to discover the meaning of the new word.

Moreover, and similar to the results of experiments 2b and 5, on the first sentence participants were faster to process the target word when appearing in real-word conditions (712 ms) than when appearing in the new-word sentences (971 ms). Based on the reanalysis of experiments 2b and 5, we also expected to observe a concreteness effect for real words. In agreement with this, a highly significant effect of Imageability and no significant interaction between Imageability and Sentence were encountered in the corresponding ANOVA analysis. However, the corresponding pairwise comparisons showed that this effect was only reliable at the second sentence position (real words, concrete 659 ms, abstract 892 ms) but not at the first one (670 ms vs. 754 ms, respectively). The differences in the design and the better matching of the different parameters used in the creation of the materials (specially the frequency of concrete and abstract words and the cloze probability in the sentences that formed the contexts) should explain the lack of difference observed in the present experiment.

In correspondence with the results of the reanalysis of experiments 2b and 5, we also observed a concreteness effect in the reading times for the new-word condition during the first sentence. In the previous reanalysis this effect was marginal (see pairwise comparisons, $P < 0.053$, new-word 1st sentence: concrete 988 ms, abstract 1245 ms), but in the present experiment this effect seems to be very reliable (890 ms vs. 1052 ms; $P < 0.009$). Even though in the new-word sentences the contextual information had a low cloze probability, new concrete words were processed faster than new abstract words. This is an interesting result which will be further discussed in the next section.

Lastly, we observed a restoration of the concreteness effect in real-word conditions at the end of the second sentence: increased mean reading time for abstract words (892 ms) than for concrete words (659 ms). This effect is surprising considering that it was not reliably present during the first sentence. Also, considering the contextual availability theory, the second real-word sentence was a highly informative one and had a larger cloze probability than the first sentence. Therefore, if they exist, these differences between abstract and concrete real words should not be present in the second sentence. In the reanalysis of the experiments 2b and 5, this effect was also observed but was marginally significant ($P = 0.068$; concrete word, 927 ms, abstract, 1450 ms). We would like to interpret this observation considering the task that participants had to do after finishing the real-word condition. After the participants finished reading the sentences, a prompt appeared that required them to write down the meaning of the new-word or a synonym in the case of real-words. In this particular context, we interpret this increase in the reading time for the second sentence in the real abstract conditions as the anticipation of the synonym task required of the participants.

The influence of the subsequent task on this reading time measure can be also inferred considering the pattern of reading times for the 1st and 2nd sentences in the first and second experiments only for the real conditions (white bars). It is clear from the figures that the reading times for the abstract and concrete real-word conditions decreased from the 1st to the 2nd sentence in both cases. In contrast, in the third sentence, an increase is observed in both cases, with this effect being significantly larger for the abstract condition. In principle, this increase in the last sentence after a decrease in the second one is not easy to explain. The easiest explanation would be that the incoming task of looking for a synonym in this condition was anticipated and therefore the participants slowed their pace in correspondence with the difficulty of the task. This explanation might be ad-hoc and will require further information, such as, for example, an experiment in which participants might be required to produce the synonyms of concrete and abstract words. Another possible evaluation would be to use a different control condition that does not require the synonym production task but could equally control the attention of participants during the task (e.g., delayed recognition of some words or the meaning of some sentences).

We will consider the implications of the present findings for the different theoretical frameworks in the General Discussion.

4.6. General discussion

The purpose of the experiments reported in this chapter was to simulate human learning of the meaning of concrete and abstract new words from verbal contexts. With this aim in mind, a new word learning task was created, in which participants were faced with groups of sentences providing differential degrees of semantic information and contextual information. In order to assess the meaning acquisition of different word types, concrete and abstract words were used. A self-paced reading task was used, as it can provide an on-line measure of reading times to the whole sentence as well as to the individual words. The pattern of reading times observed in the new-word conditions was interpreted as the amount of time required to search for possible meanings through the semantic memory, to select the meaning of the new-word, and if possible, to integrate it with the earlier context. We found that both concrete and abstract meanings were successfully inferred from congruent contextual information. Although previous studies have rarely directly addressed meaning acquisition from contextual information, there are a few findings which are consistent with the present data. We will concentrate on two main results: (i) larger differences in the reading times for the new-word non-meaning (or semantically incongruent contexts) for abstract contexts when compared to concrete contexts, and (ii) longer reading times observed for acquiring the meaning of abstract than concrete new-words during the first and second sentences.

4.6.1. Why did incongruent semantic contexts differ between concrete and abstract conditions?

Interestingly, the results from experiments 2b and 5 showed differences in the processing of sentences depending on the semantic congruence of the context, that is, between new-word meaning and new-word non-meaning conditions. In the non-meaning conditions, an incongruent context was provided that made impossible the task of discovering the meaning of the new-word. In both experiments (2b and 5; see Figures 4.1a and 4.2a), the mean reading time in the non-meaning or incongruent condition at the last word of the last sentence was larger than in the other new-word meaning and real-word conditions. This pattern was the same for concrete and abstract words, the differences between the two types of words being due to increased reading times for abstract words when compared to concrete words.

It is interesting to note that these differences in the target word (new-word) between both conditions (meaning and non-meaning) did not arise in the first sentence, which is probably due to the fact that participants did not know if they would be able to extract the meaning of the new-word, as contextual congruency or incongruency was not evident until the second sentence. However, as the sentences proceeded, differences among both new-word conditions arose and reading times for the target word in the new-word non-meaning condition were already increased at the second sentence. As participants might have already been trying to resolve the meaning of the new-word in the second sentence, this difference between meaning and non-meaning conditions might indicate the difficulty imposed by the presence of an incongruent sentence in this position. It is also interesting to mention that the presence of an incongruent abstract context had already affected the reading times when compared to the same concrete context in the second sentence. The difference, however, was larger at the third sentence, where participants took about four seconds to abort the decision of looking for the meaning of the new-word in the abstract context. This effect was less in the concrete context (at least 2 seconds).

Still, why did participants require so much time in the abstract context to give up trying to infer the meaning of the new word? Considering previous investigations, it has been shown that participants tend to report that a larger number of contexts could be associated with abstract than concrete words (Galbraith and Underwood, 1973). This variable (*associate set size or connectivity*) is usually measured, for example, by asking somebody to rate how many contexts he/she could think of in which the word "peace" could appear. This result is not in contradiction with the idea that a context is faster recruited or associated with a concrete than an abstract word (i.e., asking participants about the facility to recruit a specific context associated to a word) (Schwanenflugel and Shoben, 1983). Because the conceptual information associated with an abstract concept is more variable and unspecific and its appearance can be predicted in many contexts (situations, agents, experiences, emotions, etc.), the retrieval of a specific context or information might take longer (Wiemer-Hastings and Xu, 2005). This effect is therefore due to the type of representation of abstract concepts in semantic memory which have a greater amount of weakly and more branched associated information, most notably involving other unspecific features or abstract concepts. In fact, many abstract concepts are probably relational concepts with rich interconnections to other concepts (Gentner, 1981; Markman and Stilwell, 2001) instead of intrinsic properties, as it is the case for concrete concepts. It is the case that many of the core features that define an abstract concept are also abstract concepts by themselves. Concrete concepts are also strongly associated with specific contexts. In this regard, the presentation of three abstract incongruent sentences might be priming the activation of multiple interconnected concepts in the semantic memory (some of them also abstract concepts). In this case, disregarding the plausibility of any of these multiple primed concepts might require more time as greater interference is expected between competing concepts. Therefore, the extra amount of time required in the abstract non-meaning condition is in agreement with the idea that abstract conceptual information is weakly associated in the semantic memory with any specific context and its representation is more interlinked with other concepts. The underlying qualitative and quantitative differences of concrete and abstract contexts might explain this interesting effect.

Considering a spreading activation model of semantic processing (Collins and Loftus, 1975; Church, 1987), it is easy to conceive that the amount of semantic relatedness is larger in the concrete related concepts, and therefore, the semantic space primed in the incongruent context is less than in the abstract incongruent contexts. In this sense, and considering that activation gradually decays proportionally to the strength and the distance of the conceptual links, the abstract nature of the contexts might require a larger amount of time in order to explore all of the conceptual links activated and disregard them as possible. This view is also in agreement with the recent proposal of Barsalou and Wiemer-Hastings (2005), who have suggested that abstract and concrete concepts also differ in their amount of focus. While concrete concepts have a very clear center of focus which is normally represented by an object or specific locations, in the particular case of abstract concepts, the focus is much broader, involving a complex arrangement of entities and processes (see also Hampton, 1981). From this view, some abstract concepts could be acting as a schema or frame with some unspecific features, which could be filled by different types of agents, situations, or events (Wiemer-Hastings and Xu, 2005). In sum, multiple related concepts are probably activated (but with a lesser intensity) in the abstract incongruent condition, and therefore participants might be dealing with a larger amount of conflict in trying to abort this meaning check-out process. This extra-conflict generated by multiple possible meaning candidates might be the reason for the delay observed in this condition.

4.6.2. Are abstract words learned faster than concrete words from a verbal context?

The most compelling result of the present experiments is that longer reading times were required to infer the meaning of an abstract new-word when compared to a concrete new-word. This effect was already observed during the first sentence (the concreteness effect was app. 162 ms) and was maximum at the end of the second sentence (app., 858 ms, exp. 3, see Figure 4.3a). In experiments 2b and 5, multiple sentence contexts were provided for concrete and abstract words learning, and differences still arose, reflecting that these differences are due to the way these words are learned. The better and faster learning of concrete words is consistent with several studies (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000; de Groot, 2006). This effect might be due to the presence of referents for concrete words in the environment that support their initial learning. Concrete words can be experienced by the senses, by their perceptual features, while abstract words are learned in the context of language without any perceptual input. In this regard, Gillette et al. (1999) asked adults to identify words just from observing several videotaped mother-child interactions without linguistic accompaniment, and found that the least imaginable items were those that had been hard to identify just from cross-situational observation (Gillette et al., 1999). When the authors provided more linguistic information (e.g., syntactic frames), participants were able to acquire the meaning of these less imaginable items.

However, if what the context availability model (Schwanenflugel et al., 1992; Schwanenflugel and Shoben, 1983; Schwanenflugel and Stowe, 1989) states is true, that comprehension of abstract and concrete words is supported by the activation of the contextual information related to the linguistic input, then concreteness effects should have disappeared when abstract and concrete words were matched with respect to the amount of contextual information provided. When words are presented in isolation, contextual information is assumed to be more readily available for concrete words than for abstract words. The processing disadvantage for abstract words results either from the fact that abstract concepts are more weakly associated with other concepts in the semantic system (Schwanenflugel and Shoben, 1983), or from the fact that semantic representations of abstract concepts contain less information than representations of concrete concepts (Plaut and Shallice, 1993). It is assumed that the processing of abstract words entails more effort in retrieving contextual semantic information. As the context availability theory states, the match in the amount of contextual information should make concrete words processing advantage disappear. This is not the case in the experiments reported here, as abstract words continued showing a processing and learning disadvantage compared to concrete words. However, it is important to bear in mind that the context availability model has not been developed in order to explain the processing advantages observed for learning new concrete words, and no specific predictions are made in this regard. Thus, it is difficult to evaluate this theory and its plausibility from the present results.

In any case, it might be interesting to consider whether contextual availability was really controlled in the present experiments. Context availability is typically measured by asking the participants the ease with which they could think of a particular context or circumstance in which the target word would appear (rating scale from 1-very hard to 7-very easy) (Schwanenflugel and Shoben, 1983). Previous experiments have found that concreteness is highly correlated with context availability (Schwanenflugel et al., 1988). In the present experiment, we asked 58 new students to rate the context availability of the abstract and concrete words used in experiment 6. In fact, a strong correlation was obtained between context availability and concreteness ($r = .82$, $P < 0.001$), imageability ($r = .89$, $P < 0.001$), and with less intensity familiarity ($r = .43$, $P < 0.006$) (no significant correlations were encountered between frequency and length of the word; the correlation between imageability and concreteness was $r = 0.9$, $P < 0.001$). Considering the present correlations, it seems very difficult to think of a design in which both variables, context availability and concreteness, could be orthogonal, as it seems that both concepts tap the same phenomena (in fact, the scatterplot shows a clear separation of both clusters, concrete-high context availability and abstract-low context availability words). However, the sentences that formed our contexts were matched for cloze probability, which is the probability of completion of a given sentence with the expected word (Taylor, 1953). Considering this information, we believe that the amount of contextual information provided across the sentences was equal in both conditions (concrete and abstract sentences and contexts). In favor of this interpretation, the reading times for the first exposure did not differ between real concrete and abstract words. This result could mean that the first sentence provided enough contextual information to abolish the differences due to the inherent context availability of the word. This result is in agreement with a series of experiments performed by Schwanenflugel et al. who showed that the provision of sentences contexts eliminated the traditional bias toward faster responses for concrete words (Schwanenflugel and Shoben, 1983; Schwanenflugel and Stowe, 1989; Schwanenflugel et al., 1992). In contrast, in the first sentence, even though the sentence context had a low cloze probability, participants showed faster reading times for concrete new-words than abstract new-words. Notice also that as the sentences proceeded, differences between new-word and real-word disappeared only for concrete items at the end of the second sentence. Thus, new concrete word sentences were processed as fast and efficient as real concrete word sentences. These results are congruent with the results from the first and second experiments, when by the third sentence, real-word and new-word meaning showed no processing differences (in both abstract and concrete experiments).

Nevertheless, new abstract words showed larger reading times than real abstract words in the second sentence. This result might reflect that in the second exposure to the abstract new word, participants gathered together all the information that had been provided by the context in order to infer the meaning of the new word. This increase in reading of new abstract word conditions might reflect that the integration of the contexts provided by both sentences might be more demanding for new abstract words. On the contrary, when the new word was a concrete one, participants had already figured out the meaning of it, and thus processed it as fast as real concrete words. Unexpectedly, and as discussed in the third experiment, real-word conditions showed a concreteness effect only in the second sentence. We interpreted this finding considering the synonym production task participants had to perform after the processing of the abstract and concrete real context (see results and discussion in experiment 6).

As discussed in the introduction, several studies have shown that concrete words have an advantage over abstract words. This effect has been shown in a variety of tasks in first language processing, second language processing, and also in first language acquisition as well as in second or foreign language acquisition. The different theories reviewed in this chapter emphasize that the main difference between concrete and abstract concepts is that concrete concept representations entail additional information which makes them easier to access, learn, remember, and so on (Breedin et al., 1994; Crutch and Warrington, 2005; Paivio, 1971; Paivio, 1986). The nature of these differences has been, and still is, a matter of debate. It is important to bear in mind that these differences in the representations for concrete and abstract words might reflect the way these words are learned. In children, concrete words are learned first, as they are learned due to the presence of the direct referent (and its perceptual properties) for concrete words in the world (direct world-to-word mappings) (Gillette et al., 1999; Bloom, 2000). Abstract word concepts are acquired in the context of language with little or no physical support (Breedin et al., 1994; Bloom, 2000). Thus, it is parsimonious to think that a relationship exists between the way in which information is acquired and the format in which is stored (either perceptual or propositional representations). Moreover, some studies which investigated the differences between concrete and abstract words found that abstract concepts are more relational and linked to other concepts, situations, and personal experiences, while concrete words are characterized by their intrinsic properties, their attributes, functions, parts, and so on (Wiemer-Hastings and Xu, 2005). Furthermore, effects of word concreteness have been also shown in second or foreign language acquisition (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000). Thus, this additional information, which confers concrete words an advantage over abstract words, is the presence of perceptual properties in the representation of concrete words. Evidence comes also from patients showing a reversal of the concreteness effect. This is an unusual impairment reported a few times in the literature (Warrington, 1975; Warrington, 1981; Warrington and Shallice, 1984; Breedin et al., 1994). These patients show impairment in perceptual aspects of word meaning, which might be responsible for the abstract word advantage on these patients. All of this evidence tends to suggest that the extra or additional information that confers concrete words a processing advantage over abstract words is the perceptual attributes that characterize concrete words.

4.7. Conclusions

In conclusion, the findings from our experiments showed how different types of word meanings can be learned from contextual information and provide further evidence for concrete word advantage on the context of language learning. Considering the human simulation paradigm in which the present investigation is framed (Gillette et al., 1999), we provide evidence that abstract and concrete words show learning differences even when the information provided from context and conceptual capacities are held constant. When adults learn concrete and abstract words they show the same concrete word advantage as children; thus, conceptual development or contextual information cannot be responsible for this concrete word advantage. We conclude that these learning differences are due to the perceptual features that characterize concrete word representations.

Chapter 5[**]

Experiment 7: Functional neuroanatomy of contextual acquisition of concrete and abstract word meaning

5.1. Introduction

There is strong behavioral and neuropsychological evidence that concrete and abstract words might be differently represented in the brain. From behavioral studies it has been demonstrated that concrete words have superiority over abstract words (concreteness effect). Typically, abstract words are processed more slowly (Schwanenflugel and Shoben, 1983; Kroll and Merves, 1986), remembered worse (Paivio, 1971) and take longer to read (Schwanenflugel and Shoben, 1983; Schwanenflugel and Stowe, 1989) than concrete words. Furthermore, in the neuropsychological literature there are numerous reports of patients showing an amplified concreteness effect after brain damage (Goodglass et al., 1969; Coltheart et al., 1980; Katz and Goodglass, 1990; Martin and Saffran, 1992). However, there are several reports of patients who showed a reversal of the concreteness effect. This is an unusual impairment reported only a few times in the literature (Warrington, 1975; Warrington, 1981; Warrington and Shallice, 1984; Breedin et al., 1994; Marshall et al., 1996). These patients are characterized by selective impairment for concrete words, while showing a relative preservation of abstract words. These neuropsychological findings of different impairments which selectively damage concrete and abstract words suggest that the brain regions that sustain concrete and abstract words representations might be different.

[**] This chapter corresponds to:
Mestres-Missé, A.; Münte, T.F. & Rodriguez-Fornells, A. (submitted). Functional neuroanatomy of contextual acquisition of concrete and abstract word meaning.

Several theories have been proposed to account for the concreteness effect. As these theories were presented in a previous chapter (see Chapter 4) here we will only briefly state the main ideas of each one. The dual coding theory from Paivio (Paivio, 1971; Paivio, 1986) proposes that there are two cognitive subsystems, one specialized for the representation and processing of non-verbal objects/events (i.e., imagery), and the other specialized for dealing with linguistic representations, a verbal system. According to this qualitative account, the main difference between concrete and abstract words stems from image representations being stored only for concrete words. Whereas abstract words predominantly activate semantic representations, the processing of concrete words co-activates linguistic and imagistic representations. The facilitation associated with concrete word processing is therefore attributed to the fact that the amount of information recruited is larger. In contrast to this view, the context availability theory (Schwanenflugel and Shoben, 1983) argues that the difference between concrete and abstract words is only quantitative. The context availability theory posses that concrete words have a larger set of contextual information in semantic memory (Schwanenflugel and Shoben, 1983; Schwanenflugel and Stowe, 1989). Abstract words are comprehended more slowly when presented in isolation because they are less associated to relevant contextual knowledge in semantic memory. The reason that it is more difficult for abstract words to retrieve a specific context is based on the idea that this type of words tends to appear normally within a wider range of contexts and therefore it is more difficult to recruit a specific piece of information (Schwanenflugel and Shoben, 1983). In this regard, when abstract words are presented within an external context, such as supportative sentences, then they are processed as efficiently as concrete words. This notion is in agreement with the idea that concrete words are characterized by more context-dependent properties, whereas abstract words have more context-independent properties (Barsalou, 1982). Another quantitative alternative account of the concreteness effect postulates that the differences are due to concrete words being supported by more semantic features than abstract words (Plaut and Shallice, 1993). This hypothesis was postulated to explain the strong concreteness effect observed in deep dyslexia patients (Coltheart et al., 1980) and agrees with previous findings which showed that participants produced more associates for concrete than abstract words (de Groot, 1989).

The three theoretical approaches agree in their suggestion that the representation of concrete concepts entails some additional component that facilitates its access, activation and further remembering. However, they differ in their explanation of the nature of this component or mechanism. Furthermore, while all three theories can account for the concreteness effect in neurologically healthy participants, the dual coding and the context availability theories have difficulties in explaining the reverse of the concreteness effect. In both cases, the loss of the additional component that gives concrete words a processing advantage should render equilibrium between concrete and abstract words (equal processing cost). But, this is not the case in patients showing a reversal of the concreteness effect, where concrete words are impaired compared to abstract words. The connectionist model of deep dyslexia developed by Plaut and Shallice (1993) demonstrated that certain lesions to the model could render a selective impairment in which abstract words were more preserved than concrete words. However, this model does not account for the most fundamental distinction between concrete and abstract words, that is, the perceptual properties which are essential for concrete words representations but not for abstract words (Breedin et al., 1994).

In order to be able to build a complete theory of concrete and abstract word representation it is important to reflect on how these different types of words are learned by children. Children's first vocabularies are formed mostly of concrete words, as they are restricted to the information that is accessible through sensory experience with the material word (Gillette et al., 1999; Bloom, 2000). Abstract word concepts are acquired through their use in sentences and their relationship to other concepts with little or no physical support (Bloom, 2000). Thus, abstract words cannot be learned until a certain representational capacity is reached that permits the utilization of linguistic contexts in order to unravel the meaning of these words (Bloom, 2000). Concrete words contain a wide range of features critical to their meaning, including properties such as shape, size, color, texture, sound and so forth. These features are learned through direct experience with physical objects, and also through language. However, abstract words are learned through the support of language, and those sensorimotor properties that are crucial for learning concrete words are irrelevant for the representation of abstract word meanings. Several neuropsychological and functional neuroimaging studies (see below) suggest that the representations of abstract and concrete word attributes are not supported by the same brain regions. Accordingly, it has been proposed that there might be a relationship between the manner in which these words are learned and the format in which they are stored (Saffran and Sholl, 1999; Martin et al., 2000). Accordingly, abstract concepts might be stored in a propositional representational format, while concrete words might be represented in auditory, visual, tactile and sensorimotor formats.

Neuropsychological literature has provided evidence for dissociations between the representation of abstract and concrete concepts that may reflect qualitative differences in their acquisition and representational format. Lesions in different regions lead to the impairment of different types of words. This pattern is unlikely to reflect identical representational formats for both and suggests a more distributed representation of concept's features. In this regard, Allport (Allport, 1985) suggested that the features and properties which form the representation of a concept are distributed over different subsystems directly related to the domain (visual, auditory, tactile) through which the information was acquired. In support of Allport's distributed model of conceptual information, several neuropsychological studies have reported the loss of perceptual aspects of word meaning to be the cause of the reversed concreteness effect (Breedin et al., 1994; Marshall et al., 1996).

Furthermore, functional imaging studies investigating the neural systems that support the processing of concrete and abstract words have typically found that abstract word processing is associated with larger activations in areas mostly involved in semantic processing, such as the middle and superior temporal gyrus and the left inferior frontal gyrus (see table in Appendix C for a review). The reverse contrast, that is, regions showing enhanced activity for concrete words, has shown the involvement of regions associated with higher levels of visual processing, such as the ventral anterior part of the fusiform gyrus (see Appendix C).

To our knowledge no neuroimaging or neuropsychological study has investigated the learning of concrete and abstract novel words. If the information about a word's properties is stored in the same regions that mediated its acquisition, then we should find those regions active when learning a new concrete or abstract word. Within the extant neuropsychological and neuroimaging data, two regions stand out as playing a differential role in the comprehension, encoding and retrieval of concrete and abstract word information. These regions are the middle/superior temporal lobe and the inferior ventral temporal lobe (specifically the ventral anterior fusiform gyrus). The middle and superior temporal lobe have been consistently reported as regions showing enhanced activation for abstract words (see Appendix C). Moreover, patients who exhibit deficits in processing abstract words have lesions comprising language areas of the left hemisphere (for example, the prefrontal cortex and other perisylvian areas) (Goodglass et al., 1969; Coltheart et al., 1980; Martin and Saffran, 1992). Abstract word meanings are more dependent and specified by sentence context and in relation to other concepts; thus, the involvement of perisylvian areas in response to abstract words may reflect the greater role of the verbal semantic system on their processing. On the other hand, more inconsistently, the ventral temporal lobe has been found to be more activated for concrete words (specifically the left fusiform gyrus; see Figure 5.1) (see Appendix C). Once more, the functional data agrees with patient studies in which lesions to the inferior temporal lobe causes abstract word superiority. The ventral anterior fusiform gyrus has been associated with the retrieval of visual object information (Martin et al., 1996; Price et al., 1996; Vandenberghe et al., 1996; Martin et al., 2000). This cortical region may support the representation of perceptual properties which are critical for concrete word meaning; as previously stated, impairment in processing the perceptual properties of words is directly related to the reversal of the concreteness effect.

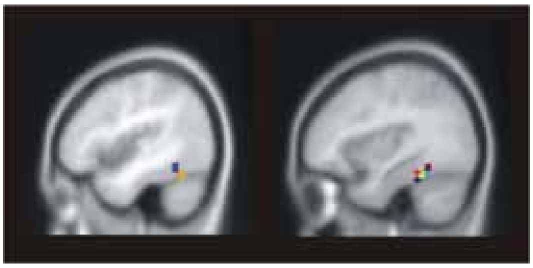

Figure 5.1. Studies reporting greater activity in the left fusiform gyrus for concrete words than for abstract words. Peak coordinates of reported activation clusters (Appendix C) were rendered as spheres (4 mm) and superimposed on an anatomical T1. Left: Blue, Sabsevitz et al., 2005; Orange, Whatmough et al., 2004; Light green, Mellet et al., 1998. Right: Dark blue, Bedny & Thompson-Schill, 2006; Red and brown, Wise et al., 2000; Yellow, Wallentin et al., 2005; Light blue, D'Esposito et al., 1997.

The aim of the present study is to investigate the neural mechanisms underlying the acquisition of new word meanings, and how these mechanisms might differ depending on word concreteness. As a working hypothesis, we predict that the same regions that store the representation of concrete and abstract words and its semantic features (see above) will be supporting the acquisition and learning of new-words and the discovery of its underlying concept. For that purpose a new-word learning task was used where adults were engaged in developing the meaning of new concrete and abstract words presented repetitively across some sentences (see previous chapters).

Differences in meaning acquisition of concrete and abstract words were studied in adults when controlling for conceptual, cognitive and/or linguistic capacity and the informativeness of the contextual information provided for learning the new words. The main difference between concrete and abstract words is the presence of referents in the external word that facilitate world-to-word mappings in concrete words. In consequence, children initially might fail to learn abstract words because the difficulty of establishing specific world-to-word mappings and the lack of a full developed linguistic representational capacity (Gillette et al., 1999; Bloom, 2000). Curiously, adults in spite of having reached a full conceptual and representational capacity, still show processing and learning disadvantages for abstract words (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000; de Groot, 2006). We aim to report in adults some evidence from the vocabulary learning perspective which taken together with other behavioral, neuropsychological and functional neuroimaging studies, can help to understand the nature of the representations that sustain concrete and abstract word processing.

5.2. Methods

5.2.1. Participants

Fifteen native Spanish speakers (9 females, mean age 23.6 ± 3 years) without any history of neurological or psychiatric disease were enrolled. All subjects were right-handed according to the Edinburgh Handedness Scale. All subjects gave written informed consent and the study was approved by the ethical committee of the University of Magdeburg.

5.2.2. Stimuli and Task

Subjects silently read groups of two sentences, each ending in the same novel word, and had to discover the meaning of this new-word. In all cases the hidden-target words were concrete and abstract nouns of middle frequency. Two conditions were created, a new-word condition and a real-word condition (control). The new-word condition required the discovery of the meaning of a novel word from the linguistic context (henceforth Nwc, new-word concrete; or Nwa, new-word abstract). In the real-word condition, two sentences were presented, closing with a real concrete or abstract word (Rwc, real-word concrete; Rwa, real-word abstract). Sentences were systematically counter-balanced across the two critical conditions by creating different sentences lists. Sentences uniformly had a length of 8 words. Novel words respected the phonotactic rules of Spanish and were created by changing one or two letters of an existing word.

The target words were 160 novel words, 80 concrete words and 80 abstract words. Concrete words were selected from previous word-learning experiments; all of them were frequent words in Spanish (mean frequency of 62.7 per million occurrences). Moreover, all of the selected words were high imaginable, concrete and familiar, as rated in a scale range from 1 (low) to 7 (high); (mean familiarity: 6.3; mean imageability: 6.2 and mean concreteness: 5.9). Abstract words were matched on frequency with concrete words (mean frequency of 65.6 per million occurrences). The selected abstract words were highly familiar, and low in imageability and concreteness (mean familiarity: 5.9; mean imageability: 3.3 and mean concreteness: 3.6).

Two lists of 160 sentence pairs were created (320 sentences per list). Each list comprised 40 new-word abstract (Nwa) sentence pairs, 40 new-word concrete (Nwc) sentence pairs, 40 abstract-real (Rwa) sentence pairs (control condition) and 40 concrete-real (Rwc) sentence pairs (control condition). Concrete sentences were chosen from previous word-learning experiments. Mean cloze probability for the final pool of concrete sentences used was: first sentence (low constraint) 15.6% (SD = 13.6) and second sentence (high constraint) 85.8% (SD = 8.4). The probability of meaning resolution after reading sequentially the two sentences was 97.6% (SD = 3.8). Abstract sentences were built and tested in the same way as concrete ones (see previous experiments). Mean cloze probability for the final pool of abstract sentences was: first sentence (low constraint) 12.7% (SD = 11.5) and second sentence (high constraint) 86.5% (SD = 11.3). The probability of meaning resolution after sequentially reading the two sentences was 94.5% (SD = 6.6).

The two lists were matched in frequency, familiarity, concreteness and imageability for the hidden-target word; abstract words were matched to abstract words and the same for concrete words (mean frequency of abstract-group 1 was 65.6 Freq/million, mean familiarity was 5.8, mean imageability was 3.3 and mean concreteness 3.5; abstract-group 2 mean frequency was 65.6, mean familiarity 6, mean imageability 3.4 and mean concreteness 3.7; and for the concrete words, group 1 mean frequency was 62.5, mean familiarity 6.3, mean imageability 6.3 and mean concreteness 5.9; concrete-group 2 mean frequency was 62.8, mean familiarity 6.2, mean imageability 6.2 and mean concreteness 5.9). Furthermore, frequency was matched between lists across all word types. The assignment of the experimental condition (Nwc, Nwa, Rwc, Rwa) was systematically rotated across the four groups of 40 sentence pairs in the two lists created. For the Rwc and Rwa conditions the sentences were presented with the appropriate real word in the terminal position. Each list of 160 sentence pairs was divided into 8 sessions comprising 5 duets of each condition as well as 5 additional fixation trials of 8 seconds.

Each session started with four baseline images (8 sec) to allow the magnetic resonance signal to reach equilibrium. Each trial began with a fixation cross lasting 500 ms, then sentence stems (seven words) were presented centrally for 2000 ms. After a variable interval between 1 and 2 seconds, the completions (last 8th word or new-word) were presented for 500 ms. After a variable interval of 1 to 6 seconds, in which the screen remained dark, the second sentence was presented in the same fashion. After the second sentence, participants were required to think covertly about the hidden word or, in the case of real word, about a synonym or semantically related word. The order of the four experimental conditions within a session was pseudorandomized, with the restriction that the same condition could not occur more than two times in a row. Stimulus presentation was controlled by Presentation 9.20 software (Neurobehavioral Systems) and synchronized with MRI data acquisition with an accuracy of 1 ms. Stimuli were presented in white on a black background and projected onto a screen and could be viewed by the participant through a mirror system mounted onto the head-coil.

Prior to the scanning session, subjects were carefully trained outside the scanner using test trials to ensure that they fully understood the task. Scanning began with a 15-min structural scan followed by the 8 functional sessions, each lasting about 7 minutes. A short rest was given between sessions.

As the fMRI design did not allow direct testing for correct meaning assignment, a short behavioral test was performed during breaks between functional sessions. The stimuli were visual word triads presented in a pyramid arrangement with the novel word positioned at the top center of the display and two word choices (actual meaning of the novel word – meaning of another novel word) on either side of the bottom of the display. Participants indicated which meaning was the one they learned for that particular novel word by pressing one of two buttons (right-left decisions with 10 trials after each block; random SOA of 1000-2000 ms). After this task, participants performed a word recognition task, in which 20 words (10 words from the Rw conditions and 10 new real words in pseudo-random order) were presented and the participants had to indicate by pressing one of two buttons whether they had seen a particular word before. This task served to induce participants to attend to the Rwc and Rwa sentences (which otherwise could have been neglected). After the scanning session, participants were presented with a list of 160 novel words (80 learned novel words, half concrete and half abstract, and 80 fillers). Data from only 14 participants was collected, as one participant was not able to complete the test. Participants were required to mark the novel words they recognized as learned during the experiment and, when possible, to recall their meaning.

5.2.3. MRI scanning methods

Images were acquired on a 3T whole-body MRI system (Siemens Magnetom Trio, Erlangen, Germany). Whole-brain T2*-weighted functional magnetic resonance images were obtained (200 scans per run) using axially-oriented echo-planar imaging (TR = 2 s; TE = 30 ms; flip angle = 80°; 32 slices; 4-mm thickness; no gap; matrix size: 64×64; field of view: 224 mm; resolution 3.5×3.5×4 mm^3). The first four volumes of each session were discarded owing to T1 equilibration effects. For anatomical reference, a high-resolution T1-weighted anatomical image was obtained (magnetization-prepared, rapid-acquired gradient echoes (MPRAGE), TR = 2500 ms, TE = 4.77 ms, TI = 1100 ms, flip angle = 7°, 192 slices, 1mm isotropic voxels). The sentences were back-projected to a screen mounted on the head coil, allowing the participants to read them through a mirror.

5.2.3.1.Preprocessing

Data were analyzed using standard procedures implemented in the Statistical Parameter Mapping software (SPM2, http://www.fil.ion.ucl.ac.uk/spm). The preprocessing included slice-timing, realignment, normalization and smoothing. First functional volumes were phase-shifted in time with reference to the first slice to minimize purely acquisition-dependent signal-variations across slices. Head-movement artifacts were corrected based on an affine rigid body transformation, where the reference volume was the first image of the first run (e.g., Friston et al., 1996). Functional data were then averaged and the mean functional image was normalized to a standard stereotactic space using the EPI-derived MNI template (ICBM 152, Montreal Neurological Institute) provided by SPM2. After an initial 12-parameter affine transformation, an iterative non-linear normalization was applied using discrete cosine basis functions by which brain warps are expanded in SPM2 (Ashburner and Friston, 1999). Resulting normalization parameters derived for the mean image were applied to the whole functional set. Finally, functional EPI volumes were resampled into 4 mm cubic voxels and then spatially smoothed with an 8 mm full-width half-maximum (FWHM) isotropic Gaussian Kernel to minimize effects of inter-subject anatomical differences.

5.2.3.2.Data analysis

The statistical evaluation was based on a least-square estimation using the general linear model by modeling the different conditions with a regressor waveform convolved with a canonical hemodynamic response function (Friston et al., 1998). Specifically, event-related design matrix included all conditions of interest, that is, 1st sentence new-word concrete (1Nwc; new-word concrete embedded in the 1st sentence context), 2nd sentence new-word concrete (2Nwc; new-word concrete embedded in the 2nd sentence context), 1st sentence new-word abstract (1Nwa), 2nd sentence new-word abstract (2Nwa), 1st sentence real-word concrete (1Rwc), 2nd sentence real-word concrete (2Rwc), 1st sentence real-word abstract (1Rwa) and 2nd sentence real-word abstract (2Rwa). The data was high-pass filtered (to a maximum of 1/128 Hz), and serial autocorrelations were estimated using an autoregressive model (AR(1) model). Resulting estimates were used for nonsphericity correction during model estimation. Confounding effects in the global mean were removed by proportional scaling, and signal-correlated motion effects were minimized by including the estimated movement parameters. Contrast images were calculated for each subject. The individual contrast images were entered into a second-level analysis using a one-sample *t* test.

The main contrasts were defined as follows:

i. Real-word analysis:

Word exposure effect: (1Rwc + 1Rwa) > (2Rwc + 2Rwa) for first sentence effect (reverse for second sentence).

Imageability effect: (1Rwc + 2Rwc) > (1Rwa + 2Rwa) for concrete word effect (reverse for abstract word)

ii. New-word analysis:

Word exposure effect: (1Nwc + 1Nwa) > (2Nwc + 2Nwa) for first sentence effect (reverse for second sentence).

Imageability effect: (1Nwc + 2Nwc) > (1Nwa + 2Nwa) for concrete new-word effect (reverse for abstract new-word effect).

iii. Real-word vs. New-word comparison (at the 2nd sentence presentation):

Word Type effect: (2Rwc + 2Rwa) > (2Nwc + 2Nwa) for real-word effect (reverse for new-word effect).

Imageability effect: (2Rwc + 2Nwc) > (2Rwa + 2Nwa) for concrete word effect (reverse for abstract word effect).

The corresponding interactions between the different factors (*Word exposure x Imageability* for Rw and Nw conditions, and *Word Type x Imageability* in the comparison between Rw and Nw conditions) were calculated accordingly. Unless mentioned otherwise, contrasts were thresholded at $P < 0.001$ with a cluster extent of > 20 contiguous voxels, and only clusters with a significant $P < 0.05$ corrected for multiple comparisons were reported and interpreted (Worsley and Friston, 1995). The maxima of suprathreshold regions were localized by rendering them onto the volunteers' mean normalized T1 structural images on the MNI reference brain (Cocosco et al., 1997). Maxima and all coordinates are reported in MNI coordinates, as used by SPM and labeled according to the Talairach atlas.

Finally, a parameter estimate analysis was conducted to determine more precisely the relationship between the observed activations and learning concrete and abstract concepts. Maps of parameter estimates (β values) were computed from the generalized linear model to assess the magnitude of activation during each condition.

The mean parameter estimate of each regressor was then calculated at the cluster activation maximum for each subject and region. These mean parameter estimates values in each condition and region were then averaged across participants. These values were used as dependent variables in 3-way repeated measures ANOVAs with the following factors: Word exposure (1^{st} vs. 2^{nd} sentence), Word Type (Real word vs. New word) and Imageability (concrete vs. abstract). Further statistical analyses with repeated measures ANOVA and planned comparisons (two-sided, paired-sample *t* tests) were used to test differences ($P < .05$) between the parameter estimates from the different conditions when necessary as result of interactions within the 3-way ANOVA design (see section 5.3.2.4.).

5.3. Results

5.3.1. Behavioral performance

The mean percentages of meaning recognition for learned concrete new-words and abstract new-words did not differ significantly (71 ± 15.3% vs. 65 ± 15.1% respectively, $t = 1.96$, $P = 0.069$). Both percentages were significant when tested against chance-level (concrete: $t_{14} = 17.93$; $P < 0.0001$; Abstract: $t_{14} = 16.65$, $P < 0.0001$). The false alarm rate did not differ significantly either (21.1 ± 10.8% vs. 24.2 ± 10.6%, $t = -1.2$, $P = 0.24$). However, the percentage of omissions was significantly lower for concrete new-words than for abstract new-words (7.9 ± 7.8% vs. 10.7 ± 8.5%, $t_{14} = -2.2$, $P < 0.044$). In addition, participants took longer to correctly recognize the meaning of the abstract new-word. Reaction times were significantly shorter for concrete new-words than for abstract new-words (1674.8 ± 187 vs. 1809.4 ± 233.6, $t_{14} = -3.38$, $P < 0.004$). This difference in reaction times, with that for abstract new-words being slower, may explain why the percentage of omissions is higher for abstract new-words, since the trial ends if no response is given in 3000 seconds.

In the old/new word recognition task the general percentage of hits was 85.1% (SD = 13.1) and false alarms was 10.8% (SD = 11.3), which clearly indicates that participants paid attention to the real-word sentence conditions. When analyzing concrete and abstract words separately no differences were found between the hits rates (concrete words: 86 ± 14.7%, abstract words: 84.2 ± 12.8%; $t < 1$), nor between false alarm rates (concrete words: 10.5 ± 13.7%, abstract words: 11.1 ± 10%; $t < 1$). The percentage of omissions did not differ significantly either (concrete words: 3.7 ± 4%, abstract words: 4.7 ± 4.8%; $t < 1$). However, participants were faster to judge concrete words as old words compared to abstract words (concrete words: 1188.9 ± 202; abstract words: 1365 ± 206, $t_{14} = -5.2$, $P < 0.0001$).

The recall test performed after the scanning session showed that participants recognized a mean of 13.43 (SD = 7.41) concrete new-words out of 40, and from those, meaning was correctly recalled for 3.5 (SD = 2.82) concrete new-words. Abstract new-word mean recognition rate was 11.57 (SD = 7.76) out of 40 new-words; from these recognized words, meaning was correctly reported for 1.93 (SD = 2.81) abstract new-words. New concrete and abstract word recognition rates did not differ from each other ($t = 1.5$, $P = 0.14$). Both significantly differed from the filler mean recognition rate [(concrete new-words vs. fillers: $t_{13} = 4.53$; $P < 0.001$) (abstract new-word vs. fillers: $t_{13} = 2.94$; $P < 0.011$)]. Interestingly, participants correctly recalled more concrete new-word meanings than abstract new-word meanings ($t_{13} = 2.70$; $P < 0.018$).

5.3.2. fMRI data

5.3.2.1.Real-word analysis

5.3.2.1.1. Word exposure

The contrast 1st sentence Real-word vs. 2nd sentence Real-word (1Rw vs. 2Rw) yielded significant activations in the left fusiform gyrus (Brodmann area (BA) 37, Visual Word Form Area (VWFA)), right middle occipital gyrus (BA 18), left cuneus (BA 17), right precuneus/superior parietal lobe (BA 7), left inferior frontal gyrus (BA 45, LIFG), right inferior/middle frontal gyrus (BA 45/46) and left middle temporal gyrus (BA 21, LMTG) (Table 5.1, Figure 5.2). There were no areas displaying significant activation for the opposite contrast. This deactivation pattern observed reflects the amount of priming elicited by the word during the second presentation (repetition suppression phenomena, (Wheatley et al., 2005; Grill-Spector et al., 2006).

		Coordinates				
Brain region	~BA	x	y	z	*t*	*P*
Effect of Time (1Rw>2Rw)						
L fusiform g.	37	-36	-52	-20	8.89	0.0001[1]
R middle occipital g.	18	24	-96	0	7.53	0.0001[1]
L cuneus (SCA)	17	-12	-88	0	6.45	0.0001[1]
R precuneus/ superior parietal lobe	7	28	-56	52	6.48	0.001
L inferior frontal g.	45	-52	32	16	6.04	0.0001
R inferior/middle frontal g.	45/46	56	24	32	4.10	0.0001
L middle temporal g.	21	-52	-40	-4	5.37	0.005
Effect of Time (2Rw>1Rw)		No significant activations				
Effect of Imageability (Rwc>Rwa)		No significant activations				
Effect of Imageability (Rwa>Rwc)		No significant activations				
Interaction		No significant activations				

Table 5.1. Activation clusters for main effects (Time and Imageability) and interaction on Real Words. MNI coordinates and *t*- value for the peak location in a particular identified anatomical cluster ($P < 0.001$, 20 voxels spatial extent; [1] $P < 0.0001$) for the statistically significant differences in the corresponding activated regions. Note that only clusters that were significant on a cluster level of $P < 0.05$ (corrected for multiple comparisons) are listed. ~BA = approximate Brodmann's area; 1Rw = first sentence real-word; 2Rw = second sentence real-word; Rwa = real-word abstract; Rwc = real-word concrete; R = Right hemisphere; L = Left hemisphere; SCA = sulcus calcarinus; *P* = *P*-value for the cluster (corrected for multiple comparisons).

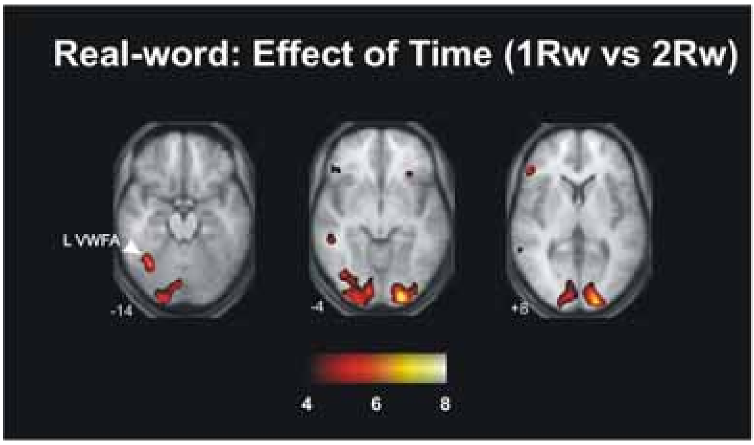

Figure 5.2. Axial view in standard stereotactic space of the group average comparisons between first sentence and second sentence for real words (effect of Time). All the views presented were superimposed on the mean anatomical image formed by averaging all 15 subjects' T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *t* values of the corresponding contrast. L: left; VWFA: Visual Word Form Area.

5.3.2.1.2. Imageability

No significant activations were found for the contrast between Real-word concrete vs. Real-word abstract (Rwc vs. Rwa), nor for the opposite contrast. However, for the contrast abstract vs. concrete words, when the threshold was lowered ($P < 0.005$, cluster extent 20 voxels) a significant activation was revealed in the right middle temporal gyrus (BA 21; RMTG, coordinates: 52, -24, -8; $t = 4.02$, $P < 0.005$).

5.3.2.1.3. Interaction Word exposure x Imageablity

No significant interaction was found.

5.3.2.2.New-word analysis

5.3.2.2.1. Word exposure

The contrast 1st sentence new-word vs. 2nd sentence new-word (1Nw vs. 2Nw) did not yield any significant activations. The opposite contrast showed significant activation in left claustrum, left middle frontal gyrus (BA 46), right anterior cingulate gyrus (BA 32), left middle temporal gyrus (BA 21), right precentral gyrus (BA 4), left inferior parietal lobe (BA 40), right putamen, right caudate body, left inferior frontal gyrus (BA 45), left putamen and left caudate body (Table 5.2, Figure 5.3).

		Coordinates				
Brain region	~BA	x	y	z	*t*	*P*
Effect of Time (1Nw>2Nw)		No significant activations				
Effect of Time (2Nw>1Nw)						
L claustrum		-28	12	12	11.83	0.0001[1]
L middle frontal g.	46	-40	44	16	9.96	0.0001[1]
R anterior cingulate cortex	32	8	24	40	7.50	0.0001[1]
L middle temporal g.	21	-60	-32	-4	7.67	0.0001[2]
R precentral g.	4	60	12	4	7.39	0.0001[2]
L inferior parietal lobe	40	-44	-40	52	7.17	0.0001[2]
R putamen (lentiform)		20	-4	16	6.65	0.0001[2]
R cerebellum		12	-80	-28	6.51	0.0001[2]
Right caudate body		16	4	12	6.10	0.0001[2]
L inferior frontal gyrus	45	-36	36	8	7.80	0.0001
Left putamen		-20	-8	12	6.70	0.0001
Left caudate body		-8	0	12	6.60	0.0001
Left brainstem (Midbrain)		0	-40	-20	5.19	0.0001
Effect of Imageability (Nwc>Nwa)						
L fusiform g.	37	-24	-40	-24	6.36	0.001[3*]
Effect of Imageability (Nwa>Nwc)		No significant activations				
Interaction						
Right brainstem (Pons)		8	-32	-32	5.35	0.040
L thalamus (pulvinar)		-8	-28	8	5.05	0.006
R putamen (lentiform)		28	-16	8	4.86	0.048
L fusiform g.	20	-32	-32	-28	4.77	0.034

Table 5.2. Activation clusters for main effects (Time and Imageability) and interaction on New-words. MNI coordinates and *t*- value for the peak location in a particular identified anatomical cluster ($P < 0.001$; 20 voxels spatial extent; [1] $P < 0.00001$; [2] $P < 0.0001$; [3] $P < 0.0005$; [*] small volume correction) for the statistically significant differences of the corresponding activated regions. Note that only clusters that were significant on a cluster level of $P < 0.05$ (corrected for multiple comparisons) are listed. ~BA = approximate Brodmann's area; 1Nw = First sentence new-word; 2Nw = second sentence new-word; Nwc = new-word concrete; Nwa = new-word abstract; R = Right hemisphere; L = Left hemisphere; *P* = *P*-value for the cluster (corrected for multiple comparisons).

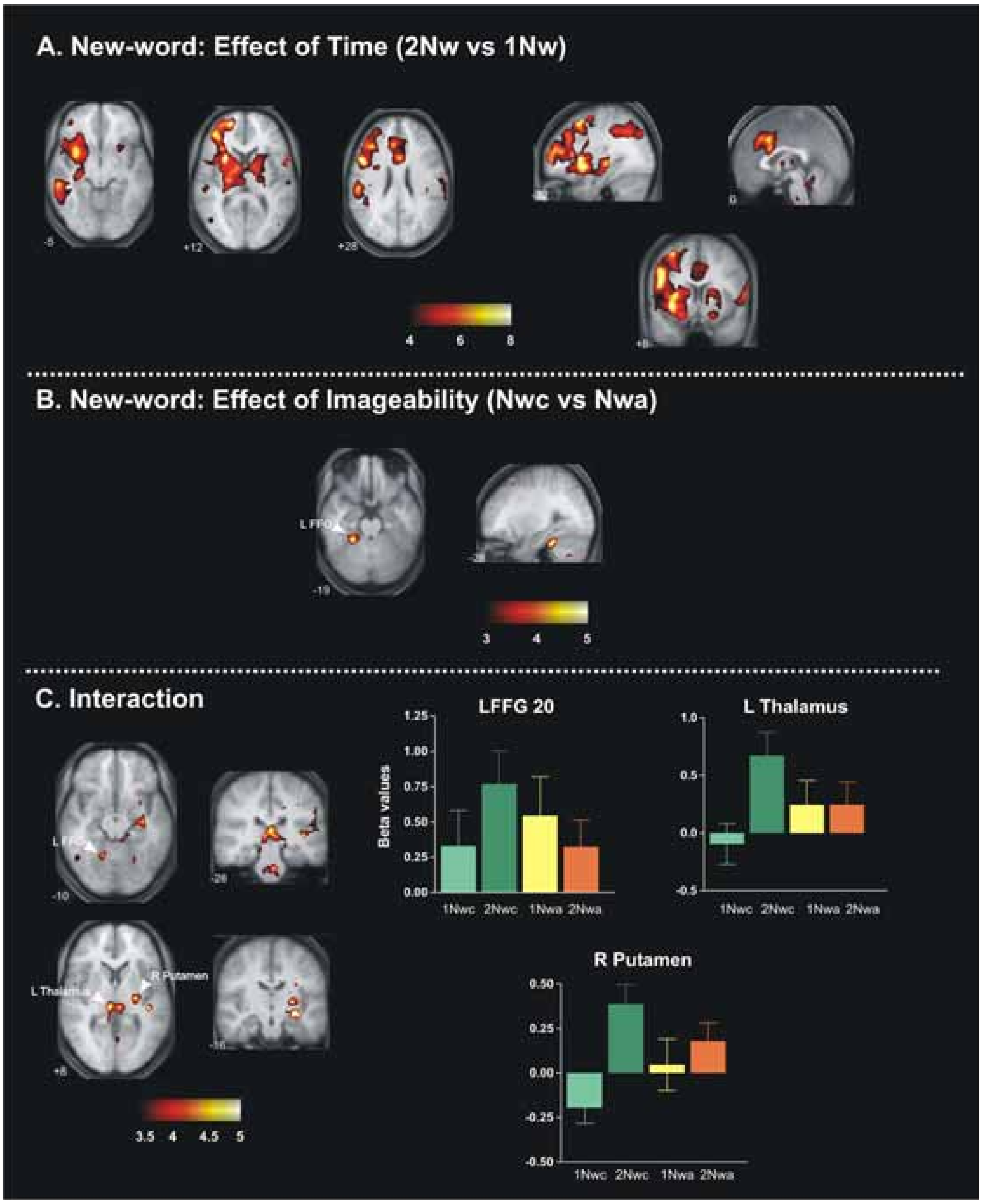

Figure 5.3. A. Axial, sagittal and coronal views in standard stereotactic space of the group average comparison between second and first sentence for new-word (effect of Time). All the views presented were superimposed on the mean anatomical image formed by averaging all 15 subjects' T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *t* values of the corresponding contrast. B. Axial and sagittal views in standard stereotactic space of the group average comparisons between new-word concrete and new-word abstract for new-word conditions (effect of Imageability). All the views presented were superimposed on the mean anatomical image formed by averaging all 15 subjects' T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *t* values of the corresponding contrast. C. Axial and coronal views in standard stereotactic space of the group average interaction between Time and Imageability. All the views presented were superimposed on the mean anatomical image formed by averaging all 15 subjects' T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *t* values of the corresponding contrast. Group-average beta values for 1st sentence new-word concrete (1Nwc), 2nd sentence new-word concrete (2Nwc), 1st sentence new-word abstract (1Nwa) and 2nd sentence new-word abstract (2Nwa) in the left fusiform gyrus (BA20, coordinates -32, -32, -28), left thalamus (coordinates -8, -28, 8) and right putamen (coordinates 28, -16, 8). Error bars indicate standard error of the mean. L: left; R: right; FFG: fusiform gyrus.

5.3.2.2.2. Imageability

The comparison new-word concrete vs. new-word abstract (Nwc vs. Nwa) yielded significant activation in the left fusiform gyrus (BA 37) (Figure 5.3, Table 5.2). The opposite contrast did not display any significant activations (Figure 5.3, Table 5.2).

5.3.2.2.3. Interaction Word exposure x Imageability

Interactions were found in the left thalamus, right putamen and left fusiform gyrus (BA 20) (Figure 5.3, Table 5.2).

5.3.2.3.New-word vs. Real-word comparison (at the 2nd sentence presentation)

5.3.2.3.1. Word Type

The contrast 2nd sentence real-word vs. 2nd sentence new-word (2Rw vs. 2Nw) revealed anterior and posterior cingulate cortex activation (Figure 5.4, Table 5.3). The opposite contrast yielded large activations in various regions of the left hemisphere, including bilateral inferior frontal gyrus (BA 45), the left middle frontal gyrus (BA 46), fusiform gyrus bilaterally (BA 37, VWFA), the anterior cingulate cortex/ pre-supplementary motor area (ACC/pre-SMA, BA 32/6), the caudate body bilaterally, the thalamus bilaterally and the superior temporal gyrus (BA 22) among other regions (see Table 5.3, Figure 5.4).

5.3.2.3.2. Imageability

The concrete vs. abstract contrast (C vs A) showed activation in the left fusiform gyrus (BA 37) (Figure 5.4, Table 5.3). There were no areas displaying significant activation for the opposite contrast.

		Coordinates				
Brain region	~BA	x	y	z	*t*	*P*
Effect of Word Type(2Rw>2Nw)						
Anterior cingulate cortex	32	0	28	-8	7.84	0.0001
L posterior cingulate g.	31	-4	-52	32	4.88	0.017
Effect of Word Type (2Nw>2Rw)						
L insula/inferior frontal gyrus	13	-36	20	16	9.15	0.0001[1]
L inferior frontal gyrus	45	-36	32	8	8.19	0.0001[1]
L inferior frontal gyrus	44	-48	8	24	8.09	0.0001[1]
L fusiform g.	37	-36	-56	-20	7.58	0.0001[2]
R middle occipital g.	18	40	-88	-8	7.25	0.0001[2]
Left middle frontal gyrus	46	-36	-4	48	7.19	0.0001[2]
R fusiform g.	37	32	-52	-24	6.81	0.0001[2]
R inferior frontal g.	45	44	24	20	6.83	0.0001[2]
L anterior cingulate cortex/pre-SMA	32/6	-4	4	64	6.55	0.0001[2]
Left caudate body		-8	-4	16	7.40	0.0001
Right caudate body		8	0	12	7.33	0.0001
L superior temporal g.	22	-60	-52	16	6.72	0.0001
L cuneus	18	-24	-96	-8	5.83	0.003
L inferior parietal lobe	40	-40	-44	44	5.77	0.0001
Left brainstem (Pons)		-4	-20	-24	5.27	0.035
Right thalamus (medial dorsal)		8	-20	12	4.92	0.0001
Left thalamus		-8	-20	16	4.88	0.0001
R middle frontal g.	6	32	-8	68	4.73	0.030
Right thalamus		20	-16	16	4.72	0.0001
L cuneus (SCA)	17	-12	-76	4	4.38	0.019
Effect of Imageability (C>A)						
L fusiform g.	37	-28	-36	-24	5.74	0.002
Effect of Imageability (A>C)		No significant activations				
Interaction		No significant activations				

Table 5.3. Activation cluster for main effects Word Type (Real-word vs. New-word) and Imageability (Concrete vs. Abstract) and interaction between these factors on the second sentence. MNI coordinates and *t*- value for the peak location in a particular identified anatomical cluster ($P < 0.001$; 20 voxels spatial extent; [1] $P < 0.00001$; [2] $P < 0.0001$) for the statistically significant differences of the corresponding activated regions. Note that only clusters that were significant on a cluster level of $P < 0.05$ (corrected for multiple comparisons) are listed. ~BA = approximate Brodmann's area; 2Rw = second sentence real-word; 2Nw = second sentence new-word; C = concrete sentence; A = abstract sentence; R = Right hemisphere; L = Left hemisphere; *P* = *P*-value for the cluster (corrected for multiple comparisons).

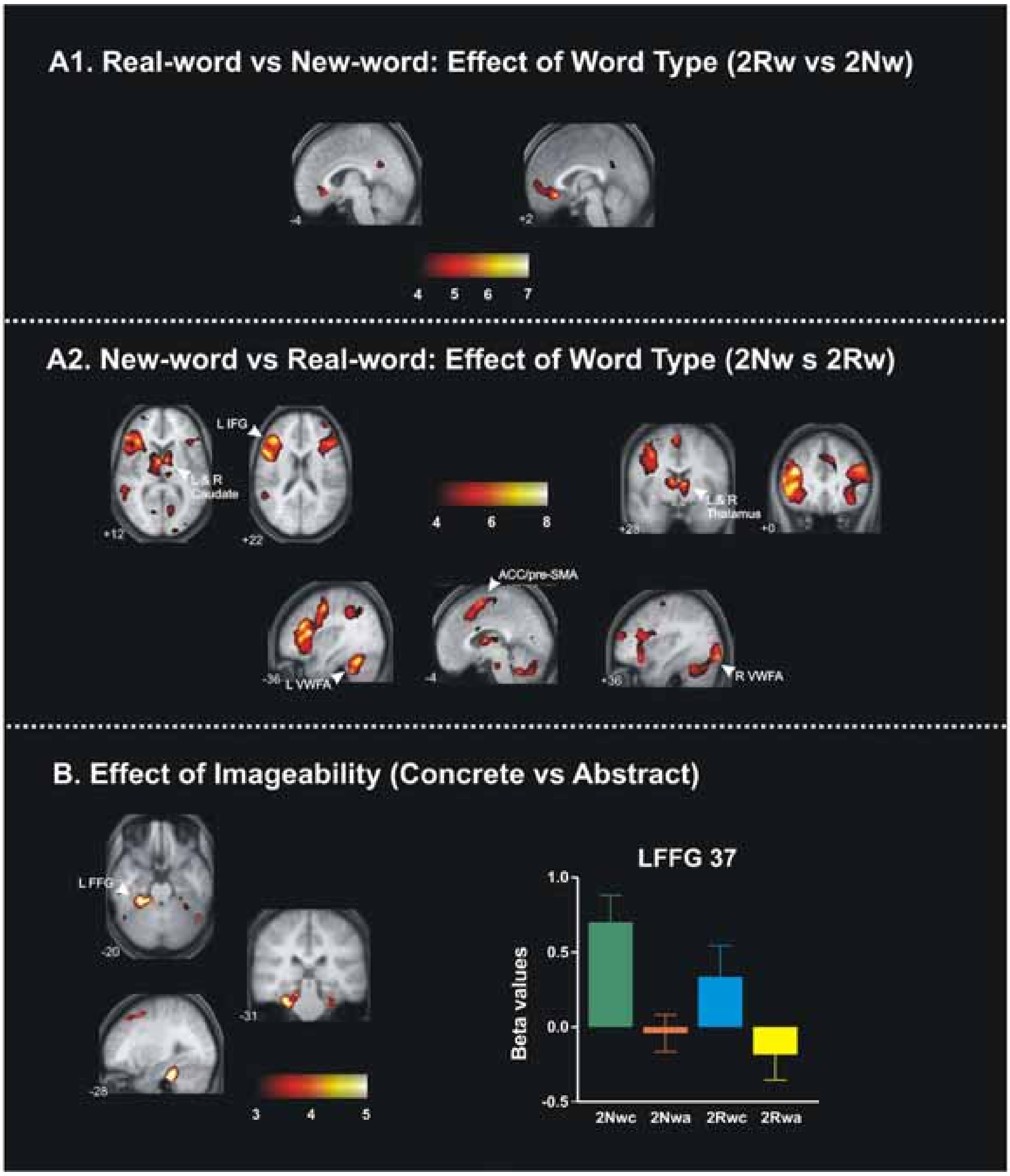

Figure 5.4. A1. Sagittal view in standard stereotactic space of the group average comparison between real-word and new-word (effect of Word Type). All the views presented were superimposed on the mean anatomical image formed by averaging all 15 subjects' T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *t* values of the corresponding contrast. A2. Axial, sagittal and coronal views in standard stereotactic space of the group average comparisons between new-word and real word (effect of Word Type). All the views presented were superimposed on the mean anatomical image formed by averaging all 15 subjects' T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *t* values of the corresponding contrast. B. Axial, sagital and coronal views in standard stereotactic space of the group average comparison between concrete and abstract (effect of Imageability). All the views presented were superimposed on the mean anatomical image formed by averaging all 15 subjects' T1 structural MRI scans mapped into normalized MNI space. Values in the color scale refer to the *t* values of the corresponding contrast. Group-average beta values for 2^{nd} sentence new-word concrete (2Nwc), 2^{nd} sentence new-word abstract (2Nwa), 2^{nd} sentence real-word concrete (2Rwc) and 2^{nd} sentence real-word abstract (2Rwa) in the left fusiform gyrus (BA37, coordinates -28, -36, -24). Error bars indicate standard error of the mean. L. left; R: right; IFG: inferior frontal gyrus; VWFA: Visual Word Form Area; ACC/pre-SMA: anterior cingulate cortex/pre-supplementary motor area; FFG: fusiform gyrus.

5.3.2.3.3. Interaction Word Type x Imageability

No significant interaction was found.

5.3.2.4. Parameter estimates analysis

5.3.2.4.1 Areas modulated by meaning acquisition

Based on the results from the previous fMRI study on new-word meaning acquisition (see Chapter 3), left inferior frontal gyrus (BA 45), left middle temporal gyrus (BA 21), bilateral ACC/pre-SMA (BA 32/6), thalamus and basal ganglia were further studied because of their previous implication in meaning acquisition.

For each studied region a 2 x 2 x 2 ANOVA repeated measures design was conducted with Word exposure (1^{st} vs. 2^{nd} sentence), Word Type (Real word vs. New word) and Imageability (Concrete vs. Abstract) as factors. The results from these analyses are reported in Table 5.4.

The left inferior frontal gyrus (LIFG, BA 45) showed more activation for new-word than real-word conditions (Figure 5.4 and 5.5). The LIFG did not show any modulation due to imageability. While new-words elicited an increase in activation on the 2^{nd} sentence respect to the 1^{st}, real words were associated with a small decrease (see Table 5.4). No differences between conditions were observed for the first sentence (F = 1.89; P = 0.19).

The left middle temporal gyrus (LMTG, BA21) (Figure 5.5) showed a similar pattern as the LIFG. New-word conditions elicited greater activation than real-word conditions in the 2^{nd} sentence but concrete and abstract new-word conditions did not differ between them. There was an increase in activation for new-word conditions from the 1^{st} sentence to the 2^{nd} sentence whereas real words showed a decrease in activation (see Table 5.4). When comparing real words during the first sentence, abstract words were associated with greater activation than concrete words (t_{14} = -2.63; P < 0.020). This difference was not observed during the 2^{nd} sentence (t < 1). Thus, this region showed some imageability modulation only for real words and only during the first sentence.

As in the two previous regions, the ACC/pre-SMA (BA 32/6) showed greater activation for new-word conditions compared to real-word conditions (Figure 5.4 and 5.5). During the first sentence, new-word conditions showed greater activation than real-word conditions. The same pattern was observed for the second sentence, where new-word conditions increased in activation while real-word conditions decreased (see Table 5.4). It is interesting to note that whereas the activation in Nwc increased from the first to the second sentence, this was not observed for Nwa. In fact, a greater activation was elicited by Nwa compared to Nwc during the first sentence (t_{14} = -2.2; P < 0.038). Both conditions showed no differences during the second sentence (t < 1).

The left and right caudate body (Figure 5.5) seemed to follow the same pattern of activation as observed in the previous regions. Both caudate nucleuses showed the same pattern of activation except that, in the left caudate, there was an interaction between Word exposure and Imageability (see Table 5.4). Greater activations were observed during the second sentence for new-words compared to real words due to learning in both the left and right caudate. However, the increase in activation from the 1st to the 2nd sentence seemed to be greater for Nwc than Nwa (see Figure 5.5), but only in the left caudate. In contrast, no differences were observed between new-words and real words during the first sentence. The level of activation in response to real words did not change across sentences (F < 1).

For the left putamen (Figure 5.5), only new-words showed an increase in activation from the 1st to 2nd sentence. While no differences between conditions were found for the first sentence, new-word conditions elicited greater activation than real-word conditions during the second sentence (see Table 5.4). In contrast, in the right putamen (Figure 5.3) a significant interaction between Word exposure and Imageability was found (see Table 5.4). For this region, a 2 x 2 ANOVA repeated measures design was restricted to new-word conditions introducing Word exposure and Imageability as factors. This analysis confirmed the existence of a Word exposure effect ($F_{1,14}$ = 17.74; P < 0.002) and a significant interaction between Word exposure and Imageability ($F_{1,14}$ = 23.18; P < 0.0001). When applied to real words the same analysis showed neither significant main effects (Word exposure: F = 3.29; P = 0.091; Imageability: F = 2.53; P = 0.134) nor an interaction between Word exposure and Imageability (F < 1). These results showed that in the left putamen there was an increase in activation from the 1st to 2nd sentence for both Nwc and Nwa (see Figure 5.5). Conversely, in the right putamen, only Nwc was associated with an increase on activation when compared to Nwa (see Figure 5.3) (1Nwc vs. 2Nwc: t_{14} = -6.29; P < 0.0001; 1Nwa vs. 2Nwa: t = -1.1; P = 0.263).

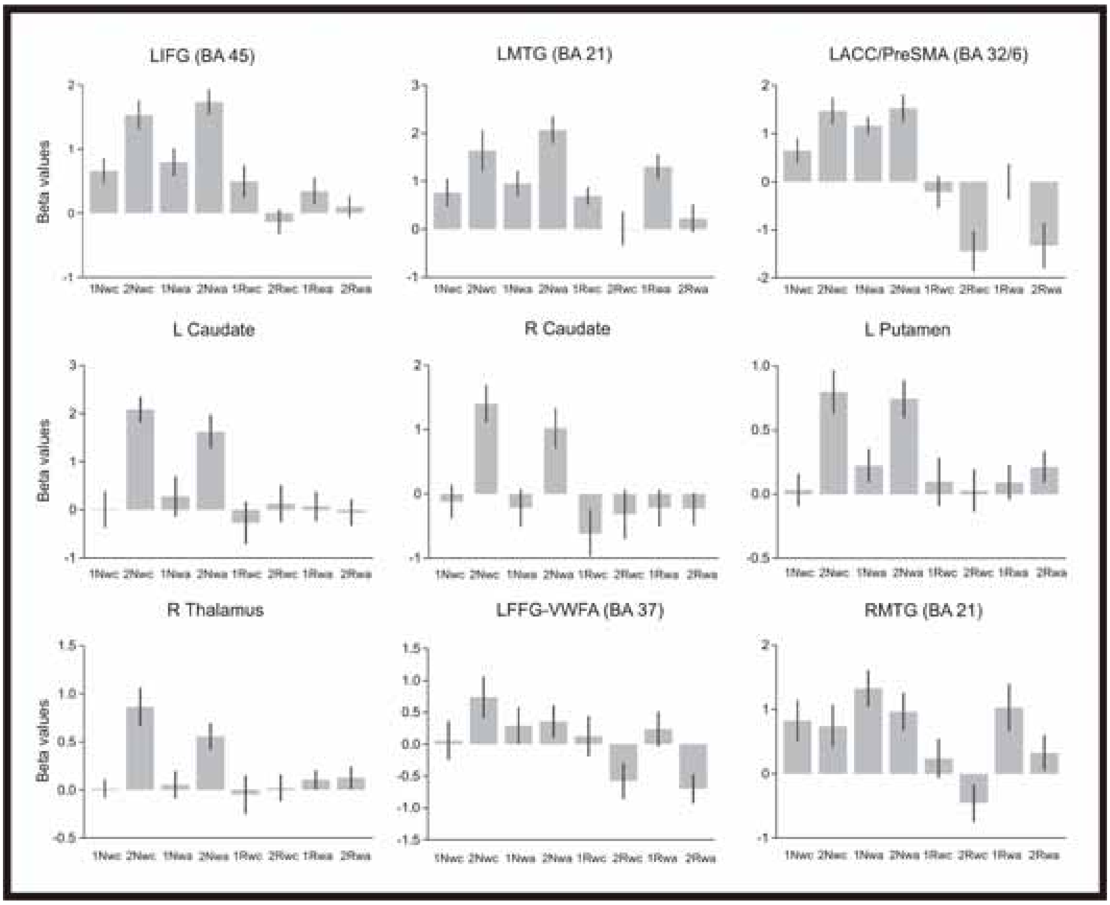

Figure 5.5. Top: Group-average beta values for 1st sentence new-word concrete (1Nwc), 2nd sentence new-word concrete (2Nwc), 1st sentence new-word abstract (1Nwa), 2nd sentence new-word abstract (2Nwa), 1st sentence real-word concrete (1Rwc), 2nd sentence real-word concrete (2Rwc), 1st sentence real-word abstract (1Rwa) and 2nd sentence real-word abstract (2Rwa) in the left inferior frontal gyrus (BA 45, coordinates of the activation maximum: -36, 32, 8), left middle temporal gyrus (BA 21, -60, -32, -4) and left anterior cingulate cortex/pre-supplementary motor area (BA 32/6, -4, 4, 64). Error bars indicate standard error of the mean. Middle: Group-average beta values for 1Nwc, 2Nwc, 1Nwa, 2Nwa, 1Rwc, 2Rwc, 1Rwa and 2Rwa in the left caudate (-8, 0, 12), right caudate (8, 0, 12) and left putamen (-20, -8, 12). Error bars indicate standard error of the mean. Bottom: Group-average beta values for 1Nwc, 2Nwc, 1Nwa, 2Nwa, 1Rwc, 2Rwc, 1Rwa and 2Rwa in the right thalamus (20, -16, 16), left fusiform gyrus/Visual Word Form Area (-36, -56, -20) and right middle temporal gyrus (BA 21, 52, -24, -8). Error bars indicate standard error of the mean.

Analysis of the right thalamus (Figure 5.5) showed a similar pattern as found in the previously analyzed areas. New-words elicited an increase in activation during the second sentence compared to real words, whereas no differences between conditions were found for the first sentence (see Table 5.4). Furthermore, when the analysis was restricted to new-word conditions, a significant interaction between Word exposure and Imageability was found ($F_{1,14} = 8.03$; $P < 0.013$). Thus, the increase in activation was greater for Nwc than Nwa. Most importantly, in the left thalamus (Figure 5.3) the increase on activation occurred only for Nwc (1Nwc vs. 2Nwc: $t_{14} = -4.75$; $P < 0.0001$; 1Nwa vs. 2Nwa: $t < 1$).

In sum, the left inferior frontal gyrus, right caudate and left putamen did not show any imageability effect. These areas showed a similar pattern of greater activation for new-word conditions during the second sentence compared to the first and to real words. The left middle temporal gyrus and the anterior cingulate gyrus/pre-SMA also showed this pattern. However, some imageability modulations were observed within these regions. In the middle temporal gyrus, Rwa was associated with greater activation than Rwc during the first sentence. In the ACC/pre-SMA, Nwa induced greater activation than Nwc during the first sentence. Notice also that real-word conditions elicited a large deactivation during the second sentence compared to the first. The basal ganglia and thalamus showed the pattern of greater activation for new-word conditions compared to real-word ones during the second sentence. However, in these regions, except in the right caudate and left putamen, imageability effects were found for new-word conditions. Concrete new-words were associated with a greater increase on activation than abstract new-words in the left caudate and right thalamus. For the right putamen and left thalamus the pattern of activation was different, as Nwa did not show differences between the first and second sentence, while Nwc showed an increase in activation during the second sentence. These results will be further discussed in the discussion.

5.3.2.4.2 Areas modulated by word imageability

The left fusiform gyrus and middle temporal gyrus were further studied. These areas have been reported in several studies as being modulated by word imageability (Bedny and Thompson-Schill, 2006; Giesbrecht et al., 2004; Noppeney and Price, 2002; Wallentin et al., 2005; Whatmough et al., 2004; Fliessbach et al., 2006; Sabsevitz et al., 2005).

For each studied region a 2 x 2 x 2 ANOVA repeated measures design was conducted with the following factors: Word exposure (1^{st} vs. 2^{nd} sentence), Word Type (Real word vs. New word) and Imageability (Concrete vs. Abstract). The results from these analyses are reported on Table 5.4.

For the anterior left fusiform gyrus (BA 37, coordinates, -28, -36, -24) (Figure 5.4) a 2 x 2 ANOVA repeated measures design restricted to the first sentence was performed with Word Type and Imageability as factors. This analysis revealed a significant main effect of Imageability ($F_{1,14} = 7.52$; $P < 0.0001$). Neither a main effect of Word Type ($F < 1$) nor the interaction between Word Type and Imageability ($F < 1$) were significant. The same analysis was applied to the 2^{nd} sentence. The analysis showed significant main effects of Word Type ($F_{1,14}$ = 5.11; P < 0.040) and Imageability ($F_{1,14}$ = 33.15; P < 0.0001). No interaction between these factors was found (F = 1.57; P = 0.23). Concrete stimuli provoked greater activation than abstract stimuli. Interestingly, when a 2 x 2 ANOVA repeated measures design was restricted to concrete stimuli with Word Type and Word exposure as factors, a main effect of Word exposure ($F_{1,14}$ = 6.47; P < 0.023) and a marginally significant interaction between Word Type and Word exposure ($F_{1,14}$ = 4.50; P < 0.052) were found. The main effect of Word Type was not significant (F = 1.75; P < 0.207). Thus, the results of these analyses showed that in the anterior left fusiform gyrus (BA 37), concrete stimuli were associated with greater activation than abstract stimuli in both the 1st and 2nd sentence, and, moreover, during the second sentence Nwc showed greater activation than Rwc (t_{14} = 2.31; P < 0.036).

	WE	TW	I	WE x TW	WE x I	TW x I	WE x TW x I
LIFG	n.s.	28.1***	n.s.	39.04***	n.s.	n.s.	n.s.
LMTG	n.s.	7.5*	n.s.	23.8***	n.s.	n.s.	n.s.
ACC/pre-SMA	n.s.	35.3***	n.s.	28.8***	n.s.	n.s.	n.s.
L Caudate	10.2**	17.5***	n.s.	32.9***	4.9*	n.s.	n.s.
R Caudate	10.8**	16.1***	n.s.	23.8***	n.s.	n.s.	n.s.
L Putamen	21.9***	8.9**	n.s.	15**	n.s.	n.s.	n.s.
R Putamen	11.7**	n.s.	n.s.	n.s.	7.1*	n.s.	n.s.
L Thalamus	n.s.	n.s.	n.s.	6.7*	4.6*	n.s.	n.s.
R Thalamus	8.6**	10.3**	n.s.	19.4***	n.s.	n.s.	n.s.
L aFFG	n.s.	n.s.	48.3***	n.s.	5.7*	n.s.	n.s.
L VWFA	n.s.	18.4***	n.s.	35.9***	4.8*	n.s.	n.s.
L FFG	n.s.	n.s.	4.9*	n.s.	11.3**	n.s.	n.s.
RMTG	13.9**	8.6**	10.3**	n.s.	n.s.	n.s.	n.s.

Table 5.4. Parameter estimates analysis: pairwise ANOVAs comparing the different conditions and regions of interest. WE: Word exposure (1st vs. 2nd sentence); TW: Type of Word (New-word vs. Real word); I: Imageability (Concrete vs. Abstract). LIFG: inferior frontal gyrus (coordinates, -36, 32, 8); LMTG: left middle temporal gyrus (-60, -32, -4); LACC/pre-SMA: left anterior cingulate cortex/ pre-supplementary motor area (-4, 4, 64); Left caudate (-8, 0, 12); Right caudate (8, 0, 12); Left putamen (-20, -8, 12); Right putamen (28, -16, 8); Left thalamus (-8, -28, 8); Right thalamus (20, -16, 16); LaFFG: left anterior fusiform gyrus (-28, -36, -24); LVWFA: left Visual Word Form Area (-36, -56, -20); LFFG: left fusiform gyrus (-32, -32, -28). Degrees of freedom: 1,14. n.s., not significant. *P < 0.05; **P < 0.01; ***P < 0.001.

A more posterior portion of the fusiform gyrus, corresponding to the Visual Word Form Area (VWFA, coordinates, -36, -56, -20), (see Figure 5.2, 5.4 and 5.5) was analyzed. Interestingly, this region showed a different pattern of activation (see Table 5.4). A 2 x 2 ANOVA repeated measures design restricted to new-word conditions introducing Word exposure and Imageability as factors showed a significant interaction between Word exposure and Imageability ($F_{1,14}$ = 13.03; P < 0.003). Neither the main effect of Word exposure ($F = 3.77$; $P < 0.072$) nor the main effect of Imageability were significant ($F < 1$). However, when this analysis was applied to the real-word condition, only a main effect of Word exposure was encountered ($F_{1,14} = 54.05$; $P < 0.0001$). Thus, Nwc elicited an increase in activation from the first to second sentence whereas Nwa showed no differences. For real words, a deactivation pattern was observed for the second sentence. The same pattern of activation was observed on the right VWFA (32, -52, -24). Thus, while the anterior part of the fusiform gyrus was modulated by imageability in general, the VWFA showed modulation only for new-words.

Another part of the left fusiform gyrus (BA 20, coordinates, -32, -32, -28) also showed effects of Imageability which interacted with Word exposure (see Table 5.4, Figure 5.3). New concrete words were associated with an increase in activation for the second sentence, while new abstract words did not show any differences between the first and second sentence (1Nwc vs. 2Nwc: $t_{14} = -2.4$; $P < 0.030$; 1Nwa vs. 2Nwa: $t = 1.3$; $P = 0.19$). Furthermore, real concrete words induced greater activation during the second sentence than real abstract words ($t_{14} = 3.3$; $P < 0.005$).

The right and left middle temporal gyrus (BA 21) (Figure 5.5) showed effects of imageability for real words. With regard to the LMTG (BA 21), we observed in the previous analysis that this region showed greater activation for 1Rwa compared to 1Rwc. For the RMTG (BA 21) a similar pattern was found (see Table 5.4). A 2 x 2 ANOVA repeated measures design was restricted to new-words introducing Word exposure and Imageability as factors. The analysis showed no significant main effects [Time: ($F = 1.96$; $P = 0.18$); Imageability: ($F = 2.2$; $P = 0.15$)] nor an interaction between these factors ($F = 1.5$; $P = 0.23$). Thus, new-word conditions did not show imageability effects in this region. For real words the same type of analysis was performed. Significant main effects of Word exposure ($F_{1,14} = 10.37$; $P < 0.006$) and Imageability ($F_{1,14} = 19.40$; $P < 0.001$) were found. No significant interaction was found ($F < 1$). Thus, Rwa showed a greater level of activity than Rwc during both the 1st and 2nd sentences. Both real-word conditions were associated with a decrease in activation during the second sentence compared to the first sentence.

In sum, the ventral anterior fusiform gyrus showed greater activation for concrete items, with the largest activation pattern being observed for the new-word concrete condition. Interestingly, the VWFA showed imageability modulation only for new-word conditions (greater activity for the Nwc condition). In contrast to the concreteness effects observed in the fusiform gyrus, the left and right middle temporal gyrus showed the reverse pattern. Abstract items were associated with greater levels of activation, but this effect was observed only for the real-word conditions. These results will be discussed in the next section.

5.4 Discussion

This experiment used functional magnetic resonance imaging to study the mapping of novel words to meaning derived from sentential context, and how this process differ depending on a word's imageability in young adults. In order to assess meaning acquisition in different word types, concrete and abstract words were used. We found that both concrete and abstract words were successfully learned from contextual information. Performance in the word pair task conducted after each functional run indicated that participants were able to acquire the meaning of novel words from contextual information (Chaffin et al., 2001). Even though both concrete and abstract new-words were successfully learned, concrete words were associated with faster reaction times and fewer omissions than abstract words. Furthermore, new concrete word meanings were better remembered and recalled than new abstract word meanings. In adults, concrete words have been found to be easier to learn than abstract words, and they are also learned and remembered better, as evidenced by their being recalled more quickly and accurately (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000; de Groot, 2006). These effects of word concreteness found in novice learners of a second language have been also observed in fluent bilinguals, indicating that concrete words are translated more quickly and accurately than abstract words (de Groot and Poot, 1997; van Hell and de Groot, 1998a; van Hell and de Groot, 1998b).

The fMRI results suggest a distributed brain network for word learning that includes the left inferior frontal gyrus (BA 45), middle temporal gyrus (BA 21), anterior cingulate cortex/pre-supplementary motor area (BA 32/6) and several subcortical areas. Furthermore, the left fusiform gyrus played a differential role depending on word imageability. It was found to be implicated only in the learning of concrete words. Whereas no region showed differential involvement in abstract new-word meaning acquisition, the right and left middle temporal gyrus (BA 21) were more activated for real abstract words. We will discuss the common regions activated when trying to discover the meaning of a new-word. Afterward, we will address the implication of region-specific recruitment that is differentially modulated by acquisition and imageability.

5.4.2 Areas activated during learning a new-word

New-word conditions in the present study were associated with activation in the middle temporal gyrus (BA 21) and inferior frontal gyrus (BA 45). Interestingly, during the first sentence all conditions (1Nwc, 1Nwa, 1Rwc and 1Rwa) showed the same pattern of activation; however, during the second sentence new-words were associated with increases in activation while real-words showed a decrease (see Figure 5.5 top).

In the previous fMRI study (see Chapter 3) prefrontal and temporal regions were found to be implicated in meaning acquisition. The involvement of these regions on new-word learning has been discussed in detail on Chapter 3. Thus, in this section we will summarize the main common results during new-word learning in the present experiment. However, note that the critical question addressed in this study is the differential recruitment of some regions depending on the imageability of the word to be learned, which will be stressed in the next section.

Several studies have implicated the middle temporal gyrus in the representation of verbal semantic information (Martin and Chao, 2001; Booth et al., 2002; Blumenfeld et al., 2006). Also, this region has been suggested to be related to increased semantic integration demands (Petersen et al., 1988; Price et al., 1996; Vandenberghe et al., 1996; Just et al., 1996; Damasio et al., 1996; Martin et al., 1996; Ni et al., 2000; Price, 2000; Martin and Chao, 2001; Baumgaertner et al., 2002). In our study greater activation in the middle temporal gyrus was observed for new-word conditions during the second sentence, which might reflect increased effort in attempting to integrate candidate concepts for the novel word into the sentence context. The anterior region of the left IFG (BA 45) was found to be more active in new-word conditions. The results suggest that the activity in left IFG was modulated by the difficulty of contextual integration; thus, increased activation was observed for those conditions requiring more elaborate semantic processing (Petersen et al., 1988; Kapur et al., 1994; Demb et al., 1995; Warburton et al., 1996)

The involvement of both left MTG and IFG in new word meaning acquisition is congruent with the previous fMRI experiment (see Chapter 3). As discussed there, the involvement of these regions in lexical acquisition is more consistent with proposals that implicate these areas in strategic retrieval of lexico-semantic information (Kapur et al., 1994; Buckner et al., 1995; Fiez, 1997; Wagner et al., 2001; Gold et al., 2006). These results allow one to discard a role of the IFG in selection from competing semantic features (Thompson-Schill et al., 1997): if that were the case, increased activation would have been found for the first sentence since more candidates that fit into the low cloze probability context would have been active at that time. Hence, reduced selection demands should result in reduced activation. This is not the case in our experiment: instead, we observed greater activation of the IFG during cases in which fewer alternatives were competing for selection.

The decrease in activation observed for real-word conditions in both middle temporal gyrus and inferior frontal gyrus is congruent with reductions in activity often observed during repetition priming (Wiggs and Martin, 1998; Wagner et al., 2000; Schacter et al., 2004; Gold et al., 2005; Gold et al., 2006).

The right caudate and left putamen nucleuses were found to be more activated for new-word conditions (with no difference between Nwc and Nwa) than for real-word conditions. The left caudate nucleus and right thalamus were also found to be more activated for new-word conditions than for real-word conditions. Even though both new-word conditions were associated with an increase in activation on these regions, this increase was greater for concrete new-words. Finally, the left thalamus and right putamen were shown to be more activated only for 2Nwc. The role of these subcortical regions in word learning will be discussed in this section. Even though some of the nucleuses showed modulation by word imageabiltiy, they are part of a neural loop that is important for meaning acquisition. The loop, its functions and implications for word learning were already described on Chapter 3. In the next section, the differential activation of this loop due to word imageability will be discussed.

The basal ganglia have been shown to play an important role in human learning (Seger, 2006; Seger and Cincotta, 2006). These structures are part of several parallel loops involving distinct regions of prefrontal and, to a lesser extent, temporal and parietal cortex (Middleton and Strick, 2000). The prefrontal cortex and the striatum are often simultaneously active during learning (Seger and Cincotta, 2006). The thalamus has been shown to be involved in object recall and lexical retrieval (Kraut et al., 2002; Crosson et al., 1999; Crosson et al., 2003). Crosson et al. (Crosson et al., 2003) found activation of the left pre-SMA-left dorsal caudate-left ventral anterior thalamic loop in tasks involving retrieval of pre-existing lexical items (for more details about this loop, see Chapter 3, discussion).

In the present study, the bilateral basal ganglia and thalamus were found to be broadly activated. Activation in the ACC/pre-SMA was also observed. Basal ganglia and thalamus (except right caudate and left putamen) showed the greatest activity for Nwc (see figure 5.5), whereas the ACC showed the largest activation for Nw in general (see figure 5.5). All these regions showed greater activation for Nw compared to Rw, except for the left thalamus and right putamen where 2Nwc was the only condition associated with differences in activation. These structures appear to facilitate retrieval of lexical items from pre-existing stores during language generation and might induce and maintain a processing bias long enough to impact controlled cognitive processes, including working memory (Crosson et al., 2003). This pattern is consistent with the previous experiment, and suggests a role of this loop in meaning extraction from sentential context.

Finally, activity decreases occurred in the anterior and posterior cingulate cortices for the Nw condition relative to the Rw condition, independent of imageability. Such differential deactivation has been found previously in language tasks (e.g., Kuperberg et al., 2003) (see also Chapter 3).

5.4.3 Areas differentially activated depending on word imageability

Several regions have shown a differential involvement in acquiring the meaning of new-words and real-word processing, depending on word imageability. Some of these regions, such as the ventral anterior fusiform gyrus or middle temporal gyrus, are regions typically found to be activated in studies comparing concrete and abstract word processing. The activation found in the ventral anterior fusiform gyrus for concrete items in the present study is congruent with studies reporting activation of this region for concrete word processing when compared to abstract word processing (see Figure 5.1 right and Table on Appendix C).

Furthermore, other regions less directly linked to word imageability itself showed modulation by this variable: for example, the basal ganglia, thalamus, and ACC/pre-SMA. As mentioned in the previous section, the basal ganglia and thalamus displayed the greatest activation for concrete new-words (Nwc) (Figure 5.3 and 5.5). The ACC showed greater activation for abstract new-words (Nwa) during the first sentence compared to concrete new-words (Nwc), although during the second sentence no differences were found between conditions. In the conditions in which meaning was extracted, the bias maintained by the loop discussed in the previous section (left pre-SMA-left dorsal caudate-left ventral anterior thalamic loop) may be overridden, allowing further processing of the selected item by frontal structures. Furthermore, the basal ganglia also projects to extrastriate and inferotemporal visual cortex; thus, visual processing should recruit basal ganglia as well (Seger and Cincotta, 2006). This loop has been related to visual categorization and category learning tasks (Seger and Cincotta, 2005;Ashby and Maddox, 2005). Concrete words were associated with ventral temporal cortex activation. We propose that in addition to the executive corticostriatal loop connecting striatum and frontal areas, novel concrete words also activated the visual loop connecting inferior temporal cortex and the caudate.

Typically, it has been demonstrated that concrete words have superiority over abstract words, as the former typically exhibit a processing advantage over the latter (Paivio, 1971; Schwanenflugel and Shoben, 1983; Kroll and Merves, 1986). Effects of word concreteness have been shown in first (Gillette et al., 1999; Bloom, 2000) and second language acquisition (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000). One of the main results of the present experiment is that we observed greater activation during learning of concrete word meaning in a loop (left pre-SMA-left dorsal caudate-left ventral anterior thalamic loop) devoted to retrieval and lexical selection of items for further frontal processing. We propose that the greater activation for concrete novel words reflects faster and easier selection of a candidate meaning; thus, the loop may be overridden more quickly and easily for further processing by frontal regions during concrete new-word conditions. The greater activation for concrete items is congruent with behavioral studies showing easier, faster and better learning of concrete words compared to abstract words (van Hell and Candia-Mahn, 1997; de Groot and Keijzer, 2000; de Groot, 2006).

This study has shown clearly the implication of the ventral anterior fusiform gyrus on concrete novel word learning and, in general, concrete word processing. The fusiform gyrus is a region of the inferotemporal cortex associated with high-level visual processing (D'Esposito et al., 1997; Mellet et al., 1998; Chao et al., 1999; Ishai et al., 2000). Activation of this region has been reported in studies of word reading (Buchel et al., 1998; Cohen et al., 2002; Dehaene et al., 2002), object categorization (Martin et al., 1996; Gerlach et al., 1999; Gerlach et al., 2000; Martin et al., 2000; Gerlach et al., 2002), semantic association (Vandenberghe et al., 1996), object naming (Martin et al., 1996; Price et al., 1996; Damasio et al., 1996), encoding of pictures (Stern et al., 1996) and words (Wagner et al., 1998) and word concreteness (Fletcher et al., 1995; D'Esposito et al., 1997; Mellet et al., 1998; Fiebach and Friederici, 2004; Wallentin et al., 2005; Sabsevitz et al., 2005; Bedny and Thompson-Schill, 2006). The left ventral anterior fusiform gyrus has also been recruited in context verification tasks where participants had to link the meaning of a target word with the meaning of a preceding sentential context (Ryan et al., 2001; Hoenig and Scheef, 2005). Evidence for the implication of this part of the fusiform gyrus in the processing of concrete words also comes from neuropsychological studies of patients with lesions in the inferior temporal cortex. These patients tend to show a selective preservation of abstract compared to concrete concepts, known as the reversal of the concreteness effect (Warrington, 1975; Warrington, 1981; Warrington and Shallice, 1984; Breedin et al., 1994; Marshall et al., 1996). Breedin et al. (Breedin et al., 1994) showed that the patient they studied was more impaired in the perceptual aspects of word meaning than non-perceptual. The authors argued that the essential distinction between concrete and abstract words is the perceptual nature of concrete words. In contrast, abstract word meanings lack perceptual properties. Thus, they concluded that if perceptual properties confer to concrete words the classical concrete word superiority, then, the loss of these perceptual properties might result in the reversal of the concreteness effect (Breedin et al., 1994).

Our results corroborated the previous findings which have related the ventral anterior part of the fusiform gyrus to the processing of concrete words and extend them to include the learning of new concrete words. The condition associated with the greatest levels of activation within this region was new concrete words (Nwc). Martin et al. (Martin et al., 2000) proposed that retrieving information about object attributes should engage the same areas that mediate their perception and that the information about those attributes would be stored within the same regions active when that information was acquired. Concrete words fundamentally differ from abstract words in that they refer to objects that are present in the world, are tangible and have perceptual (somatosensorial) properties that define them. Concrete words are learned through the senses whereas abstract words are learned through the support of language and their relation to other concepts (mostly also abstract) (Wiemer-Hastings and Xu, 2005). The meanings of abstract words are more dependent on culture and context, while the meanings of concrete words tend to be more stable as the perceptual objects they refer to are physically available. There are several interesting studies investigating the nature of the difference between abstract and concrete words. Wiemer-Hastings and Xu (2005) studied those differences and determined that abstract concepts are relational concepts characterized by their links to external concepts rather than to intrinsic properties. As these relational concepts vary widely across situations, their properties are quite non-specific, linked more to personal experiences, interactions and situations, making them more subjective, non-specific, and therefore, less imaginable. Thus, abstract words should elicit more activation within regions involved in deeper semantic processing. In keeping with these ideas, our results showed middle temporal gyrus involvement in the processing of abstract real words (see Figure 5.5). However, this activation was not too strong and no differential activation was found for the learning of abstract novel words compared to concrete novel words. The activation in the middle temporal gyrus might be confounded with the task of meaning extraction, since both new-word conditions have high semantic processing demands.

In our study, we also found that a more posterior region of the fusiform gyrus, known as the visual word form area (VWFA), showed a stronger response to the concrete new-word condition (Nwc). The VWFA has been related to visual word recognition, and this region responds preferentially to letter strings than to other categories of visual stimuli (for a review see Cohen and Dehaene, 2004). There are several pieces of evidence for the VWFA. Activation of the fusiform gyrus has been reported during reading (Wagner et al., 1998; Brunswick et al., 1999; Fiez et al., 1999; Paulesu et al., 2000; Baumgaertner et al., 2002; Dehaene et al., 2002). The VWFA responds strongly to word and word-like (pseudowords) stimuli than consonant strings (Buchel et al., 1998; Dehaene et al., 2002; Cohen et al., 2002; Binder et al., 2006). This region shows word repetition priming effects independently of word letter case

(Dehaene et al., 2001). The VWFA responds with the same intensity whether words are presented in the left or in the right hemifield (Cohen et al., 2000). Furthermore, some studies have found activation in this area for words presented in a non-visual modality (Buchel et al., 1998). Adults with dyslexia fail to activate this region (McCandliss et al., 2003) and patients with pure alexia have lesions in this area (Cohen and Dehaene, 2004). Some authors have suggested the involvement of this region in lexical access from semantics (Foundas et al., 1998; Brunswick et al., 1999).

The present study showed greater activation in the VWFA for concrete new-words during the second sentence (see Figure 5.5). During the first sentence no differences between conditions were encountered; however, for the second sentence different patterns arose for each condition. While real-word conditions did not show an imageability effect, new-word conditions did. Real-word conditions showed decreases in activation in occipital and inferotemporal regions (see Figure 5.2 and 5.5), congruent with effects of repetition priming (Wiggs and Martin, 1998; Dehaene et al., 2001; Schacter et al., 2004; Ganel et al., 2006). New-word abstract conditions did not show any differences in activation between the first and second sentence (Figure 5.5). Interestingly, the new-word concrete condition showed an increase in activation for the second sentence (Figure 5.5). The lack of differences during the first sentence between real words and novel words is congruent with studies demonstrating that the VWFA is involved in prelexical representation of visual words (Dehaene et al., 2002; Cohen et al., 2002; Binder et al., 2006). Furthermore, no differences in activation in this region have been found as a function of semantic category (Dehaene et al., 2002) nor of word imageability (Buchel et al., 1998). Thus, we suggest that the greater activation for new-word concrete words during the second exposure might be due to lexical access from semantics, as novel concrete words might be activating a larger categorical network of synonyms than abstract words. This finding would support the idea that a candidate meaning for a novel concrete word is selected more quickly and easily than for a novel abstract word.

5.5 Conclusions

Acquiring the meaning of a new-word can be achieved by extracting it from a linguistic context. The aim of the present investigation was to simulate word learning of new-words associated with concrete and abstract concepts in a variant of the human simulation paradigm that provided linguistic context information. Young adult native speakers were required to silently read two related sentences in order to derive the meaning of a novel word that appeared in the terminal position of each of these sentences. Using functional magnetic resonance imaging we demonstrated that the acquisition of the meaning associated with concrete and abstract new-words was qualitatively different and recruited the same brain regions devoted to the processing of the real concrete and abstract words. In particular, learning the meaning of new concrete words selectively boosted the activation of the ventral anterior fusiform gyrus. This finding is in agreement with neuropsychological studies which have demonstrated that lesions to the inferior ventral temporal cortex cause impairments in concrete word processing. Thus, the finding that different brain regions mediate concrete and abstract word processing provides evidence for the existence of qualitative differences in learning and processing concrete and abstract words.

Chapter 6

General Discussion

In the previous chapters, seven experiments employing behavioral, electrophysiological and hemodynamic techniques have explored the nature of lexical acquisition of various types of words. Two ERPs experiments investigated the time course of new word meaning acquisition when congruent and incongruent semantic contexts were provided. Experiment 1 revealed a rapid development of a brain signature related to lexical and semantic processing during contextual word learning. After three exposures to contextual semantic information, brain potentials for novel words in meaningful contexts were indistinguishable from those for real words, although the acquisition effect was not observed for novel words, for which sentence contexts allowed no meaning derivation. Moreover, experiment 3 showed that when the novel words were paired with their meanings, as compared to being paired with unrelated ones, a typical semantic priming effect occurred, although the process was slower than for real words. Experiment 2 demonstrated that the differences observed between novel words in meaningful and non-meaningful contexts were not due to participants giving up the process of meaning extraction for non-meaningful contexts. Importantly, participants successfully discerned what concept the novel word was referring to, using only the semantic context provided by three sentences. Experiment 4 aimed to localize the underlying neural networks of new word learning and meaning acquisition. Overall, a distributed brain network comprising the left anterior inferior frontal gyrus (BA 45), middle temporal gyrus (BA 21), parahippocampal gyrus and several subcortical structures (the thalamus and the striatum) was shown to be involved in the retrieval, selection and encoding of new words meaning. The experiments described in Chapters 4 and 5 provided further knowledge of new word learning by assessing word concreteness effects in lexical acquisition. Experiments 4 and 5 suggested that semantic context is sufficient to successfully learn the meaning of an abstract new word, although this process is slower than the acquisition of new concrete words. Finally, experiment 7 revealed a common neural network for novel abstract word and concrete word learning, similar to that found in experiment 4. Notwithstanding the latter, one region (the fusiform gyrus) was found engaged solely in the learning and processing of concrete word meaning.

The experiments reported in this dissertation show that the combined investigation of electrophysiological and hemodynamic data is important for the understanding of the neurocognitive bases of new word learning and meaning acquisition. The results from the ERPs experiments suggest that the phenomenon of “fast mapping,” as observed in children, also occurs when adults encounter a novel word for the first time. Thus, the referred results provide evidence on how, after only a few exposures to a novel word and its context, information about that word’s phonemic, visual, semantic and syntactic characteristics is rapidly acquired and probably temporarily stored until further experience with the word redefines, updates and consolidates its representation. This rapid word learning ability is reflected in the change of the brain potential signature for novel words from a meaningful condition toward that of the real words over the sentence triplets. Moreover, the priming effect observed when novel words were paired with their meaning suggests that participants not only grasped some aspect of the meaning but that they also linked it to the new word form. As discussed earlier, whether the amplitude reduction of the N400 in experiment 3 is due to the activation of the concept associated to the novel word or to the activation of the L1 equivalent (the hidden word) cannot be conclusively explained, however it is more likely that in the first stages of word learning the novel word is more strongly linked to its L1 translation than to the concept it denotes (Kroll and Steward, 1994). Nevertheless, both real and novel words showed a priming effect, while the effect for novel words was both delayed and associated with a more frontal distribution. One of the explanations introduced earlier for the topographic differences between real and novel words is that novel words might be weakly associated to preexisting information and, therefore, a cognitive control mechanism might be required to guide semantic knowledge retrieval and selection. The fMRI results from experiment 4 and 7 confirm this hypothesis. New word learning has been shown to greatly engage inferior frontal regions, which reflects an increase in cognitive control for those conditions requiring more elaborate semantic processing. Although in this respect the results from the ERP and fMRI studies may be explained, there are also differences between ERP and fMRI effects that are less easy to explain. First, due to restrictions on the temporal resolution of fMRI, the actual process of rapid word learning and changes associated with it might be more difficult to detect using this technique. Second, while the comparison between novel words that were meaningful and non-meaningful elicited large differences in ERP, the same comparisons led to small and weak differences in the fMRI data.

There are three possible explanations for the differences between the findings of the ERP experiment and the fMRI experiment. First, it is possible that, although the changes in the N400 time-window were clearly identifiable in the ERPs, they were not strong enough to show large differences between new-word conditions in the fMRI experiment. Second, the ERP design allowed a sentence by sentence comparison while the fMRI design was a block design, thus reflecting changes on activation for the whole triplet. This lower level of sensitivity in the fMRI design could explain the differences observed between the two experiments. Third, it might also be the case that both conditions involved the same meaning processing network with little differential regions, thus, the differences in those common regions might be confounded, as both conditions require high semantic processing demands. On the other hand, differences between novel word conditions indeed arose in the fMRI study; the previous explanations, then, may be viewed as factors influencing the intensity of the difference, and due to differences in technique, design, or both.

The neural network found to be engaged in new word learning was not restricted to classical perisylvian areas; rather it included subcortical and parahippocampal regions, as well. First, it is worth mentioning that parahippocampal gyrus involvement in meaning acquisition was only observed in the first fMRI experiment. The lack of parahippocampal gyrus activation in the second fMRI experiment is probably due to design differences between both studies, as the first is a block design and the second an event-related design. The findings from the fMRI experiments suggest the involvement of a distributed neural network for meaning acquisition. This network includes prefrontal and temporal regions typically found activated in language tasks; however, other regions were shown to be involved in the process of word learning. These regions, including the thalamus and striatum, anterior cingulate gyrus, parahippocampal gyrus and fusiform gyrus, are not part of the classically considered “language areas”. For instance, the left ventral anterior fusiform gyrus, a region associated with high level visual processing (D'Esposito et al., 1997; Mellet et al., 1998; Chao et al., 1999; Ishai et al., 2000), was found to be part of the network for concrete word learning. Likewise, the involvement of the parahippocampal gyrus in word learning suggests that the storage and retrieval of linguistic information is not significantly different from the storage and retrieval of other knowledge. Thus, the involvement in new word meaning acquisition of regions not specifically related to language functions suggests that the acquisition and processing of linguistic knowledge is sustained by regions functionally dedicated to language processing and by regions dedicated to other functions, such as visual processing, memory, learning and cognitive control. Thus, these results may suggest that language acquisition and processing do not rely on a special, domain-specific component in the human mind, such as “the language module”. Although at the present there is not enough empirical evidence for the existence, or for the absence, of a “language module”, it seems more plausible to lean toward a theory of language acquisition and processing that operates with general principles rather than a separate, domain-specific cognitive ability.

The studies reported in this dissertation further investigated word learning by studying the learning of new words varying in imageability. The review of the literature showed evidence about the importance of word concreteness for meaning acquisition. Children’s early productive vocabularies are dominated by nouns, and nouns are acquired earlier than verbs (Gentner, 1982). Further research with nouns and verbs suggests that, compared to adults, children’s early word meanings are relatively concrete (Gentner, 2003). Several studies have shown that children learn verbs as easily as nouns if the actions they denote are relatively concrete (Gillette et al., 1999; Gentner and Boroditsky, 2001; Snedeker and Gleitman, 2004). Thus, the imageability of words is a crucial factor for word learning. Concrete words have a more straightforward and transparent relation to the real word than abstract words. Thus, the concepts they denote are easily individuated because they refer to natural bounded referents, and in order to learn a particular word a child has to attach the noun to a referent already isolated. Verbs and more abstract words have a less transparent relation to the perceptual world, thus a child has to rely more on linguistic information in order to determine their referents and relations with the world. For this reason, their meanings vary more cross-linguistically. The results from the experiments discussed above show that adults follow the same pattern as children, that is, concrete words are easier and more quickly learned than abstract words. Importantly, the fMRI results showed differential involvement of the fusiform gyrus depending on a word's imageability. Despite there having been many empirical investigations into the cognitive and neural architecture of semantic representations, we know little about the nature of these representations. Specifically, it remains unsolved whether semantic information is organized as a unitary system that employs a verbal amodal representational code (Caramazza et al., 1990), whether concepts are represented perceptually (Barsalou, 1991; Barsalou et al., 2003) or whether different types of semantic information are stored as separate perceptual and verbal codes (Warrington and McCarthy, 1987; Shallice, 1988; Paivio, 1991). The finding of the fusiform gyrus' involvement in concrete word meaning acquisition and processing compared to abstract makes a contribution to a semantic conceptual system that utilizes a perceptually based representational code for concrete words, and probably employs a verbal format for abstract words.

6.1. Critics

The work presented in this dissertation has not been exempt from criticism. There are three aspects of the study that have been criticized. Here we will reply to those criticisms by providing arguments against them. First, some have raised the question of whether participants were actually learning the new words or just filling up the sentences with the corresponding L1 words and ignoring the new word forms. The answer to this criticism is found in the second ERP experiment, where a priming effect was observed when newly-learned words were paired with their meanings as compared to when they were paired with unrelated words. Second, the ecological validity of the studies has been criticized for not accurately reflecting second language acquisition due to the fact that the novel words were embedded in sentences of the participants' native languages. However, the word learning paradigm presented in this dissertation does closely resemble second language acquisition, although with the assumption that the second language learner has already some knowledge and experience with the second language. For instance, imagine a learner has been studying English for several years and one day while reading a novel he/she encounters the following sentence: "The lawyer laid the two sheets of paper alongside and sedulously compared their contents."

Even if the learner does not know what *sedulously* means, the context of the sentence provides enough information that he/she could ascertain without problem that *sedulously* is an adverb that may refer to a meticulous, diligent, or persistent way of doing something. Thus, in this context, semantic information guides meaning acquisition and new word learning. Furthermore, children might approach the learning of their first language in the same way once they have already learned some words. The studies assessing infants' word learning reviewed in Chapter 1 use a word learning paradigm first introduced by Carey and colleagues in which children are exposed to novel items in the context of playing a game. Thus, children are introduced to new words and use the semantic, social and situational contexts to infer their meanings. This is a paradigm that is thought to closely simulate natural vocabulary acquisition. The word learning paradigm employed here resembles those used when a second language learner encounters an unknown word and when an infant learns words. The last criticism is not specific to the paradigm itself, but rather it concerns a topic that has been a matter of debate for years. Some have criticized that the studies presented here cannot simulate first language word learning because children have to learn not only the word but also the concept, while adults already have those concepts. This brings us to an old question: Do our thoughts exist independently from natural language? Or do we think because we have language? A famous hypothesis, outlined by Benjamin Whorf (Whorf, 1956), asserts that the categories and relations that we use to understand the world come from our particular language, so that speakers of different languages conceptualize the world in different ways. From this point of view, learning a language means learning to think in that language. It also suggests that speakers of a particular language think differently than speakers of other languages, and that people who have no language, whether due to deprivation or injury, will lack the ability of rich and abstract cognition. This hypothesis has been rejected by many cognitive scientists (for example, see Pinker, 1994). Some evidence that our thought may exist independently from language comes from studies showing that infants may be able to think before they can talk (Hespos and Spelke, 2004). These studies suggest that babies know about the objects, actions, and individuals that make up their world but still have to learn the names of these things. People also do a lot of thinking visually and can make up new words and expressions for things and distinctions that they perceive, even though some of these things are not expressible using current language. For example, most people have had the experience of having a particular insight and having then been unable (at least momentarily) to find the words to express it. So, despite the fact that first language learners and second language learners differ in many aspects, the process of word learning itself may not significantly differ between the two groups.

6.2. Future directions

Future research in this topic must address how further exposures and training in newly-learned words may shape these new learned words relationship with the L1 and how new word labels are consolidated into the mental lexicon. Another interesting possibility would be to use different kinds of information for the assignment of words to meaning, for example providing visual contextual information or syntactic frames where new words are embedded.

Furthermore, the paradigm used in this study seems suitable for studying the learning of words of different lexical classes, such as nouns vs. verbs, or open- vs. closed-class words. In fact, recently we have collected some behavioral and ERP-fMRI data on the acquisition of new-word nouns and new-word verbs. Although not included in the present dissertation, an ERP experiment contrasting concrete and abstract words acquisition was performed for which time-domain and time-frequency analysis will be carried out. From the neuropsychological perspective and considering the implication of basal ganglia in word-learning in the fMRI studies heretofore presented, we have applied the self-paced learning paradigm to the study of patients with basal ganglia lesions (microinfarcts), and in the future it will also be applied to patients suffering from Huntington's disease.

References

Akhtar N, Carpenter M, Tomasello M (1996) The role of discourse novelty in early word learning. Child Development 67:635-645.

Allport DA (1985) Distributed memory, modular subsystems and dysphasia. In: Current perspectives in dysphasia (S.K.Newman, R.Epstein, eds), Edinburgh: Churchill Livingstone.

Amunts K, Schleicher A, Burgel U, Mohlberg H, Uylings HB, Zilles K (1999) Broca's region revisited: cytoarchitecture and intersubject variability. J Comp Neurol 412:319-341.

Anderson JR (1983) The architecture of cognition. Cambrige, MA: Harvard Univeristy Press.

Ardal S, Donald MW, Meuter R, Muldrew S, Luce M (1990) Brain responses to semantic incongruity in bilinguals. Brain Lang 39:187-205.

Ashburner J, Friston KJ (1999) Nonlinear spatial normalization using basis functions. Hum Brain Mapp 7:254-266.

Ashby FG, Maddox WT (2005) Human category learning. Annu Rev Psychol 56:149-178.

Augustinus (398) Confessiones.

Baddeley A (1975) Word length and the structure of short-term memory. Journal of verbal learning and verbal behaviour 14:575-589.

Baddeley A (2000) The episodic buffer: a new component of working memory? Trends Cogn Sci 4:417-423.

Baddeley A (2003) Working memory and language: an overview. J Commun Disord 36:189-208.

Baddeley A, Gathercole S, Papagno C (1998) The phonological loop as a language learning device. Psychol Rev 105:158-173.

Baddeley A, Hitch GJ (1974) Working memory. In: Recent advances in learning and motivation (G.A.Bower, ed), New York: Academic Press.

Baddeley A, Papagno C, Vallar G (1988) When long-term learning depends on short-term storage. Journal of Memory and Language 27:586-595.

Baddeley A, Wilson BA (2002) Prose recall and amnesia: implications for the structure of working memory. Neuropsychologia 40:1737-1743.

Badre D, Wagner AD (2002) Semantic Retrieval, Mnemonic Control and Prefrontal Cortex. Behavioral and Cognitive Neuroscience Reviews 1:206-218.

Baldwin DA (1989) Priorities in children's expectations about object label reference: form over color. Child Dev 60:1291-1306.

Baldwin DA, Markman EM, Bill B, Desjardins RN, Irwin JM, Tidball G (1996) Infants' reliance on a social criterion for establishing word-object relations. Child Dev 67:3135-3153.

Barsalou LW (1982) Context-independent and context-dependent information in concepts. Mem Cognit 10:82-93.

Barsalou LW (1991) Flexibility, structure, and linguistic vagary in concepts: manifestations of a compositional system of perceptual symbols. In: Theories of memories (A.F.Collins, S.E.Gathercole, M.A.Conway, P.E.Morries, eds), New York: Erlbaum.

Barsalou LW, Kyle SW, Barbey AK, Wilson CD (2003) Grounding conceptual knowledge in modality-specific systems. Trends Cogn Sci 7:84-91.

Barsalou LW, Wiemer-Hastings K (2005) Situating abstract concepts. In: Grounding cognition: The role of perception and action in memory, language, and thought (Pecher D, Zqaan R, eds), pp 129-163. New York: Cambridge University Press.

Bartha L, Brenneis C, Schocke M, Trinka E, Koylu B, Trieb T, Kremser C, Jaschke W, Bauer G, Poewe W, Benke T (2003) Medial temporal lobe activation during semantic language processing: fMRI findings in healthy left- and right-handers. Brain Res Cogn Brain Res 17:339-346.

Baumgaertner A, Weiller C, Buchel C (2002) Event-related fMRI reveals cortical sites involved in contextual sentence integration. Neuroimage 16:736-745.

Bedny M, Thompson-Schill SL (2006) Neuroanatomically separable effects of imageability and grammatical class during single-word comprehension. Brain Lang 98:127-139.

Bentin S, McCarthy G, Wood CC (1985) Event-related potentials, lexical decision and semantic priming. Electroencephalogr Clin Neurophysiol 60:343-355.

Bialystok E, Hakuta K (1994) In other words: The science and psychology of second language acquisition. New York: Basic Books.

Binder JR, Medler DA, Westbury CF, Liebenthal E, Buchanan L (2006) Tuning of the human left fusiform gyrus to sublexical orthographic structure. Neuroimage 33:739-748.

Birdsong D (2003) Authenticité de prononciation en français L2 chez des apprenants tardifs anglophones: Analyses segmentales et globales. Acquisition et Interaction en Langue Étrangère 18:17-36.

Birdsong D (1992) Ultimate attainment in second language acquisition. Language 68:706-755.

Birdsong D (2005) Interpreting age effects in second language acquisition. In: Handbook of bilingualism: Psycholinguistic approaches (J.F.Kroll, A.M.B.de Groot, eds), New York: Oxford University Press.

Birdsong D, Molis M (2001) On the Evidence for Maturational Constraints in Second Language Acquisition. Journal of Memory and Language 44:235-249.

Bloom P (1997) Language acquisition in its developmental context. In: The handbook of child psychology: Vol. 2, Cognition, Perception, and Language (D.Kuhn, R.Siegel, eds), New York: Wiley.

Bloom P (2002) Mindreading, communication and the learning of names for things. Mind and Language 17:37-54.

Bloom P (2000) How children learn the meanings of words. Cambridge, MA: MIT Press.

Blumenfeld HK, Booth JR, Burman DD (2006) Differential prefrontal-temporal neural correlates of semantic processing in children. Brain Lang 99:226-235.

Bokde AL, Tagamets MA, Friedman RB, Horwitz B (2001) Functional interactions of the inferior frontal cortex during the processing of words and word-like stimuli. Neuron 30:609-617.

Bongaerts T (1999) Ultimate attainment in L2 pronunciation: The case of very advanced late learners. In: Second language acquisition and the critical period hypothesis (D.Birdsong, ed), Mahwah, NJ: Erlbaum.

Bongaerts T, Mennen S, van der Slik S (2000) Authenticity of pronunciation in naturalistic second language acquisition: The case of very advanced late learners of Dutch as a second language. Studia linguistica 54:298-308.

Bongaerts T, van Summeren C, Planken B, Schils E (1997) Age and ultimate attainment in the pronunciation of a foreign language. Studies in Second Language Acquisition 19:447-465.

Bookheimer S (2002) Functional MRI of language: new approaches to understanding the cortical organization of semantic processing. Annu Rev Neurosci 25:151-188.

Booth JR, Burman DD, Meyer JR, Gitelman DR, Parrish TB, Mesulam MM (2002) Modality independence of word comprehension. Hum Brain Mapp 16:251-261.

Breedin SD, Saffran EM, Coslett HB (1994) Reversal of the concreteness effect in a patient with semantic dementia. Cognitive Neuropsychology 11:617-660.

Breitenstein C, Jansen A, Deppe M, Foerster AF, Sommer J, Wolbers T, Knecht S (2005) Hippocampus activity differentiates good from poor learners of a novel lexicon. Neuroimage 25:958-968.

Breitenstein C, Knecht S (2002) Development and validation of a language learning model for behavioral and functional-imaging studies. Journal of Neuroscience Methods 114:173-179.

Brown C, Hagoort P (1993) The processing nature of the N400: Evidences from masked priming. Journal of Cognitive Neuroscience 5:34-44.

Brunswick N, McCrory E, Price CJ, Frith CD, Frith U (1999) Explicit and implicit processing of words and pseudowords by adult developmental dyslexics: A search for Wernicke's Wortschatz? Brain 122 (Pt 10):1901-1917.

Buchel C, Price C, Friston K (1998) A multimodal language region in the ventral visual pathway. Nature 394:274-277.

Buckner RL, Raichle ME, Petersen SE (1995) Dissociation of human prefrontal cortical areas across different speech production tasks and gender groups. J Neurophysiol 74:2163-2173.

Cain K, Oakhill JV, Elbro C (2003) The ability to learn new word meanings from context by school-age-children with and without language comprehension difficulties. Journal of Child Language 30:681-694.

Cameron-Faulkner T, Lieven E, Tomasello M (2003) A construction based analysis of child directed speech. Cognitive Science 27:843-873.

Caramazza A, Hillis AE, Rapp BC, Romani C (1990) the multiple semantics hypothesis: multiple confusions? Cognitive Neuropsychology 7:161-189.

Carey S (1978) The child as word learner. In: Linguistic theory and psychological reality (M.Halle, J.Bresnan, G.Miller, eds), Cambrige, MA: MIT Press.

Carey S, Barlett E (1978) Acquiring a single new word. Papers and Reports on Child Language Development 15:17-29.

Carver RP (1990) Reading rate: A review of research and theory. San Diego CA: Academic Press.

Carver RP, Leibert R (1995) The effect of reading library books of different levels of difficulty upon gain in reading ability. Reading Research Quarterly 30:26-47.

Chaffin R (1997) Associations to unfamiliar words: learning the meanings of new words. Mem Cognit 25:203-226.

Chaffin R, Morris RK, Seely RE (2001) Learning new word meanings from context: a study of eye movements. J Exp Psychol Learn Mem Cogn 27:225-235.

Chao LL, Haxby JV, Martin A (1999) Attribute-based neural substrates in temporal cortex for perceiving and knowing about objects. Nat Neurosci 2:913-919.

Chee MW, Tan EW, Thiel T (1999) Mandarin and English single word processing studied with functional magnetic resonance imaging. J Neurosci 19:3050-3056.

Choi S, Gopnik A (1995) Early acquisition of verbs in Korean: a cross-linguistic study. Journal of Child Language 22:497-529.

Church KW (1987) Phonological parsing and lexical retrieval. Cognition 25:53-69.

Clark EV (1983) Meanings and concepts. In: Handbook of child psychology, vol.3: Conginitve development (J.Flavell, E.Markman, eds), New York: John Wiley.

Clark EV (1993) The lexicon in acquisition. New York: Cambridge University Press.

Clark EV, Svaib TA (1997) Speaker perspective and reference in young children. First Language 17:54-73.

Cocosco CA, Kollokian V, Kwan RKS, Evans AC (1997) Online interface to a 3-D MRI simulated brain database. Neuroimage 5:S425.

Cohen L, Dehaene S (2004) Specialization within the ventral stream: the case for the visual word form area. Neuroimage 22:466-476.

Cohen L, Dehaene S, Naccache L, Lehericy S, haene-Lambertz G, Henaff MA, Michel F (2000) The visual word form area: spatial and temporal characterization of an initial stage of reading in normal subjects and posterior split-brain patients. Brain 123 (Pt 2):291-307.

Cohen L, Lehericy S, Chochon F, Lemer C, Rivaud S, Dehaene S (2002) Language-specific tuning of visual cortex? Functional properties of the Visual Word Form Area. Brain 125:1054-1069.

Colle HA, Welsh A (1976) Acoustic masking in primary memory. Journal of verbal learning and verbal behaviour 15:17-32.

Collins AM, Loftus EF (1975) Spreading Activation Theory of Semantic Processing. Psychological Review 82:407-428.

Coltheart M, Patterson K, Marshall J (1980) Deep dyslexia. London: Routledge and Kegan Paul.

Conrad R, Hull AJ (1964) Information, acoustic confusion and memory span. Br J Psychol 55:429-432.

Coppieters R (1987) Competence differences between natives and near-native speakers. Language 65:544-573.

Cornelissen K, Laine M, Renvall K, Saarinen T, Martin N, Salmelin R (2004) Learning new names for new objects: cortical effects as measured by magnetoencephalography. Brain Lang 89:617-622.

Cornelissen K, Laine M, Tarkiainen A, Jarvensivu T, Martin N, Salmelin R (2003) Adult brain plasticity elicited by anomia treatment. J Cogn Neurosci 15:444-461.

Crosson B, Benefield H, Cato MA, Sadek JR, Moore AB, Wierenga CE, Gopinath K, Soltysik D, Bauer RM, Auerbach EJ, Gokcay D, Leonard CM, Briggs RW (2003) Left and right basal ganglia and frontal activity during language generation: Contributions to lexical, semantic, and phonological processes. Journal of the International Neuropsychological Society 9:1061-1077.

Crosson B, Rao SM, Woodley SJ, Rosen AC, Bobholz JA, Mayer A, Cunningham JM, Hammeke TA, Fuller SA, Binder JR, Cox RW, Stein EA (1999) Mapping of semantic, phonological, and orthographic verbal working memory in normal adults with functional magnetic resonance imaging. Neuropsychology 13:171-187.

Crosson B, Zawacki T, Brinson G, Lu L, Sadek JR (1997) Models of subcortical functions in language: Current status. Journal of Neurolinguistics 10:277-300.

Crutch SJ, Warrington EK (2005) Abstract and concrete concepts have structurally different representational frameworks. Brain 128:615-627.

Cunillera T, Toro JM, Sebastian-Galles N, Rodriguez-Fornells A (2006) The effects of stress and statistical cues on continuous speech segmentation: an event-related brain potential study. Brain Res 1123:168-178.

Curtis ME (1987) Vocabulary testing and vocabulary instruction. Hillsdale, NJ: Lawrence Erlbaum Associates.

Curtiss S (1977) Genie: a Psycholinguistic Study of a Modern-Day 'Wild Child'. New York, NY: Academic Press.

D'Esposito M, Detre JA, Aguirre GK, Stallcup M, Alsop DC, Tippet LJ, Farah MJ (1997) A functional MRI study of mental image generation. Neuropsychologia 35:725-730.

Damasio H, Grabowski TJ, Tranel D, Hichwa RD, Damasio AR (1996) A neural basis for lexical retrieval. Nature 380:499-505.

Dapretto M, Bookheimer SY (1999) Form and content: dissociating syntax and semantics in sentence comprehension. Neuron 24:427-432.

de Groot AMB (2006) Effects of stimulus characteristics and background music on foreign-language vocabulary learning and forgetting. Language Learning 56:463-506.

de Groot AMB (1989) Representational aspects of word imageability and word frequency as assessed through word association. Journal of Experimental Psychology: Learning, Memory and Cognition 15:824-845.

de Groot AMB (1992) Bilingual lexical representation: A closer look at conceptual representations. In: Orthography, phonology, morphology, and meaning (R.Frost & L.Katz, ed), pp 389-412. Amsterdam: Elsevier Science.

de Groot AMB, Keijzer R (2000) What is Hard to Learn Is Easy to Forget: The Roles of Word Concreteness, Cognate Status, and Word Frequency in Foreign-Language Vocabulary Learning and Forgetting. Language Learning 50:1-56.

de Groot AMB, Poot R (1997) Word translation at three levels of proficiency in a second language: The ubiquitous involvement of conceptual memory. Language Learning 47:215-264.

Deak GO, Maratsos M (1998) On having complex representations of things: Preschoolers use multiple words for objects and people. Developmental Psychology 34:224-240.

Dehaene S, Dupoux E, Mehler J, Cohen L, Paulesu E, Perani D, Van de Moortele PF, Lehericy S, Le BD (1997) Anatomical variability in the cortical representation of first and second language. Neuroreport 8:3809-3815.

Dehaene S, Le CG, Poline JB, Le BD, Cohen L (2002) The visual word form area: a prelexical representation of visual words in the fusiform gyrus. Neuroreport 13:321-325.

Dehaene S, Naccache L, Cohen L, Bihan DL, Mangin JF, Poline JB, Riviere D (2001) Cerebral mechanisms of word masking and unconscious repetition priming. Nat Neurosci 4:752-758.

Demb JB, Desmond JE, Wagner AD, Vaidya CJ, Glover GH, Gabrieli JD (1995) Semantic encoding and retrieval in the left inferior prefrontal cortex: a functional MRI study of task difficulty and process specificity. J Neurosci 15:5870-5878.

Desmond JE, Gabrieli JD, Glover GH (1998) Dissociation of frontal and cerebellar activity in a cognitive task: evidence for a distinction between selection and search. Neuroimage 7:368-376.

Diesendruck G, Markson L, Akhtar N, Reudor A (2004) Two-year-olds' sensitivity to speakers' intent: an alternative account of Samuelson and Smith. Dev Sci 7:33-41.

Dollaghan C (1985) Child meets word: "fast mapping" in preschool children. J Speech Hear Res 28:449-454.

Dong Y, Gui S, MacWhinney B (2005) Shared and separate meanings in the bilingual mental lexicon. Bilingualism: Language and Cognition 8:221-238.

Dufour R, Kroll JF (1995) Matching words to concepts in two languages: a test of the concept mediation model of bilingual representation. Mem Cognit 23:166-180.

Durkin D (1979) What classroom observations reveal about reading comprehension. Reading Research Quarterly 14:518-544.

Duyck W, Szmalec A, Kemps E, Vandierendonck A (2003) Verbal working memory is involved in associative word learning unless visual codes are available. Journal of Memory and Language 48:527-541.

Elman JL (1993) Learning and development in neural networks: the importance of starting small. Cognition 48:71-99.

Fernald A, Hurtado N (2006) Names in frames: infants interpret words in sentence frames faster than words in isolation. Dev Sci 9:F33-F40.

Ferstl EC, von Cramon DY (2001) The role of coherence and cohesion in text comprehension: an event-related fMRI study. Brain Res Cogn Brain Res 11:325-340.

Fiebach CJ, Friederici AD (2004) Processing concrete words: fMRI evidence against a specific right-hemisphere involvement. Neuropsychologia 42:62-70.

Fiez JA (1997) Phonology, semantics, and the role of the left inferior prefrontal cortex. Hum Brain Mapp 5:79-83.

Fiez JA, Balota DA, Raichle ME, Petersen SE (1999) Effects of lexicality, frequency, and spelling-to-sound consistency on the functional anatomy of reading. Neuron 24:205-218.

Fiez JA, Raichle ME, Balota DA, Tallal P, Petersen SE (1996) PET activation of posterior temporal regions during auditory word presentation and verb generation. Cereb Cortex 6:1-10.

Fletcher PC, Frith CD, Baker SC, Shallice T, Frackowiak RS, Dolan RJ (1995) The mind's eye--precuneus activation in memory-related imagery. Neuroimage 2:195-200.

Fliessbach K, Weis S, Klaver P, Elger CE, Weber B (2006) The effect of word concreteness on recognition memory. Neuroimage 32:1413-1421.

Foundas AL, Daniels SK, Vasterling JJ (1998) Anomia: case studies with lesion localization. Neurocase 4:35-43.

Friederici AD, Opitz B, von Cramon DY (2000) Segregating semantic and syntactic aspects of processing in the human brain: an fMRI investigation of different word types. Cereb Cortex 10:698-705.

Friederici AD, Ruschemeyer SA, Hahne A, Fiebach CJ (2003) The role of left inferior frontal and superior temporal cortex in sentence comprehension: localizing syntactic and semantic processes. Cereb Cortex 13:170-177.

Friederici AD, Steinhauer K, Pfeifer E (2002) Brain signatures of artificial language processing: evidence challenging the critical period hypothesis. Proc Natl Acad Sci U S A 99:529-534.

Friederici AD, Wessels JM (1993) Phonotactic knowledge of word boundaries and its use in infant speech perception. Percept Psychophys 54:287-295.

Friston KJ, Holmes AP, Worsley KJ, Poline JB, Frith CD, Frackowiak RS (1995) Statistical Parametric Maps in Functional Imaging: A General Linear Approach. Hum Brain Mapp189-210.

Friston KJ, Josephs O, Rees G, Turner R (1998) Nonlinear event-related responses in fMRI. Magn Reson Med 39:41-52.

Friston KJ, Williams S, Howard R, Frackowiak RS, Turner R (1996) Movement-related effects in fMRI time-series. Magn Reson Med 35:346-355.

Gabrieli JD, Cohen NJ, Corkin S (1988) The impaired learning of semantic knowledge following bilateral medial temporal-lobe resection. Brain Cogn 7:157-177.

Gabrieli JD, Poldrack RA, Desmond JE (1998) The role of left prefrontal cortex in language and memory. Proc Natl Acad Sci U S A 95:906-913.

Galbraith RC, Underwood BJ (1973) Perceived frequency of concrete and abstract words. Mem Cognit 1:56-60.

Ganel T, Gonzalez CL, Valyear KF, Culham JC, Goodale MA, Kohler S (2006) The relationship between fMRI adaptation and repetition priming. Neuroimage 32:1432-1440.

Gaskell MG, Dumay N (2003) Lexical competition and the acquisition of novel words. Cognition 89:105-132.

Gathercole S, Baddeley A (1990a) Phonological memory deficits in language disordered children: Is there a causal connection? Journal of Memory and Language 29:336-360.

Gathercole SE, Baddeley A (1993) Working memory and language. Hillsdale, NJ: Erlbaum.

Gathercole SE, Baddeley A (1990b) The role of phonological memory in vocabulary acquisition: A study of young children learning new names. Br J Psychol 81:439-454.

Gathercole SE, Baddeley A (1989) Evaluation of the role of phonological STM in the development of vocabulary in children: A longitudinal study. Journal of Memory and Language 28:200-213.

Gathercole SE, Hitch GJ, Service E, Martin AJ (1997) Phonological short-term memory and new word learning in children. Dev Psychol 33:966-979.

Gathercole SE, Willis C, Emslie H, Baddeley A (1992) Phonological memory and vocabulary development during the early school years: A longitudinal study. Developmental Psychology 28:887-898.

Gelman SA, Markman EM (1986) Categories and induction in young children. Cognition 23:183-209.

Gelman SA, Markman EM (1987) Young children's inductions from natural kinds: the role of categories and appearances. Child Dev 58:1532-1541.

Gentner D (2003) Why are we so smart? In: Language in mind: Advances in the study of language and thought (D.Gentner, S.Goldin-Meadow, eds), Cambridge, MA: MIT Press.

Gentner D (1981) Some interesting differences between verbs and nouns. Cognition and Brain Theory 4:161-178.

Gentner D (1982) Why nouns are learned before verbs: Linguistical relativity versus natural partitioning. In: Language development: Vol. 2. Language, thought, and culture (S.A.Kuczaj II, ed), Hillsdale, NJ: Lawrence Erlbaum.

Gentner D, Boroditsky L (2001) Individualtion, relativity and early word learning. In: Language, culture, and cognition Vol. 3: Language acquisition and conceptual development (M.Bowerman, S.C.Levinson, eds), New York, NY: Cambridge University Press.

Gerlach C, Aaside CT, Humphreys GW, Gade A, Paulson OB, Law I (2002) Brain activity related to integrative processes in visual object recognition: bottom-up integration and the modulatory influence of stored knowledge. Neuropsychologia 40:1254-1267.

Gerlach C, Law I, Gade A, Paulson OB (2000) Categorization and category effects in normal object recognition: a PET study. Neuropsychologia 38:1693-1703.

Gerlach C, Law I, Gade A, Paulson OB (1999) Perceptual differentiation and category effects in normal object recognition: a PET study. Brain 122 (Pt 11):2159-2170.

Ghika-Schmid F, Bogousslavsky J (2000) The acute behavioral syndrome of anterior thalamic infarction: a prospective study of 12 cases. Ann Neurol 48:220-227.

Giesbrecht B, Camblin CC, Swaab TY (2004) Separable effects of semantic priming and imageability on word processing in human cortex. Cereb Cortex 14:521-529.

Gillette J, Gleitman H, Gleitman L, Lederer A (1999) Human simulations of vocabulary learning. Cognition 73:135-176.

Gleitman L, Cassidy K, Papafragou A, Nappa R, Trueswell JT (2005) Hard words. Journal of Language Learning and Development 1:23-64.

Gleitman L (1990) The Structural Sources of Verb Meanings. Language Acquisition 1:3-55.

Gold BT, Balota DA, Jones SJ, Powell DK, Smith CD, Andersen AH (2006) Dissociation of automatic and strategic lexical-semantics: functional magnetic resonance imaging evidence for differing roles of multiple frontotemporal regions. J Neurosci 26:6523-6532.

Gold BT, Balota DA, Kirchhoff BA, Buckner RL (2005) Common and dissociable activation patterns associated with controlled semantic and phonological processing: evidence from FMRI adaptation. Cereb Cortex 15:1438-1450.

Gold BT, Buckner RL (2002) Common prefrontal regions coactivate with dissociable posterior regions during controlled semantic and phonological tasks. Neuron 35:803-812.

Golestani N, Molko N, Dehaene S, LeBihan D, Pallier C (2007) Brain structure predicts the learning of foreign speech sounds. Cereb Cortex 17:575-582.

Golestani N, Pallier C (2007) Anatomical correlates of foreign speech sound production. Cereb Cortex 17:929-934.

Golestani N, Paus T, Zatorre RJ (2002) Anatomical correlates of learning novel speech sounds. Neuron 35:997-1010.

Golinkoff RM, Mervis CB, Hirsh-Pasek K (1994) Early object labels: the case for a developmental lexical principles framework. J Child Lang 21:125-155.

Goodglass H, Hyde MR, Blumstein S (1969) Frequency, picturability and availability of nouns in aphasia. Cortex 5:104-119.

Grill-Spector K, Henson R, Martin A (2006) Repetition and the brain: neural models of stimulus-specific effects. Trends in Cognitive Sciences 10:14-23.

Gronholm P, Rinne JO, Vorobyev V, Laine M (2005) Naming of newly learned objects: a PET activation study. Brain Res Cogn Brain Res 25:359-371.

Groot PJM (2000) Computed assisted second language vocabulary acquisition. Language Learning and Technology 4:60-81.

Hagoort P, Indefrey P, Brown C, Herzog H, Steinmetz H, Seitz RJ (1999) The neural circuitry involved in the reading of German words and pseudowords: A PET study. J Cogn Neurosci 11:383-398.

Hahne A (2001) What's different in second-language processing? Evidence from event-related brain potentials. J Psycholinguist Res 30:251-266.

Hahne A, Friederici AD (2001) Processing a second language: Late learners' comprehension mechanisms as revealed by event-related brain potentials. Bilingualism: Language and Cognition 4:123-141.

Halgren E, Dhond RP, Christensen N, Van Petten C, Marinkovic K, Lewine JD, Dale AM (2002) N400-like magnetoencephalography responses modulated by semantic context, word frequency, and lexical class in sentences. Neuroimage 17:1101-1116.

Hall DG, Belanger J (2005) Young children's use of range-of-reference information in word learning. Dev Sci 8:8-15.

Hall DG, Graham SA (1999) Lexical form class information guides word-to-object mapping in preschoolers. Child Dev 70:78-91.

Hall DG, Waxman S.R, Hurwitz WM (1993) How two- and four-year-old children interpret adjectives and count nouns. Child Development 64:1651-1664.

Hampton JA (1981) An Investigation of the Nature of Abstract Concepts. Memory & Cognition 9:149-156.

Heibeck TH, Markman EM (1987) Word learning in children: an examination of fast mapping. Child Dev 58:1021-1034.

Henke K, Weber B, Kneifel S, Wieser HG, Buck A (1999) Human hippocampus associates information in memory. Proc Natl Acad Sci U S A 96:5884-5889.

Hespos SJ, Spelke ES (2004) Conceptual precursors to language. Nature 430:453-456.

Hirsh-Pasek K, Golinkoff RM (1991) Language comprehension: A new look at some old themes. In: Biological and behavioral determinants of language development (N.Krasnegor, D.M.Rumbaugh, R.L.Schiefelbusch, M.Studdert-Kennedy, eds), Hillsdale, NJ: Erlbaum.

Hoenig K, Scheef L (2005) Mediotemporal contributions to semantic processing: fMRI evidence from ambiguity processing during semantic context verification. Hippocampus 15:597-609.

Holcomb PJ (1993) Semantic priming and stimulus degradation: implications for the role of the N400 in language processing. Psychophysiology 30:47-61.

Holcomb PJ, Neville HJ (1990) Semantic priming in visual and auditory lexical decision: a between modality comparison. Language and Cognitive Processes 5:281-312.

Hollich GJ, Hirsh-Pasek K, Golinkoff RM, Brand RJ, Brown E, Chung HL, Hennon E, Rocroi C (2000) Breaking the language barrier: an emergentist coalition model for the origins of word learning. Monogr Soc Res Child Dev 65:i-123.

Holowka S, Brosseau-Lapré F, Petitto LA (2002) Semantic and Conceptual Knowledge Underlying Bilingual Babies' First Signs and Words. Language Learning 52:205-262.

Howard D, Patterson K, Wise R, Brown WD, Friston K, Weiller C, Frackowiak R (1992) The cortical localization of the lexicons. Positron emission tomography evidence. Brain 115 (Pt 6):1769-1782.

Hyltenstam K (1992) Non-native features of near-native speakers: On the ultimate attainment of childhood L2 learners. In: Cognitive processing bilinguals (R.J.Harris, ed), Amsterdam: Elsevier Science.

Hyltenstam K, Abrahamsson N (2003) Maturational constraints on SLA. In: The handbook of second language acquisition (C.J.Doughty, M.H.Long, eds), Malden, Ma and Oxford, UK: Blackwell.

Indefrey P, Levelt WJ (2004) The spatial and temporal signatures of word production components. Cognition 92:101-144.

Ishai A, Ungerleider LG, Haxby JV (2000) Distributed neural systems for the generation of visual images. Neuron 28:979-990.

James TW, Gauthier I (2004) Brain areas engaged during visual judgments by involuntary access to novel semantic information. Vision Res 44:429-439.

Jenkins JR, Stein ML, Wysocki K (1984) Learning vocabulary through reading. American Educational Research Journal 21:767-787.

Johnson JS, Newport EL (1989) Critical period effects in second language learning: the influence of maturational state on the acquisition of English as a second language. Cognit Psychol 21:60-99.

Jones GV (1985) Deep dyslexia, imageability, and ease of predication. Brain Lang 24:1-19.

Jones SS, Smith LB, Landau B (1991) Object properties and knowledge in early lexical learning. Child Dev 62:499-516.

Jusczyk PW (1999) How infants begin to extract words from speech. Trends Cogn Sci 3:323-328.

Jusczyk PW, Houston DM, Newsome M (1999) The beginnings of word segmentation in english-learning infants. Cognit Psychol 39:159-207.

Just MA, Carpenter PA, Keller TA, Eddy WF, Thulborn KR (1996) Brain activation modulated by sentence comprehension. Science 274:114-116.

Kapur S, Rose R, Liddle PF, Zipursky RB, Brown GM, Stuss D, Houle S, Tulving E (1994) The role of the left prefrontal cortex in verbal processing: semantic processing or willed action? Neuroreport 5:2193-2196.

Katz RB, Goodglass H (1990) Deep dysphasia: analysis of a rare form of repetition disorder. Brain Lang 39:153-185.

Keller TA, Carpenter PA, Just MA (2001) The neural bases of sentence comprehension: a fMRI examination of syntactic and lexical processing. Cereb Cortex 11:223-237.

Kemler Nelson DG, Frankenfield A, Morris C, Blair E (2000a) Young children's use of functional information to categorize artifacts: three factors that matter. Cognition 77:133-168.

Kemler Nelson DG, Russell R, Duke N, Jones K (2000b) Two-year-olds will name artifacts by their functions. Child Dev 71:1271-1288.

Kensinger EA, Ullman MT, Corkin S (2001) Bilateral medial temporal lobe damage does not affect lexical or grammatical processing: evidence from amnesic patient H.M. Hippocampus 11:347-360.

Kersten AW, Earles JL (2001) Less really is more for adults learning a miniature artificial language. Journal of Memory and Language 44:250-273.

Kieras D (1978) Beyond pictures and words: alternative information-processing models for imagery effects in verbal memory. Psychological Bulletin 85:532-554.

Kim KH, Relkin NR, Lee KM, Hirsch J (1997) Distinct cortical areas associated with native and second languages. Nature 388:171-174.

Klein W (1996) Language acquisition at different ages. In: The lifespan development of individuals: behavioral, neurobiological, and psychosocial perspectives (D.Magnusson, ed), Cambridge, NY: University Press.

Kotz SA, Cappa SF, von Cramon DY, Friederici AD (2002) Modulation of the lexical-semantic network by auditory semantic priming: an event-related functional MRI study. Neuroimage 17:1761-1772.

Kraut MA, Kremen S, Segal JB, Calhoun V, Moo LR, Hart J (2002) Object activation from features in the semantic system. Journal of Cognitive Neuroscience 14:24-36.

Kroll JF, Curley J (1988) Lexical memory in novice bilinguals: The role of concepts in retrieving second language words. In: Practical aspects of memory Vol.2 (M.Gruneberg, P.Morris, R.Sykes, eds), London: John Wiley & Sons.

Kroll JF, Tokowicz N (2001) The development of conceptual representation for words in a second language. In: One mind, two languages: Bilingual language processing (J.L.Nicol, ed), Malden, MA: Blackwell Publishers.

Kroll JF, Merves JS (1986) Lexical access for concrete and abstract words. Journal of Experimental Psychology: Learning, Memory and Cognition 12:92-107.

Kroll JF, Steward E (1994) Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. Journal of Memory and Language 33:149-174.

Kuhl PK (2004) Early language acquisition: cracking the speech code. Nat Rev Neurosci 5:831-843.

Kuperberg GR, Holcomb PJ, Sitnikova T, Greve D, Dale AM, Caplan D (2003) Distinct patterns of neural modulation during the processing of conceptual and syntactic anomalies. Journal of Cognitive Neuroscience 15:272-293.

Kutas M, Federmeier KD (2000) Electrophysiology reveals semantic memory use in language comprehension. Trends Cogn Sci 4:463-470.

Kutas M, Hillyard SA (1984) Brain potentials during reading reflect word expectancy and semantic association. Nature 307:161-163.

Kutas M, Hillyard SA (1980) Reading senseless sentences: brain potentials reflect semantic incongruity. Science 207:203-205.

Kutas M, Hillyard SA (1989) An electrophysiological probe of incidental semantic association. Journal of Cognitive Neuroscience 1:38-49.

Landau B, Jones S, Smith L (1992) Perception, ontology, and naming in young children: commentary on Soja, Carey, and Spelke. Cognition 43:85-91.

Landauer TK (1986) How much do people remember? Some estimates of the quantity of learned information in long-term memory. Cognitive Science 10:477-493.

Landauer TK, Dumais ST (1997) A solution to Plato's problem: the Latent Semantic Analysis theory of acquisition, induction and representation of knowledge. Psychological Review 104:211-240.

Laubach M (2005) Who's on first? What's on second? The time course of learning in corticostriatal systems. Trends Neurosci 28:509-511.

Lenneberg EH (1967) Biological Foundations of Language. New York, NY: John Wiley.

Lepage M, Habib R, Tulving E (1998) Hippocampal PET activations of memory encoding and retrieval: the HIPER model. Hippocampus 8:313-322.

Locke J (1964) An essay concerning human understanding. Cleveland: Meridian Books.

Long MH (1990) Maturational constraints on language development. Studies in Second Language Acquisition 12:251-285.

Macnamara J (1972) Cognitive basis of language learning in infants. Psychol Rev 79:1-13.

Markman AB, Stilwell CH (2001) Rule-governed categories. Journal of Experimental and Theoretical Artificial Intelligence 13:329-358.

Markman EM (1989) Categorization and naming in children. Cambridge, MA: MIT Press.

Markman EM, Wachtel GF (1988) Children's use of mutual exclusivity to constrain the meanings of words. Cognit Psychol 20:121-157.

Markson L, Bloom P (1997) Evidence against a dedicated system for word learning in children. Nature 385:813-815.

Marshall J, Pring T, Chiat S, Robson J (1996) Calling a salad a federation: An investigation of semantic jargon. Part I - Nouns. Journal of Neurolinguistics 9:237-250.

Martin A, Chao LL (2001) Semantic memory and the brain: structure and processes. Curr Opin Neurobiol 11:194-201.

Martin A, Ungerleider LG, Haxby JV (2000) Category specificity and the brain: the sensory/motor model of semantic representations. In: The New Cognitive Neurosciences (M.S.Gazzaniga ed, ed), pp 1023-1036. Cambrideg, MA: MIT Press.

Martin A, Wiggs CL, Ungerleider LG, Haxby JV (1996) Neural correlates of category-specific knowledge. Nature 379:649-652.

Martin N, Saffran EM (1992) A computational account of deep dysphasia: evidence from a single case study. Brain Lang 43:240-274.

Matsumoto A, Iidaka T, Haneda K, Okada T, Sadato N (2005) Linking semantic priming effect in functional MRI and event-related potentials. Neuroimage 24:624-634.

Mattys SL, Jusczyk PW, Luce PA, Morgan JL (1999) Phonotactic and prosodic effects on word segmentation in infants. Cognit Psychol 38:465-494.

Mayberry RI, Fischer SD (1989) Looking through phonological shape to lexical meaning: the bottleneck of non-native sign language processing. Mem Cognit 17:740-754.

Mayberry RI, Lock E (2003) Age constraints on first versus second language acquisition: evidence for linguistic plasticity and epigenesis. Brain Lang 87:369-384.

Mayberry RI, Lock E, Kazmi H (2002) Linguistic ability and early language exposure. Nature 417:38.

McCandliss BD, Cohen L, Dehaene S (2003) The visual word form area: expertise for reading in the fusiform gyrus. Trends Cogn Sci 7:293-299.

McCarthy G, Nobre AC, Bentin S, Spencer DD (1995) Language-related field potentials in the anterior-medial temporal lobe: I. Intracranial distribution and neural generators. J Neurosci 15:1080-1089.

McCarthy G, Wood CC (1985) Scalp distributions of event-related potentials: an ambiguity associated with analysis of variance models. Electroencephalogr Clin Neurophysiol 62:203-208.

McDonald JL (2000) Grammaticality judgments in a second language: Influences of age acquisition and native language. Applied Psycholinguistics 21:395-423.

McGregor KK, Friedman RM, Reilly RM, Newman RM (2002) Semantic representation and naming in young children. J Speech Lang Hear Res 45:332-346.

McLaughlin J, Osterhout L, Kim A (2004) Neural correlates of second-language word learning: minimal instruction produces rapid change. Nat Neurosci 7:703-704.

Mellet E, Tzourio N, Denis M, Mazoyer B (1998) Cortical anatomy of mental imagery of concrete nouns based on their dictionary definition. Neuroreport 9:803-808.

Middleton FA, Strick PL (2000) Basal ganglia and cerebellar loops: motor and cognitive circuits. Brain Research Reviews 31:236-250.

Mitchell DC (1984) An evaluation of subject-paced reading tasks and other methods for investigating immediate processes in reading. In: New Methods in Reading Comprehension Research (D.E.Kieras, M.A.Just, eds), Hillsdale, NJ: Lawrence Erlbaum Associates.

Moreno EM, Kutas M (2005) Processing semantic anomalies in two languages: an electrophysiological exploration in both languages of Spanish-English bilinguals. Brain Res Cogn Brain Res 22:205-220.

Moyer A (1999) Ultimate attainment in L2 phonology: The critical factors of age, motivation, and instruction. Studies in Second Language Acquisition 21:81-108.

Münte TF, Urbach TP, Düzel F, Kutas M (2001) Event-related-brain potentials in the study of human cognition and neuropsychology. In: Handbook of Neuropsychology Amsterdam: Elsevier Science.

Murphy GL, Lassaline ME (1997) Hierarchical structure in concepts and the basic level of categorization. In: Knowlegde, concepts and categories (K.Lamberts, D.R.Shanks, eds), Cambridge, MA: MIT Press.

Nadeau SE, Crosson B (1997) Subcortical aphasia. Brain and Language 58:355-402.

Nagy WE, Anderson RC, Herman PA (1987) Learning word meanings from context during normal reading. American Educational Research Journal 24:237-270.

Nagy WE, Anderson RC (1984) How many words are there in printed English? Reading Research Quarterly 19:304-330.

Nagy WE, Herman PA, Anderson RC (1985) Learning words from context. Reading Research Quarterly 20:233-253.

Nelson K (1988) Constraints on word learning? Cognitive Development 3:221-246.

Newport EL (1990) Maturational Constraints on Language Learning. Cognitive Science 14:11-28.

Newport EL (2002) Critical periods in language development. In: Encyclopedia of Cognitive Science (L.Nadel, ed), London: Macmillan Publishers Ltd./Nature Publishing Group.

Newport EL (1988) Constraints on learning and their role in language acquisition: Studies of the acquisition of American Sign Language. Language Sciences 10:147-172.

Newport EL, Supalla T (1987) A critical period effect in the acquisition of a primary language.

Ni W, Constable RT, Mencl WE, Pugh KR, Fulbright RK, Shaywitz SE, Shaywitz BA, Gore JC, Shankweiler D (2000) An event-related neuroimaging study distinguishing form and content in sentence processing. J Cogn Neurosci 12:120-133.

Nobre AC, Allison T, McCarthy G (1994) Word recognition in the human inferior temporal lobe. Nature 372:260-263.

Nobre AC, McCarthy G (1995) Language-related field potentials in the anterior-medial temporal lobe: II. Effects of word type and semantic priming. J Neurosci 15:1090-1098.

Noppeney U, Price CJ (2002) Retrieval of visual, auditory, and abstract semantics. Neuroimage 15:917-926.

Opitz B, Friederici AD (2003) Interactions of the hippocampal system and the prefrontal cortex in learning language-like rules. Neuroimage 19:1730-1737.

Oyama S (1976) A sensitive period for the acquisition of a nonnative phonological system. Journal of Psycholinguistic Research 5:261-285.

Paivio A (1971) Imagery and verbal processes. New York: Holt, Rinehart, Winston.

Paivio A (1986) Mental representations: A dual coding approach. New York: Oxford University Press.

Paivio A (1991) Dual coding theory: Retrospect and current status. Canadian Journal of Psychology 45:255-287.

Pallier C, Dehaene S, Poline JB, LeBihan D, Argenti AM, Dupoux E, Mehler J (2003) Brain imaging of language plasticity in adopted adults: can a second language replace the first? Cereb Cortex 13:155-161.

Papagno C, Valentine T, Baddeley A (1991) Phonological short-term memory and foreign-language vocabulary learning. Journal of Memory and Language 30:331-347.

Papagno C, Vallar G (1992) Phonological short-term memory and the learning of novel words: The effect of phonological similarity and item length. Q J Exp Psychol A 44:47-67.

Paulesu E, McCrory E, Fazio F, Menoncello L, Brunswick N, Cappa SF, Cotelli M, Cossu G, Corte F, Lorusso M, Pesenti S, Gallagher A, Perani D, Price C, Frith CD, Frith U (2000) A cultural effect on brain function. Nat Neurosci 3:91-96.

Penfield W, Roberts L (1959) Speech and brain mechanisms. New York: Athenaeum.

Perani D, Dehaene S, Grassi F, Cohen L, Cappa SF, Dupoux E, Fazio F, Mehler J (1996) Brain processing of native and foreign languages. Neuroreport 7:2439-2444.

Perani D, Paulesu E, Galles NS, Dupoux E, Dehaene S, Bettinardi V, Cappa SF, Fazio F, Mehler J (1998) The bilingual brain. Proficiency and age of acquisition of the second language. Brain 121 (Pt 10):1841-1852.

Perfetti CA, Wlotko EW, Hart LA (2005) Word learning and individual differences in word learning reflected in event-related potentials. J Exp Psychol Learn Mem Cogn 31:1281-1292.

Petersen SE, Fox PT, Posner MI, Mintun M, Raichle ME (1988) Positron emission tomographic studies of the cortical anatomy of single-word processing. Nature 331:585-589.

Petitto LA (1992) Modularity and constraints in early lexical acquisition: Evidence from children's first words/signs and gestures. In: Modularity and constraints in language and cognition: The Minnesota Symposia on Child Psychology (M.R.Gunnar & Maratsos, ed), Hillsdale, NJ: Erlbaum.

Pihlajamaki M, Tanila H, Hanninen T, Kononen M, Mikkonen M, Jalkanen V, Partanen K, Aronen HJ, Soininen H (2003) Encoding of novel picture pairs activates the perirhinal cortex: an fMRI study. Hippocampus 13:67-80.

Pinker S (1984) Language learnability and language development. Cambridge, MA: Harvard University Press.

Pinker S (1994) The language instinct. New York: Morrow.

Plaut DC, Shallice T (1993) Deep dyslexia: a case study of connectionist neuropsychology. Cognitive Neuropsychology 10:377-500.

Poldrack RA, Wagner AD, Prull MW, Desmond JE, Glover GH, Gabrieli JD (1999) Functional specialization for semantic and phonological processing in the left inferior prefrontal cortex. Neuroimage 10:15-35.

Postle BR, Corkin S (1998) Impaired word-stem completion priming but intact perceptual identification priming with novel words: evidence from the amnesic patient H.M. Neuropsychologia 36:421-440.

Potter MC, So K-F, Von Eckardt B, Feldman LB (1984) Lexical and conceptual representation in beginning and more proficient bilinguals. Journal of verbal learning and verbal behaviour 23:23-38.

Price CJ (2000) The anatomy of language: contributions from functional neuroimaging. J Anat 197 Pt 3:335-359.

Price CJ, Wise RJ, Frackowiak RS (1996) Demonstrating the implicit processing of visually presented words and pseudowords. Cereb Cortex 6:62-70.

Prince SE, Daselaar SM, Cabeza R (2005) Neural correlates of relational memory: successful encoding and retrieval of semantic and perceptual associations. J Neurosci 25:1203-1210.

Pruden SM, Hirsh-Pasek K, Golinkoff RM, Hennon EA (2006) The birth of words: ten-month-olds learn words through perceptual salience. Child Dev 77:266-280.

Pugh KR, Shaywitz BA, Shaywitz SE, Constable RT, Skudlarski P, Fulbright RK, Bronen RA, Shankweiler DP, Katz L, Fletcher JM, Gore JC (1996) Cerebral organization of component processes in reading. Brain 119 (Pt 4):1221-1238.

Pulvermüller F, Schumann JH (1994) Neurobiological Mechanisms of Language Acquisition. Language Learning 44:681-734.

Quine WVO (1960) Word and object. Cambridge, MA: MIT Press.

Raboyeau G, Marie N, Balduyck S, Gros H, Demonet JF, Cardebat D (2004) Lexical learning of the English language: a PET study in healthy French subjects. Neuroimage 22:1808-1818.

Rice ML, Woodsmall L (1988) Lessons from television: children's word learning when viewing. Child Dev 59:420-429.

Rodriguez-Fornells A, de Diego Balaguer R, Munte TF (2006) Executive functions in bilingual language processing. Language Learning 56:133-190.

Rohde DL, Plaut DC (1999) Language acquisition in the absence of explicit negative evidence: how important is starting small? Cognition 72:67-109.

Ruschemeyer SA, Fiebach CJ, Kempe V, Friederici AD (2005) Processing lexical semantic and syntactic information in first and second language: fMRI evidence from German and Russian. Hum Brain Mapp 25:266-286.

Ryan L, Nadel L, Keil K, Putnam K, Schnyer D, Trouard T, Moscovitch M (2001) Hippocampal complex and retrieval of recent and very remote autobiographical memories: evidence from functional magnetic resonance imaging in neurologically intact people. Hippocampus 11:707-714.

Sabsevitz DS, Medler DA, Seidenberg M, Binder JR (2005) Modulation of the semantic system by word imageability. Neuroimage 27:188-200.

Saffran EM, Boyo LC, Schwartz MF, Martin OSM (1980) Does deep dyslexia reflect right hemisphere reading? In: Deep dyslexia (M.Coltheart, K.Patterson, J.Marshall, eds), London: Routledge.

Saffran EM, Sholl A (1999) Clues to the functional and neural architecture of word meaning. In: The neurocognition of language (C.M.Brown, P.Hagoort, eds), New York: Oxford University Press.

Saffran JR, Aslin RN, Newport EL (1996a) Statistical learning by 8-month-old infants. Science 274:1926-1928.

Saffran JR, Newport EL, Aslin RN (1996b) Word segmentation: The role of distributional cues. Journal of Memory and Language 35:606-621.

Samuelson LK, Smith LB (1998) Memory and attention make smart word learning: an alternative account of Akhtar, Carpenter, and Tomasello. Child Dev 69:94-104.

Sanders LD, Newport EL, Neville HJ (2002) Segmenting nonsense: an event-related potential index of perceived onsets in continuous speech. Nat Neurosci 5:700-703.

Saykin AJ, Johnson SC, Flashman LA, McAllister TW, Sparling M, Darcey TM, Moritz CH, Guerin SJ, Weaver J, Mamourian A (1999) Functional differentiation of medial temporal and frontal regions involved in processing novel and familiar words: an fMRI study. Brain 122 (Pt 10):1963-1971.

Schacter DL, Dobbins IG, Schnyer DM (2004) Specificity of priming: a cognitive neuroscience perspective. Nat Rev Neurosci 5:853-862.

Schultz W (2006) Behavioral theories and the neurophysiology of reward. Annu Rev Psychol 57:87-115.

Schwanenflugel PJ, Akin C, Luh WM (1992) Context availability and the recall of abstract and concrete words. Mem Cognit 20:96-104.

Schwanenflugel PJ, Harnishfeger KK, Stowe RW (1988) Context Availability and Lexical Decisions for Abstract and Concrete Words. Journal of Memory and Language 27:499-520.

Schwanenflugel PJ, Shoben EJ (1983) Differential context effects in the comprehension of abstract and concrete verbal materials. Journal of Experimental Psychology: Learning, Memory and Cognition 9:82-102.

Schwanenflugel PJ, Stowe RW (1989) Context availability and the processing of abstract and concrete words in sentences. Reading Research Quarterly 24:114-126.

Sebastian-Gallés N, Martí MA, Carreiras M, Cuetos F (2000) LEXESP: Léxico informatizado del Español. Barcelona: Edicions Universitat de Barcelona.

Segal JB, Williams R, Kraut MA, Hart J (2003) Semantic memory deficit with a left thalamic infarct. Neurology 61:252-254.

Seger CA (2006) The basal ganglia in human learning. Neuroscientist 12:285-290.

Seger CA, Cincotta CM (2005) The roles of the caudate nucleus in human classification learning. J Neurosci 25:2941-2951.

Seger CA, Cincotta CM (2006) Dynamics of frontal, striatal, and hippocampal systems during rule learning. Cereb Cortex 16:1546-1555.

Service E (1992) Phonology, working memory, and foreign-language learning. Q J Exp Psychol A 45:21-50.

Shallice T (1988) Specialisation within the semantic system. Cognitive Neuropsychology 5:133-142.

Singleton D (1999) Exploring the Second Language Mental Lexicon. Cambridge: Cambridge University Press.

Smith LB (2000) Learning how to learn words: An associative crane. In: Becoming a word learner: A debate on lexical acquisition (R.M.Golinkoff, K.Hirsh-Pasek, L.Bloom, L.B.Smith, A.L.Woodard, N.Akhtar, M.Tomasello, G.Hollich, eds), New York: Oxford University Press.

Smith LB, Jones SS, Landau B (1992) Count nouns, adjectives, and perceptual properties in children's novel word interpretations. Child Development 28:273-286.

Snedeker J, Gleitman L (2004) Why it is hard to label our concepts. In: Weaving a Lexicon (G.Hall, S.Waxman, eds), Cambridge, MA: MIT Press.

Soja NN, Carey S, Spelke ES (1991) Ontological categories guide young children's inductions of word meaning: object terms and substance terms. Cognition 38:179-211.

Squire LR, Zola-Morgan S (1991) The medial temporal lobe memory system. Science 253:1380-1386.

Stern CE, Corkin S, Gonzalez RG, Guimaraes AR, Baker JR, Jennings PJ, Carr CA, Sugiura RM, Vedantham V, Rosen BR (1996) The hippocampal formation participates in novel picture encoding: evidence from functional magnetic resonance imaging. Proc Natl Acad Sci U S A 93:8660-8665.

Sternberg RJ (1987) Most vocabulary is learned from context. In: The nature of vocabulary acquisition (M.G.McKeown, M.E.Curtis, eds), Hillsdale, NJ: Lawrence Erlbaum Associates.

Stowe LA, Sabourin L (2005) Imaging the processing of a second language: Effects of maturation and proficiency on the neural processes involved. International Review of Applied Linguistics 43:329-354.

Subrahmanyam K, Landau B, Gelman R (1999) Shape, Material, and Syntax: Interacting Forces in Children's Learning in Novel Words for Objects and Substances. Language and Cognitive Processes 14:249-281.

Swaab TY, Baynes K, Knight RT (2002) Separable effects of priming and imageability on word processing: an ERP study. Brain Res Cogn Brain Res 15:99-103.

Taylor WL (1953) "Cloze" procedure: A new tool for measuring readability. Journalism Quarterly 30:415-417.

Thompson-Schill SL, D'Esposito M, Aguirre GK, Farah MJ (1997) Role of left inferior prefrontal cortex in retrieval of semantic knowledge: a reevaluation. Proc Natl Acad Sci U S A 94:14792-14797.

Tokowicz N, Kroll JF, de Groot AM, van Hell JG (2002) Number-of-translation norms for Dutch-English translation pairs: a new tool for examining language production. Behav Res Methods Instrum Comput 34:435-451.

Tomasello M (2003) A Usage-Based Theory of Language Acquisition. In: Constructing a Language Cambridge, Massachusetts: Harvard Univ. Press.

Tomasello M (1992) The social bases of language acquisition. Social Development 1:67-87.

Tomasello M, Akhtar N (1995) Two-year-olds use pragmatic cues to differentiate reference to objects and actions. Cognitive Development 10:201-224.

Tomasello M, Barton M (1994) Learning words in non-ostensive contexts. Developmental Psychology 30:639-650.

Tomasello M, Strosberg R, Akhtar N (1996) Eighteen-month-old children learn words in non-ostensive contexts. J Child Lang 23:157-176.

Ullman MT (2001c) The declarative/procedural model of lexicon and grammar. J Psycholinguist Res 30:37-69.

Ullman MT (2001a) A neurocognitive perspective on language: the declarative/procedural model. Nat Rev Neurosci 2:717-726.

Ullman MT (2001b) The neural basis of lexicon and grammar in first and second language: the declarative/procedural model. Bilingualism: Language and Cognition 4:105-122.

Ullman MT (2004) Contributions of memory circuits to language: the declarative/procedural model. Cognition 92:231-270.

van Hell JG, Candia-Mahn A (1997) Keyword Mnemonics versus rote rehearsal: learning concrete and abstract foreign words by experienced and inexperienced learners. Language Learning 47:507-546.

van Hell JG, de Groot AMB (1998b) Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association. Bilingualism: Language and Cognition 1:193-211.

van Hell JG, de Groot AMB (1998a) Disentangling context availability and concreteness in lexical decision and word translation. The Quarterly Journal of Experimental Psychology 51A:41-63.

Vandenberghe R, Price C, Wise R, Josephs O, Frackowiak RS (1996) Functional anatomy of a common semantic system for words and pictures. Nature 383:254-256.

Wagner AD, Koutstaal W, Maril A, Schacter DL, Buckner RL (2000) Task-specific repetition priming in left inferior prefrontal cortex. Cereb Cortex 10:1176-1184.

Wagner AD, Pare-Blagoev EJ, Clark J, Poldrack RA (2001) Recovering meaning: left prefrontal cortex guides controlled semantic retrieval. Neuron 31:329-338.

Wagner AD, Schacter DL, Rotte M, Koutstaal W, Maril A, Dale AM, Rosen BR, Buckner RL (1998) Building memories: remembering and forgetting of verbal experiences as predicted by brain activity. Science 281:1188-1191.

Wallentin M, Ostergaard S, Lund TE, Ostergaard L, Roepstorff A (2005) Concrete spatial language: see what I mean? Brain Lang 92:221-233.

Warburton E, Wise RJ, Price CJ, Weiller C, Hadar U, Ramsay S, Frackowiak RS (1996) Noun and verb retrieval by normal subjects. Studies with PET. Brain 119 (Pt 1):159-179.

Warrington EK (1975) The selective impairment of semantic memory. Q J Exp Psychol 27:635-657.

Warrington EK (1981) Concrete word dyslexia. Br J Psychol 72:175-196.

Warrington EK, McCarthy RA (1987) Categories of knowledge: Further fractionation and an attempted integration. Brain 100:1273-1296.

Warrington EK, Shallice T (1984) Category specific semantic impairments. Brain 107 (Pt 3):829-854.

Waxman SR, Markow DB (1995) Words as invitations to form categories: evidence from 12- to 13-month-old infants. Cognit Psychol 29:257-302.

Waxman SR, Philippe M, Branning A (1999) A matter of time: novel nouns mark object categories when delays are imposed. Developmental Science 2:59-66.

Weber-Fox C, Neville HJ (1996) Maturational constraints on functional specializations for language processing: ERP and behavioral evidence in bilingual speakers. Journal of Cognitive Neuroscience 8:231-256.

Werker JF, Tees RC (1984) Phonemic and phonetic factors in adult cross-language speech perception. J Acoust Soc Am 75:1866-1878.

Whatmough C, Verret L, Fung D, Chertkow H (2004) Common and constrasting areas of activation for abstract and concrete concepts: an H2 15O PET study. J Cogn Neurosci 16:1211-1226.

Wheatley T, Weisberg J, Beauchamp MS, Martin A (2005) Automatic priming of semantically-related words reduces activity in the fusiform gyrus. Journal of Cognitive Neuroscience 17:1871-1885.

White L, Genesee F (1996) How native is near-native? The issue of ultimate attainment in adult second language acquisition. Second language research 12:233-265.

Whorf BL (1956) Language, Thought, and Reality. Cambridge, MA: MIT Press.

Wiemer-Hastings K, Xu X (2005) Content Differences for Abstract and Concrete Concepts. Cognitive Science 29:719-736.

Wiggs CL, Martin A (1998) Properties and mechanisms of perceptual priming. Curr Opin Neurobiol 8:227-233.

Wittgenstein L (1953) Philosophical Investigations. Oxford: Basic Blackwell.

Worsley KJ, Friston KJ (1995) Analysis of fMRI time-series revisited--again. Neuroimage 2:173-181.

Appendix A: Stimulus Material for Chapter 2 and 3

Materials for Chapter 2 and 3

Experiment 1 and 3

A. Novel words – corresponding Spanish word

Alusira - medusa; ambil - interruptor; anclana – bicicleta; añiro - problema; arniso - horno; astiro – cenicero; ateloso - tomate; bacono – pantalón; balicon – metro; banita – nube; belto – pájaro; beteso – coche; bilsa – manzana; bina – serpiente; bisaco – plátano; biteco – ajo; buino – horóscopo; cajuro – sorteo; califiro – aeropuerto; campeto – biquini; catela – mosca; cema - baile; cemaco – ascensor; cerino – barco; ceteno – cinturón; chacorena – guitarra; cija – llave; cilso – pan; cirana – uña; cireto – saxofón; cirito – parchís; clisea – montaña; clito – oso; cratino – buzón; culiseo – avestruz; dalina – ciudad; desala – isla; dico – lazo; dilera – tarjeta; dileto – autobús; dirita – hormiga; dito – hacha, dodero – café; ectero – martillo; endole – avión; enlufe – tenedor; eritino – chocolate; escrayo – payaso; esreso – plato; eteiso – salero; fagarino – pegamento; faleto – semáforo; falito – árbol; falliro – grifo; farena – película; ferieto – mapa; fimeta – toalla; fisena – vacuna; fiteto – periódico; fleta – bufanda; flipeto – casco; futa – mancha; gareta – lavadora; gerias – tijeras; gitero - teléfono; gopeta – rosa; gurato – hotel; hareta – pila; helita – mano; histana – almohada; hiteco – móvil; ilero – regalo; imbra – flor; intrial – helicóptero; iprita – pirámide; jarilo – elefante; jarina – canción; laena – peluquería; laeta – grapadora; lecato – guante; lepito – cuchillo; lertico – pez; lesico – lápiz; liantro – dinosaurio; licana – estrella; licata – raqueta; limino – colegio; lineto – gato; liñero – despertador; lizeno – chiste; logarino – otoño; lopero – satélite; lucata – ducha; luerca – pistola; macito – diente; malinro – queso; malisiro – calcetín; mecrallo – abrigo; metico – ejercicio; milso – ojo; miluto – termómetro; misaleta – agua; muneiera – autopista; nagato – bigote; nalposa – naranja; niepa – uva; nilanera – sábana; nilata – casa; nileca – bombilla; nilopo – taxi; nocanal – globo; nosa – caja; oerelo – anillo; oleta – plancha; olieto – fútbol; oprisa – cabra; ovisera – panadería; paceto – río; pano – cubo; patora – campana; pecua – mariposa; peltro – brazo; penrota – silla; petira – cama; pieta – abeja; pilso – bolígrafo; pireje – cigarro; pireliso – médico; pirter – collar; pitsal – cine; puca – maleta; quiro – corazón; ralao – color; recola – taza; remoca – pierna; respo – oído; ricata – paella; rinaca – patata; rinilo – padre; ristro – dedo; riteto – esquí; sabeta – lámpara; saceyo – televisor; safena – cocina; saleca – vaca; saleno – león; sendelio – espejo; sileca – libreta; silera – vela; silino – zapato; siltra – aguja; siptio – sombrero; sitera – puerta; sito – pollo; sofireto – restaurante; sogaro – pastel; solefa – bandera; sufeto – calendario; sulico – amigo; tacela – luna; tacetelo – ordenador; talino – aceite; tareta – matrícula; tarra – piscina; tastera – zanahoria; tealena – serie; telepo – libro; tepa – botella; tepoto – canguro; tesa – leche; tezo – botón; ticha – pelota; tilapo – reloj; tileco – vestido; tilena – flecha; tilina – nariz; tombro – bolso; traum – bocadillo; trepto – cuadro; trilebo – sofá; tristero – paraguas; tulsas – gafas; ulina – gota; urtilera – iglesia; utileco – bar; valireta – escalera; valirino – girasol; vatesa – nevera; viato – azúcar; vieleto – mensaje; vileta – ventana; yalito – microondas; yutiro – fuego; zilatera – calculadora, zineta – cebolla.

B. Sentences

1. Como cada año me toca limpiar la piscina.
2. Este verano no iré a la misma piscina.
3. Me ducho antes de bañarme en la piscina.

1. En invierno me apetece siempre comer muchas naranjas.
2. Una de mis frutas preferidas son las naranjas.
3. De mañana me apetece un zumo de naranjas.

1. Hoy para comer me he cocinado unas patatas.
2. Rosa suele combinar sus platos preferidos con patatas.
3. En España es típica la tortilla de patatas.

1. Desde aquí me resulta imposible ver la luna.
2. Esta noche quizá no podamos ver la luna.
3. En el futuro habrá ciudades en la luna.

1. Por seguridad nos decidimos a cambiar el interruptor.
2. En esta habitación me cuesta encontrar el interruptor.
3. La luz se enciende al apretar el interruptor.

1. Iván tiene una lesión importante en el corazón.
2. Su padre tuvo un grave ataque de corazón.
3. Un trasplante muy difícil es el de corazón.

1. La policía no pudo nunca encontrar la pistola.
2. El criminal se decidió a comprar una pistola.
3. Sólo nos queda una bala en la pistola.

1. Después de comer, cuesta soplar bien el saxofón.
2. Uno instrumento que me gusta es el saxofón.
3. Oigo jazz para poder tocar bien el saxofón.

1. En verano me apetecen de postres las uvas.
2. Este año no hubo buena cosecha de uvas.
3. Este fin de año olvidé comprar las uvas.

1. Hoy Mario mientras esquiaba ha perdido los guantes.
2. En el skating es obligatorio llevar siempre guantes.
3. Como es friolera, siempre lleva puestos los guantes.

1. No encuentro un espacio apropiado para el cubo.
2. Normalmente la basura la tiramos en el cubo.
3. Cuanto este lleno, ves a vaciar el cubo.

1. Esther se pinchó al sentarse encima del tenedor.
2. A la cubertería nueva le falta un tenedor.
3. Cambia los cubiertos, a la izquierda el tenedor.

1. El insecto que menos gusta es la mosca.
2. Con este insecticida no podrás matar la mosca.
3. La Tsé-tsé es un tipo especial de mosca.

1. De noche, caí y me corte mi dedo.
2. En vacaciones, Pablo se ha roto un dedo.

3. Al cerrar la puerta se pilló el dedo.

1. Desde ayer, Pepe tiene dolor en un oído.
2. Me he puesto un auricular en un oído.
3. De pequeño tuve una infección en el oído.

1. En la tienda de muebles no quedaban sofás.
2. A esta casa le falta en buen sofá.
3. A veces hago la siesta en el sofá.

1. Me ha pedido prestado de nuevo mi abrigo.
2. Esta tarde iré a comprarme un buen abrigo.
3. Este invierno hace mucho frío, ponte mi abrigo.

1. Este año me voy a disfrazar de payaso.
2. En su fiesta de cumpleaños había un payaso.
3. Me encanta hacer reír, me gustaría ser payaso.

1. El hombre del tiempo dice que vendrán nubes.
2. Es muy relajante poder quedarse mirando las nubes.
3. Lloverá, el cielo está todo lleno de nubes.

1. Voy a encender el horno para hacer pollo.
2. En esta granja de Manresa se crían pollos.
3. Le gusta sobre todo el muslo del pollo.

1. En el piso nuevo todavía no tengo sillas.
2. Se ha roto una pata de la silla.
3. Esta mesa no hace conjunto con las sillas.

1. Esta mañana se ha perdido mi querido gato.
2. Desde pequeña, Luisa tiene alergia a los gatos.
3. Como tiene ratones se ha comprado un gato.

1. En la nevera no queda nada de leche.
2. Silvia se ha bebido un vaso de leche.
3. Me apetece un bol de cereales con leche.

1. Esta mañana he ido a comprar unas gafas.
2. No me gusta nada tener que usar gafas.
3. Para leer o ver la televisión necesito gafas.

1. Siempre suelo llevar en la mochila algún bolígrafo.
2. No se puede hacer el examen sin bolígrafo.
3. Me he manchado con la tinta del bolígrafo.

1. Cuando compramos la casa cambiamos todas las ventanas.
2. El despacho donde trabaja Carmen no tiene ventanas.
3. Hay demasiado ruido fuera, puedes cerrar las ventanas.

1. Me gusta pasar el rato con el periódico.
2. Supe de aquel empleo a través del periódico.
3. Pablo cada día compra y lee el periódico.

1. Me gusta el ruido metálico de las llaves.
2. Para abrir las puertas son necesarias las llaves.
3. Pedro está buscando en su bolsillo las llaves.

1. Paloma olvidó guardar en su bolso la bufanda.
2. Nada más llegar, María, se quitó la bufanda.

3. En invierno protejo mi garganta con una bufanda.

1. He olvidado comprar las entradas para el cine.
2. Hoy hemos quedado todos para ir al cine.
3. Compraré palomitas antes de entrar en el cine.

1. Desde que era pequeña me encanta comer tomate.
2. El bocadillo estará mucho más bueno con tomate.
3. En Cataluña es típico el pan con tomate.

1. Ten cuidado no se te caigan los platos.
2. Sara ha dejado en la cocina los platos.
3. Sirvió la comida de los invitados en platos.

1. La profesora escribió el problema en la libreta.
2. ¿Dónde hay una papelería para comprar una libreta?.
3. Se ha roto la espiral de la libreta.

1. Desde ayer que me duelen mucho los ojos.
2. Marrón claro es el color de sus ojos.
3. Me han recetado unas gotas para los ojos.

1. Me acercaré al mercado a comprar algunos ajos.
2. Siempre me gusta añadir a los sofritos ajos.
3. A los vampiros no les gustan los ajos.

1. Acabaré de decorar la casa con una lámpara.
2. Encima de la mesa he puesto una lámpara.
3. Falta luz en ese rincón pondré una lámpara.

1. En el Carrefour hay grandes ofertas en camas.
2. Donde más cómodo estoy es en la cama.
3. Cada mañana se va sin hacer la cama.

1. Has olvidado poner en la mesa mi cuchillo.
2. En la cocina no he encontrado ningún cuchillo.
3. Se ha cortado el dedo con un cuchillo.

1. Debajo de la ropa llevo puesto el biquini.
2. Para este verano me he comprado un biquini.
3. He olvidado la parte de arriba del biquini.

1. A Laura le encantan los colores del cuadro.
2. De este paisaje podría hacerse un buen cuadro.
3. Patricia ya ha llevado ha enmarcar el cuadro.

1. Carmen siempre ha querido tener un gran espejo.
2. El lavabo ha quedado bonito con el espejo.
3. Es un presumido siempre mirándose en el espejo.

1. Me gustaría ahorrar para comprarme un buen ordenador.
2. José pasa todo el día delante del ordenador.
3. Es imposible conectarse a internet desde este ordenador.

1. Ese punto en el cielo es un avión.
2. Óscar nunca ha visto de cerca un avión.
3. Todavía no he subido nunca en un avión.

1. Es muy sano comer a diario una manzana.
2. De postre Paula se ha comido una manzana.

3. Los expulsaron del paraíso por comer una manzana.

1. Pedro tiene una gran cicatriz en el brazo.
2. El perro mordió a Cristina en el brazo.
3. No podrás cogerlo si no estiras el brazo.

1. En toda la casa no hay ningún cenicero.
2. En clase de cerámica he hecho un cenicero.
3. Voy a apagar el cigarro en el cenicero.

1. Juan tendría que llevar a afilar el hacha.
2. Supongo que todos los leñadores tienen un hacha.
3. Salió a buscar leña y olvidó el hacha.

1. Hoy para desayunar he tomado batido de plátano.
2. Antes de comértelo quítale la piel al plátano.
3. La fruta típica de Canarias es el plátano.

1. A Carolina le dan mucho miedo las abejas.
2. No lo toques o te picarán las abejas.
3. La miel la tenemos gracias a las abejas.

1. No puedo llevar este traje sin un cinturón.
2. En esta tienda de ropa no venden cinturones.
3. Se me caen los pantalones sin el cinturón.

1. Cada día Luís va al colegio en bicicleta.
2. Se rompió el brazo cayendo de la bicicleta.
3. Tengo que cambiar los pedales de la bicicleta.

1. Juan le ha regalado a Arancha un libro.
2. Me he dejado en la biblioteca el libro.
3. ¿Quién ha mojado las hojas de este libro?.

1. Pepa ha metido en el horno el pan.
2. Para mantener la línea intenta no comer pan.
3. Cada día suele comprar dos barras de pan.

1. Como Lola es diabética no puede comer pastel.
2. Iré a la confitería a comprar un pastel.
3. Mi madre preparó para mi cumpleaños un pastel.

1. Cuidado Carlos, no te quemes con la vela.
2. Para el mal olor mejor poner una vela.
3. Me manché con la cera de la vela.

1. En el huerto no hay plantada ninguna zanahoria.
2. A esta ensalada le falta poner una zanahoria.
3. Esta verdura de color naranja debe ser zanahoria.

1. María detesta mucho el olor de los cigarros.
2. Paco ve a comprar un paquete de cigarros.
3. Después de comer casi siempre fumo dos cigarros.

1. Juan siempre se deja en casa el reloj.
2. Se me ha roto la correa del reloj.
3. Mañana tengo que atrasar una hora el reloj.

1. En medio de la carretera había una vaca.
2. En toda la granja solo hay una vaca.

3. El granjero atendió el parto de una vaca.

1. Carol, no deberías poner al sol esta flor.
2. Me gustaría comprar una planta que de flor.
3. No queda ni un pétalo en esta flor.

1. Para colgar el cuadro es necesario un martillo.
2. En la caja de herramientas está el martillo.
3. Me he golpeado el dedo con el martillo.

1. El fuerte viento se ha llevado su sombrero.
2. No se suele ver a nadie con sombrero.
3. Protégete la cabeza del sol con este sombrero.

1. Si miras al cielo podrás ver el helicóptero.
2. ¿Por qué es imposible que despegue el helicóptero?.
3. Hacen mucho ruido las hélices de este helicóptero.

1. Un animal que me gusta es el canguro.
2. Ir saltando es como se desplaza el canguro.
3. Cuando fui a Australia no vi ningún canguro.

1. Mañana para la fiesta me pondré este collar
2. Pedro me gustaría que me regalases un collar.
3. Podrías ponerte en el cuello este precioso collar.

1. Debes tener cuidado en donde dejas la aguja.
2. Has olvidado sacar de la camisa una aguja.
3. Mi abuela ya no puede enhebrar la aguja.

1. Voy a ir al supermercado a comprar cebollas.
2. A Lucía le encanta la hamburguesa con cebolla.
3. Le lloran los ojos siempre que pela cebollas.

1. Sacó el monedero lleno de billetes del bolso.
2. Patricia nunca olvida llevar con ella su bolso.
3. María siempre lleva de todo dentro del bolso.

1. Esta tarde me traen a casa la nevera.
2. Voy a bajar la temperatura de la nevera.
3. La bebida debe estar enfriándose en la nevera.

1. Le voy a poner tomate a este bocadillo.
2. Que duro está el pan de este bocadillo.
3. Para comer me voy a preparar un bocadillo.

1. Me parece que es demasiado grande esta maleta.
2. Todo no va a caber en una maleta.
3. Al llegar al aeropuerto habían perdido mi maleta.

1. Si no barres bien puede llenarse de hormigas.
2. Esther tiene toda la cocina llena de hormigas.
3. He comprado insecticida para acabar con las hormigas.

1. Por el camino no he visto ninguna flecha.
2. Para encontrar la salida debes seguir la flecha.
3. Jugando a indios se lastimó con una flecha.

1. Manolo y yo vamos a clases de baile.
2. Desde pequeña siempre le ha gustado el baile.

3. Todavía no ha encontrado pareja para el baile.

1. Le ha regalado a su hijo una pelota.
2. Es imposible jugar si no conseguimos una pelota.
3. El portero fue capaz de atrapar la pelota.

1. A Pedro le encantaría poder practicar el esquí.
2. Acaban de abrir unas nuevas pistas de esquí
3. En octubre ya empezó la temporada de esquí.

1. Ayer al ir al zoo vimos muchos osos.
2. ¡Ten cuidado! en este bosque viven muchos osos.
3. En los dibujos Yoggi y Bubú eran osos.

1. Es una gran aficionada a observar los pájaros.
2. En invierno no se suelen ver muchos pájaros.
3. En este árbol hay un nido de pájaros.

1. Aquí pone que no debemos rellenar la botella.
2. Se cortó con el trozo de una botella.
3. María encontró un mensaje dentro de una botella.

1. Iván está empezando a aprender a hacer lazos.
2. Carmen a tu vestido le sobran tantos lazos.
3. ¡No hagas un nudo! mejor haz dos lazos.

1. Ha ido a la tienda a pedir cajas.
2. Es imposible poner tantos libros en estas cajas.
3. Para la mudanza mejor ponerlo todo en cajas.

1. Carlos ha vuelto a perder el último autobús.
2. A esta hora ya no pasa ningún autobús.
3. Estuve media hora en la parada del autobús.

1. En el museo hay una exposición de mariposas.
2. Todos los insectos son asquerosos menos las mariposas.
3. Las orugas se acaban convirtiendo en bonitas mariposas.

1. No te lo puedo arreglar sin el botón.
2. En la caja de costura habrá algún botón.
3. Pepe, a esta camisa le falta un botón.

1. Mario siempre olvida donde ha dejado el coche.
2. Ha salido muy cara la reparación del coche.
3. Ha vuelto a pinchar la rueda del coche.

1. Después del temporal tuvo que cambiar la puerta.
2. Acabamos de pintar, intenta no tocar la puerta.
3. Fuimos a verte pero estaba cerrada la puerta.

1. Le da mucho respeto entrar en una iglesia.
2. Hace 500 años se construyó esta magnífica iglesia.
3. Aunque es creyente nunca va a la iglesia.

1. Sin querer se me ha roto una taza.
2. No me gusta tomar la leche en taza.
3. Elena quiere tomar el té en una taza.

1. Por su cumpleaños Juan le regaló un casco.
2. Si quieres ver las obras debes llevar casco.

3. Para ir en moto es obligatorio ponerse casco.

1. María no puede permitirse comprarse un nuevo vestido.
2. Ves a la tintorería a buscar el vestido.
3. Cuando se casó se diseñó ella el vestido.

1. Para ganar el juego debes coger la bandera.
2. Debes saber que cada país tiene su bandera.
3. En lo alto del castillo ondeaba una bandera.

1. El veterinario dijo que no tocaras los peces.
2. A Pablo se le murieron todos los peces.
3. Ayer me regalaron una pecera llena de peces.

1. En África viven la mayoría de los elefantes.
2. El otro día en el circo vi elefantes.
3. Los mamuts eran los antepasados de los elefantes.

1. Imposible, Carlos nunca aprenderá a utilizar la plancha.
2. Manolito, vigila no te quemes con la plancha.
3. Cuando se seque la camisa, pásale la plancha.

1. En nuestra calle ya han puesto otro semáforo.
2. Tuvo el accidente porque no vio el semáforo.
3. Los coches pasarán cuando esté verde el semáforo.

1. En casa de María no tienen ningún televisor.
2. El técnico vendrá mañana a reparar el televisor.
3. No pudo sintonizar ningún canal en este televisor.

1. Para mi cumpleaños necesito comprarme un nuevo paraguas.
2. Con ese viento era imposible abrir el paraguas.
3. Va a llover, mejor que cojas el paraguas.

1. Aunque parezcan bolsas, no te fíes, son medusas.
2. El otro día en la playa vi medusas.
3. Vigila que hoy en el agua hay medusas.

1. Mario fue a hacer un viaje en globo.
2. Juanito me pidió que le hinchara el globo.
3. El payaso repartió para cada niño un globo.

1. Joaquín ya ha cambiado otra vez de móvil.
2. He tenido que cambiar la batería del móvil.
3. He olvidado el código PIN de mi móvil.

1. Mañana o pasado iré a comprar un regalo.
2. Aunque eran sus padres solo trajeron un regalo.
3. Es mi cumpleaños seguramente me traerán un regalo.

1. Tendrías que ir a comprar el nuevo calendario.
2. Para no olvidarte, mejor márcalo en el calendario.
3. Ya es septiembre, pasa la hoja del calendario.

1. El gran sueño de Carolina es ser médico.
2. Al llegar había muchísima gente esperando al médico.
3. Me duele mucho la barriga, iré al médico.

1. Si vas fuera, mejor búscate un buen hotel.
2. No se si hay piscina en este hotel.

3. Carmen prefirió las cuatro estrellas de este hotel.

1. Juan casi siempre se pierde buscando el metro.
2. Ayer tarde hubo un accidente en el metro.
3. En Barcelona hay cinco líneas diferentes de metro.

1. Luís se pasa el día en el bar.
2. Debajo de mi casa han abierto un bar.
3. Mañana iremos a tomar algo a aquel bar.

1. Esta tarde Juan se ha comprado un microondas.
2. La cocina es pequeña, no cabe un microondas.
3. Tengo la leche caliente enseguida gracias al microondas.

1. Fernando siempre toma por las noches un café.
2. A Luisa nunca le ha gustado el café.
3. Toda esta cafetera, si solo yo tomaré café

1. En casa de María aún no tienen horno.
2. Llamaré para que vengan a reparar el horno.
3. Antes de meter la pizza calienta el horno.

1. Juan le ha regalado a Nieves una guitarra.
2. Pablo se ha apuntado a clases de guitarra.
3. Santana es de los mejores tocando la guitarra.

1. María se equivocó al salir de la autopista.
2. Están haciendo obras, mejor no coger la autopista.
3. 120 es el máximo permitido en la autopista.

1. Aunque parezca imposible Juan no soporta el fútbol.
2. Mario se pone nervioso cuando ve el fútbol.
3. El Barça es un gran equipo de fútbol.

1. La otra noche Carmen lucía un precioso anillo.
2. María estaba triste porque había perdido el anillo.
3. No se puede sacar del dedo el anillo.

1. Es imposible que no quede nada de agua.
2. Juan se pasa todo el día bebiendo agua.
3. Estábamos sedientos y compramos unas botellas de agua.

1. Han decidido que van a cambiar el grifo.
2. No se quién siempre deja abierto el grifo.
3. Después de beber tienes que cerrar el grifo.

1. Antonio todavía no sabe como funciona la calculadora.
2. Para el curso que viene necesitaré una calculadora.
3. Esta división es muy complicada utilizaré la calculadora.

1. Juana tiene una perra que se llama estrella.
2. Esta noche no se ve ni una estrella.
3. No sabía que el sol es una estrella.

1. Busca en ese cajón si encuentras una pila.
2. Esto no funciona porque le falta una pila.
3. Este reloj está parado, mejor cambiaré la pila.

1. La profesora escribió en la pizarra un problema.
2. Sin querer siempre se encuentra con algún problema.

3. Es demasiado difícil, no puedo solucionar el problema.

1. María olvidó poner su nombre en el buzón.
2. Alguien me ha robado las cartas del buzón.
3. No sé el piso, míralo en el buzón.

1. Carmen está deseando poderse comprar una nueva casa.
2. Iba tan borracho que no encontró su casa.
3. Después del trabajo me voy directamente a casa.

1. Iba paseando y me encontré con una cabra.
2. A José le encanta el queso de cabra.
3. Hay leche de vaca pero también de cabra.

1. A Cristina se le ha estropeado el despertador.
2. Mario odia el ruido que hace su despertador.
3. Mario siempre se despierta sin necesidad del despertador.

1. Esto es un peligro, deberían arreglar esta escalera.
2. He tenido que pedir a Carmen una escalera.
3. El ascensor no funciona sube por la escalera.

1. Al caer se rompió un par de uñas.
2. María tiene unas manchas blancas en las uñas.
3. El gato se defendió arañándole con las uñas.

1. Suerte que se dio cuenta que había fuego.
2. Se me acercó misteriosamente y me pidió fuego.
3. Vigila, te puedes quemar si juegas con fuego.

1. Pablo tendrás que aprender a utilizar la lavadora.
2. Mi gato se metió dentro de la lavadora.
3. Esta camiseta no puede ponerse en la lavadora.

1. El coche que me he comprado lleva termómetro.
2. Solo llegar el médico le puso un termómetro.
3. Que calor, nunca había marcado tanto el termómetro.

1. Vigila, no te hagas daño con la grapadora.
2. Encima de mi escritorio podrás encontrar la grapadora.
3. No queda ni una grapa en esta grapadora.

1. No sabía que habías ido a esa montaña.
2. A Juan le encanta ir a la montaña.
3. Jaime y Nieves fueron a escalar una montaña.

1. Jesús no sabe donde ha metido su tarjeta.
2. Al irnos del hotel nos dieron una tarjeta.
3. En esta tienda no me aceptaron la tarjeta.

1. Pídele a la vecina un poco de chocolate.
2. Paula no puede hacer el pastel sin chocolate.
3. A partir del cacao se hace el chocolate.

1. Déjalo ya, no te van bien estos calcetines.
2. Mañana en el mercadillo me compraré unos calcetines.
3. Antes de ponerte los zapatos ponte los calcetines.

1. Vigila, Luisa, se te ha caído una gota.
2. De este medicamento debes tomarte solo una gota.

3. Está lloviendo, me acaba de caer una gota.

1. Juan no está ha salido a hacer ejercicio.
2. Vigila, no te hagas daño haciendo este ejercicio.
3. Para adelgazar nada mejor que dieta y ejercicio.

1. Pedro se ha dejado en casa la toalla.
2. En la playa alguien me robó la toalla.
3. Después de ducharte sécate bien con la toalla.

1. Todavía no sabe de quien es la canción.
2. Pablo le ha escrito a María una canción.
3. En el colegio aprendió a cantar esta canción.

1. A Esther no le vendrán bien estos zapatos.
2. Juan no ha querido comprarse unos nuevos zapatos.
3. Esta zapatería no tiene mucha variedad de zapatos.

1. Primero de todo se fija en sus dientes.
2. En una pelea se le rompieron dos dientes.
3. Después de comer debes cepillarte bien los dientes.

1. A Carmen no le gusta nada su nariz.
2. Este niño siempre se está tocando la nariz.
3. No puede oler nada, tiene tapada la nariz.

1. José siempre lleva en el bolsillo un lápiz.
2. Jaimito necesita para el colegio un nuevo lápiz.
3. Lo podrás borrar si lo escribes en lápiz.

1. Baja a la ferretería a comprar una bombilla.
2. Si quieres luz tendrás que poner otra bombilla.
3. Para ahorrar luz, compra este tipo de bombilla.

1. Los niños en la granja vieron un avestruz.
2. El pájaro más grande existente es el avestruz.
3. Este huevo tan grande debe ser de avestruz.

1. En un reportaje vi como vivían los leones.
2. Mañana en el zoo veremos a muchos leones.
3. Los reyes de la selva son los leones.

1. Mi hijo solo quiere juguetes que sean dinosaurios.
2. Juan sabe mucho de como vivían los dinosaurios.
3. En la película Jurassic Park salían muchos dinosaurios.

1. Juanito se pasaría todo el día comiendo queso.
2. Voy a la tienda a por un queso.
3. En los dibujos los ratones siempre comen queso.

1. Víctor es un gran estudioso de las pirámides.
2. Todavía no saben como se construyeron las pirámides.
3. Navegando por el Nilo pude ver las pirámides.

1. El técnico vendrá mañana a reparar la ducha.
2. Cuando llego a casa siempre tomo una ducha.
3. Ahorró espacio en el baño poniendo una ducha.

1. En este mundo cada vez hay menos árboles.
2. Desde casa de Juan se ven muchos árboles.

3. En este bosque ya han talado demasiados árboles.

1. Ayer José se fue a comprar una raqueta.
2. No podemos jugar si no tienes la raqueta.
3. Para jugar a tenis necesitas tener una raqueta.

1. Es muy difícil sacar las manchas de aceite.
2. En el supermercado estaba de oferta el aceite.
3. Para freír los calamares debes poner abundante aceite.

1. Todo el mundo tiene en casa un parchís.
2. Amarillo, azul, rojo, verde los colores del parchís.
3. La mayoría de gente sabe jugar al parchís.

1. El padre de Juan tiene un gran bigote.
2. El novio de María ha decidido dejarse bigote.
3. El gran pintor Dalí tenía un característico bigote.

1. Joaquín y María se han cambiado de ciudad.
2. Mis tíos todavía viven en la misma ciudad.
3. La gente de campo no soporta la ciudad.

1. Mi madre me ha enseñado a hacer paella.
2. Ayer al mediodía Marina hizo para comer paella.
3. Tienes que comprar arroz para hacer la paella.

1. Iba paseando y se cayó en un río.
2. Detrás de esta montaña hay un gran río.
3. Te pueden multar si pescas en este río.

1. La madre de Carmen quiere que estudie peluquería.
2. Mañana tarde me gustaría ir a la peluquería.
3. María es peluquera, y tiene su propia peluquería.

1. Encima de la mesa pequeña había una rosa.
2. Que pena ya se ha marchitado la rosa.
3. Por San Jordi Carlos me regaló una rosa.

1. A Carmen le regalaron un juego de sábanas.
2. Juan se disfrazó poniéndose por encima unas sábanas.
3. José, a tu cama toca cambiarle las sábanas.

1. Era un paisaje precioso todo lleno de girasoles.
2. Me han regalado unas cuantas semillas de girasoles.
3. Las pipas son las semillas de los girasoles.

1. Los padres de Mario tienen un nuevo barco.
2. Este verano Carlos tendrá que viajar en barco.
3. Como adora navegar se ha comprado un barco.

1. Parece mentira que no te gusten estos colores.
2. No me gusta nada esta combinación de colores.
3. Carlos me ha regalado flores de distintos colores.

1. Sin querer se me ha roto el salero.
2. Ves a la cocina y tráeme el salero.
3. No queda nada de sal en el salero.

1. Estuvo dando vueltas pero no encontró el aeropuerto.
2. Tendrías que llegar un poco antes al aeropuerto.

3. Su avión sale a las siete del aeropuerto.

1. Ayer tarde su padre le regaló una película.
2. Han elegido a Carmen para hacer una película.
3. En la cartelera no hay ninguna buena película.

1. Carlos no sabía que Bea no tenía padre.
2. Cuando llegó a casa ya estaba su padre.
3. Mañana comeremos con mi madre y mi padre.

1. Carmen ayer empezó a trabajar en un colegio.
2. Pablo ya tiene edad para ir al colegio.
3. Carlitos va a natación cuando sale del colegio.

1. A Carlos le gustaría vivir en una isla.
2. Este verano iremos de vacaciones a una isla.
3. Hoy he aprendido que Menorca es una isla.

1. He buscado pero no he encontrado tu amigo.
2. Es triste, pero Juan no tiene ningún amigo.
3. Siempre me ayuda, Pedro es mi mejor amigo.

1. Esta mañana temprano se ha estropeado el ascensor.
2. Se compró un piso que no tenía ascensor.
3. Ves por las escaleras no funciona el ascensor.

1. El coche de Carlos ha perdido la matrícula.
2. Todavía no he ido a pagar la matrícula.
3. Gracias a la beca no pago la matrícula.

1. José ha empezado ha trabajar en una serie.
2. Maria cree que Dallas fue una gran serie.
3. A mi abuela le encanta ver esta serie.

1. A mi padre no le gusta este chiste.
2. Que memoria, siempre se acuerda de algún chiste.
3. No puedo parar de reír, cuéntame otro chiste.

1. No entiendo como te puedes creer el horóscopo.
2. Norma se pasa el día leyendo el horóscopo.
3. Yo soy Virgo, ¿Carmen cuál es tu horóscopo?.

1. Carlos y Carmen tienen pensado irse en otoño.
2. La época que más me gusta es otoño.
3. Verano, invierno, primavera y me falta el otoño.

1. Por favor cuando vengas podrías traerme una almohada.
2. Tendrías que comprar una funda para esta almohada.
3. Me duele el cuello de dormir sin almohada.

1. Esta noche dan por la televisión el sorteo.
2. Carlos y Marina no participaron en el sorteo.
3. He comprado números para participar en el sorteo.

1. Sus padres le han regalado la nueva cocina.
2. Carmen está ahorrando para poder reformar la cocina.
3. Después de hacer la cena limpia la cocina.

1. Carlitos hoy ha aprendido que es un satélite.
2. Hoy han enviado al espacio un nuevo satélite.

3. No sabía que la luna es un satélite.

1. No puedo acabar el trabajo no tengo pegamento.
2. Manolo baja a la papelería a comprar pegamento.
3. Si quieres que te lo pegue tráeme pegamento.

1. Ya le has dado a Carlos tu mensaje.
2. Carmen todavía no me ha mandado el mensaje.
3. Cuando abrí el Outlook no tenía ningún mensaje.

1. Te has dejado en el coche el mapa.
2. Para el viaje no olvides coger un mapa.
3. No se dónde estamos, míralo en el mapa.

1. Es un científico muy famoso, descubrió una vacuna.
2. A mi hijo ya le toca la vacuna.
3. Si no quieres padecer tétanos ponte la vacuna.

1. Los niños no deberían jugar con las tijeras.
2. No se dónde Juana ha metido las tijeras.
3. No cortan nada, lleva a afilar las tijeras.

1. Al cruzar no vio que venía un taxi.
2. A Carlos le fue imposible encontrar un taxi.
3. Cuando quieras irte, avísame que llamaré un taxi.

1. A María le encanta trabajar en la panadería.
2. Si quieres un bocadillo baja a la panadería.
3. Está muy bueno el pan de esta panadería.

1. Nos dimos cuenta que le faltaba una pierna.
2. Al caerse Juan se lastimó en una pierna.
3. Se rompió el fémur, le enyesaron la pierna.

1. Esta tarde iremos a comprar un nuevo pantalón.
2. Carmen, tengo que coserte otra vez el pantalón.
3. Esta chaqueta no te combina con el pantalón.

1. Nos vimos y no quiso darme la mano.
2. Hoy Juan le pedirá a María la mano.
3. María fue a que le leyeran la mano.

1. Joaquín sueña tener de mascota a dos serpientes.
2. Tiene en un terrario un par de serpientes.
3. En India podemos encontrar muchos encantadores de serpientes.

1. Hoy vendrá el técnico a instalarme el teléfono.
2. A Marcos no le gusta hablar por teléfono.
3. Vi a Juan y me pidió tu teléfono.

1. No se pude salir después de la campana.
2. Arriba en el campanario podemos ver una campana.
3. ¿Entramos a clase? Ya ha sonado la campana.

1. Laura había trabajado en una fábrica de azúcar.
2. Esta tarta no sabe bien, hay demasiado azúcar.
3. El pastel quedará demasiado dulce, échale menos azúcar.

1. Miriam ha empezado a trabajar en un restaurante.
2. Luisa me recomendó que fuéramos a este restaurante.

3. Para cenar mejor reservar mesa en el restaurante.

1. No se como podía ir con tantas manchas.
2. Iré al médico que me mire estas manchas.
3. Ponte otra camisa, esta está llena de manchas.

Experiment 2

A. Novel words – corresponding Spanish word

Anclana – bicicleta; ateloso - tomate; bacono – pantalón; beteso – coche; bisaco – plátano; ceteno – cinturón; farena – película; fiteto – periódico; fleta – bufanda; gitero - teléfono; gurato – hotel; imbra – flor; laeta – grapadora; lertico – pez; lesico – lápiz; lineto – gato; macito – diente; nalposa – naranja; nilata – casa; oerelo – anillo; olieto – fútbol; peltro – brazo; penrota – silla; petira – cama; pitsal – cine; quiro – corazón; ristro – dedo; sendelio – espejo; sogaro – pastel; telepo – libro; trepto – cuadro; tulsas – gafas; vatesa – nevera; vileta – ventana; yutiro – fuego; zineta – cebolla.

B. Sentences

1. La otra noche Carmen lucía un precioso anillo.
2. María estaba triste porque había perdido el anillo.
3. No se puede sacar del dedo el anillo.

1. Cada día Luís va al colegio en bicicleta.
2. Se rompió el brazo cayendo de la bicicleta.
3. Tengo que cambiar los pedales de la bicicleta.

1. Pedro tiene una gran cicatriz en el brazo.
2. El perro mordió a Cristina en el brazo.
3. No podrás cogerlo si no estiras el brazo.

1. Paloma olvidó guardar en su bolso la bufanda.
2. Nada más "llegar," "María," se quitó la bufanda.
3. En invierno protejo mi garganta con una bufanda.

1. En el Carrefour hay grandes ofertas en camas.
2. Donde más cómodo estoy es en la cama.
3. Cada mañana se va sin hacer la cama.

1. Carmen está deseando poderse comprar una nueva casa.
2. Iba tan borracho que no encontró su casa.
3. Después del trabajo me voy directamente a casa.

1. Voy a ir al supermercado a comprar cebollas.
2. A Lucía le encanta la hamburguesa con cebolla.
3. Le lloran los ojos siempre que pela cebollas.

1. He olvidado comprar las entradas para el cine.
2. Hoy hemos quedado todos para ir al cine.
3. Compraré palomitas antes de entrar en el cine.

1. No puedo llevar este traje sin un cinturón.
2. En esta tienda de ropa no venden cinturones.
3. Se me caen los pantalones sin el cinturón.

1. Mario siempre olvida donde ha dejado el coche.
2. Ha salido muy cara la reparación del coche.
3. Ha vuelto a pinchar la rueda del coche.

1. Iván tiene una lesión importante en el corazón.
2. Su padre tuvo un grave ataque de corazón.
3. Un trasplante muy difícil es el de corazón.

1. A Laura le encantan los colores del cuadro.
2. De este paisaje podría hacerse un buen cuadro.
3. Patricia ya ha llevado ha enmarcar el cuadro.

1. De "noche," caí y me corte mi dedo.
2. En "vacaciones," Pablo se ha roto un dedo.
3. Al cerrar la puerta se pilló el dedo.

1. Primero de todo se fija en sus dientes.
2. En una pelea se le rompieron dos dientes.
3. Después de comer debes cepillarte bien los dientes.

1. Carmen siempre ha querido tener un gran espejo.
2. El lavabo ha quedado bonito con el espejo.
3. Es un presumido siempre mirándose en el espejo.

1. "Carol," no deberías poner al sol esta flor.
2. Me gustaría comprar una planta que de flor.
3. No queda ni un pétalo en esta flor.

1. Suerte que se dio cuenta que había fuego.
2. Se me acercó misteriosamente y me pidió fuego.
3. "Vigila," te puedes quemar si juegas con fuego.

1. Aunque parezca imposible Juan no soporta el fútbol.
2. Mario se pone nervioso cuando ve el fútbol.
3. El Barça es un gran equipo de fútbol.

1. Esta mañana he ido a comprar unas gafas.
2. No me gusta nada tener que usar gafas.
3. Para leer o ver la televisión necesito gafas.

1. Esta mañana se ha perdido mi querido gato.
2. Desde "pequeña," Luisa tiene alergia a los gatos.
3. Como tiene ratones se ha comprado un gato.

1. "Vigila," no te hagas daño con la grapadora.
2. Encima de mi escritorio podrás encontrar la grapadora.
3. No queda ni una grapa en esta grapadora.

1. Si vas "fuera," mejor búscate un buen hotel.
2. No se si hay piscina en este hotel.
3. Carmen prefirió las cuatro estrellas de este hotel.

1. José siempre lleva en el bolsillo un lápiz.
2. Jaimito necesita para el colegio un nuevo lápiz.
3. Lo podrás borrar si lo escribes en lápiz.
1. Juan le ha regalado a Arancha un libro.

2. Me he dejado en la biblioteca el libro.
3. ¿Quién ha mojado las hojas de este libro?.
1. En invierno me apetece siempre comer muchas naranjas.

2. Una de mis frutas preferidas son las naranjas.
3. De mañana me apetece un zumo de naranjas.

1. Esta tarde me traen a casa la nevera.
2. Voy a bajar la temperatura de la nevera.
3. La bebida debe estar enfriándose en la nevera.

1. Desde ayer que me duelen mucho los ojos.
2. Marrón claro es el color de sus ojos.
3. Me han recetado unas gotas para los ojos.

1. Como Lola es diabética no puede comer pastel.
2. Iré a la confitería a comprar un pastel.
3. Mi madre preparó para mi cumpleaños un pastel.

1. El veterinario dijo que no tocaras los peces.
2. A Pablo se le murieron todos los peces.
3. Ayer me regalaron una pecera llena de peces.

1. Ayer tarde su padre le regaló una película.
2. Han elegido a Carmen para hacer una película.
3. En la cartelera no hay ninguna buena película.

1. Me gusta pasar el rato con el periódico.
2. Supe de aquel empleo a través del periódico.
3. Pablo cada día compra y lee el periódico.

1. Hoy para desayunar he tomado batido de plátano.
2. Antes de comértelo quítale la piel al plátano.
3. La fruta típica de Canarias es el plátano.

1. En el piso nuevo todavía no tengo sillas.
2. Se ha roto una pata de la silla.
3. Esta mesa no hace conjunto con las sillas.

1. Hoy vendrá el técnico a instalarme el teléfono.
2. A Marcos no le gusta hablar por teléfono.
3. Vi a Juan y me pidió tu teléfono.

1. Desde que era pequeña me encanta comer tomate.
2. El bocadillo estará mucho más bueno con tomate.
3. En Cataluña es típico el pan con tomate.

1. Cuando compramos la casa cambiamos todas las ventanas.
2. El despacho donde trabaja Carmen no tiene ventanas.
3. Hay demasiado ruido "fuera," puedes cerrar las ventanas.

Experiment 4

A. Novel words – corresponding Spanish word

Ambil - interruptor; anclana – bicicleta; arniso - horno; astiro – cenicero; ateloso - tomate; banita – nube; belto – pájaro; beteso – coche; bilsa – manzana; bina – serpiente; bisaco – plátano; biteco – ajo; campeto – biquini; catela – mosca; cemaco – ascensor; cerino – barco; ceteno – cinturón; chacorena – guitarra; cija – llave; cilso – pan; cirana – uña; clito – oso; cratino – buzón; culiseo – avestruz; desala –

isla; dico – lazo; dilera – tarjeta; dileto – autobús; dodero – café; ectero – martillo; endole – avión; enlufe – tenedor; eritino – chocolate; esreso – plato; fagarino – pegamento; faleto – semáforo; falito – árbol; falliro – grifo; farena – película; ferieto – mapa; fimeta – toalla; fiteto – periódico; fleta – bufanda; flipeto – casco; gareta – lavadora; gerias – tijeras; gitero - teléfono; gopeta – rosa; gurato – hotel; hareta – pila; histana – almohada; hiteco – móvil; ilero – regalo; imbra – flor; intrial – helicóptero; iprita – pirámide; jarilo – elefante; laeta – grapadora; lecato – guante; lepito – cuchillo; lertico – pez; lesico – lápiz; liantro – dinosaurio; licata – raqueta; lineto – gato; liñero – despertador; lizeno – chiste; luerca – pistola; macito – diente; malinro – queso; malisiro – calcetín; mecrallo – abrigo; milso – ojo; miluto – termómetro; nagato – bigote; nalposa – naranja; niepa – uva; nilanera – sábana; nilata – casa; nileca – bombilla; nilopo – taxi; nosa – caja; oerelo – anillo; oleta – plancha; olieto – fútbol; oprisa – cabra; ovisera – panadería; paceto – río; pano – cubo; patora – campana; pecua – mariposa; peltro – brazo; penrota – silla; petira – cama; pieta – abeja; pilso – bolígrafo; pireje – cigarro; pireliso – médico; pirter – collar; pitsal – cine; puca – maleta; quiro – corazón; recola – taza; remoca – pierna; rinaca – patata; ristro – dedo; sabeta – lámpara; saceyo – televisor; safena – cocina; saleca – vaca; saleno – león; sendelio – espejo; sileca – libreta; silera – vela; silino – zapato; siltra – aguja; siptio – sombrero; sitera – puerta; sito – pollo; sofireto – restaurante; sogaro – pastel; solefa – bandera; tacela – luna; tacetelo – ordenador; talino – aceite; tarra – piscina; tastera – zanahoria; telepo – libro; tepoto – canguro; tesa – leche; tezo – botón; ticha – pelota; tilapo – reloj; tileco – vestido; tilina – nariz; tombro – bolso; trepto – cuadro; trilebo – sofá; tristero – paraguas; tulsas – gafas; ulina – gota; urtilera – iglesia; utileco – bar; valireta – escalera; valirino – girasol; vatesa – nevera; viato – azúcar; vileta – ventana; yalito – microondas; yutiro – fuego; zilatera – calculadora, zineta – cebolla.

B. Sentences

1. Como cada año me toca limpiar la piscina.
2. Este verano no iré a la misma piscina.
3. Me ducho antes de bañarme en la piscina.

1. En invierno me apetece siempre comer muchas naranjas.
2. Una de mis frutas preferidas son las naranjas.
3. De mañana me apetece un zumo de naranjas.

1. Hoy para comer me he cocinado unas patatas.
2. Rosa suele combinar sus platos preferidos con patatas.
3. En España es típica la tortilla de patatas.

1. Desde aquí me resulta imposible ver la luna.
2. Esta noche quizá no podamos ver la luna.
3. En el futuro habrá ciudades en la luna.

1. Por seguridad nos decidimos a cambiar el interruptor.
2. En esta habitación me cuesta encontrar el interruptor.
3. La luz se enciende al apretar el interruptor.

1. Iván tiene una lesión importante en el corazón.
2. Su padre tuvo un grave ataque de corazón.
3. Un trasplante muy difícil es el de corazón.

1. La policía no pudo nunca encontrar la pistola.
2. El criminal se decidió a comprar una pistola.

3. Sólo nos queda una bala en la pistola.

1. En verano me apetecen de postres las uvas.
2. Este año no hubo buena cosecha de uvas.
3. Este fin de año olvidé comprar las uvas.

1. Hoy Mario mientras esquiaba ha perdido los guantes.
2. En el skating es obligatorio llevar siempre guantes.
3. Como es friolera, siempre lleva puestos los guantes.

1. No encuentro un espacio apropiado para el cubo.
2. Normalmente la basura la tiramos en el cubo.
3. Cuanto este lleno, ves a vaciar el cubo.

1. Esther se pinchó al sentarse encima del tenedor.
2. A la cubertería nueva le falta un tenedor.
3. Cambia los cubiertos, a la izquierda el tenedor.

1. El insecto que menos gusta es la mosca.
2. Con este insecticida no podrás matar la mosca.
3. La Tsé-tsé es un tipo especial de mosca.

1. De noche, caí y me corte mi dedo.
2. En vacaciones, Pablo se ha roto un dedo.
3. Al cerrar la puerta se pilló el dedo.

1. En la tienda de muebles no quedaban sofás.
2. A esta casa le falta en buen sofá.
3. A veces hago la siesta en el sofá.

1. Me ha pedido prestado de nuevo mi abrigo.
2. Esta tarde iré a comprarme un buen abrigo.
3. Este invierno hace mucho frío, ponte mi abrigo.

1. El hombre del tiempo dice que vendrán nubes.
2. Es muy relajante poder quedarse mirando las nubes.
3. Lloverá, el cielo está todo lleno de nubes.

1. Voy a encender el horno para hacer pollo.
2. En esta granja de Manresa se crían pollos.
3. Le gusta sobre todo el muslo del pollo.

1. En el piso nuevo todavía no tengo sillas.
2. Se ha roto una pata de la silla.
3. Esta mesa no hace conjunto con las sillas.

1. Esta mañana se ha perdido mi querido gato.
2. Desde pequeña, Luisa tiene alergia a los gatos.
3. Como tiene ratones se ha comprado un gato.

1. En la nevera no queda nada de leche.
2. Silvia se ha bebido un vaso de leche.
3. Me apetece un bol de cereales con leche.

1. Esta mañana he ido a comprar unas gafas.
2. No me gusta nada tener que usar gafas.
3. Para leer o ver la televisión necesito gafas.

1. Siempre suelo llevar en la mochila algún bolígrafo.
2. No se puede hacer el examen sin bolígrafo.

3. Me he manchado con la tinta del bolígrafo.

1. Cuando compramos la casa cambiamos todas las ventanas.
2. El despacho donde trabaja Carmen no tiene ventanas.
3. Hay demasiado ruido fuera, puedes cerrar las ventanas.

1. Me gusta pasar el rato con el periódico.
2. Supe de aquel empleo a través del periódico.
3. Pablo cada día compra y lee el periódico.

1. Me gusta el ruido metálico de las llaves.
2. Para abrir las puertas son necesarias las llaves.
3. Pedro está buscando en su bolsillo las llaves.

1. Paloma olvidó guardar en su bolso la bufanda.
2. Nada más llegar, María, se quitó la bufanda.
3. En invierno protejo mi garganta con una bufanda.

1. He olvidado comprar las entradas para el cine.
2. Hoy hemos quedado todos para ir al cine.
3. Compraré palomitas antes de entrar en el cine.

1. Desde que era pequeña me encanta comer tomate.
2. El bocadillo estará mucho más bueno con tomate.
3. En Cataluña es típico el pan con tomate.

1. Ten cuidado no se te caigan los platos.
2. Sara ha dejado en la cocina los platos.
3. Sirvió la comida de los invitados en platos.

1. La profesora escribió el problema en la libreta.
2. ¿Dónde hay una papelería para comprar una libreta?.
3. Se ha roto la espiral de la libreta.

1. Desde ayer que me duelen mucho los ojos.
2. Marrón claro es el color de sus ojos.
3. Me han recetado unas gotas para los ojos.

1. Me acercaré al mercado a comprar algunos ajos.
2. Siempre me gusta añadir a los sofritos ajos.
3. A los vampiros no les gustan los ajos.

1. Acabaré de decorar la casa con una lámpara.
2. Encima de la mesa he puesto una lámpara.
3. Falta luz en ese rincón pondré una lámpara.

1. En el Carrefour hay grandes ofertas en camas.
2. Donde más cómodo estoy es en la cama.
3. Cada mañana se va sin hacer la cama.

1. Has olvidado poner en la mesa mi cuchillo.
2. En la cocina no he encontrado ningún cuchillo.
3. Se ha cortado el dedo con un cuchillo.

1. Debajo de la ropa llevo puesto el biquini.
2. Para este verano me he comprado un biquini.
3. He olvidado la parte de arriba del biquini.

1. A Laura le encantan los colores del cuadro.
2. De este paisaje podría hacerse un buen cuadro.

3. Patricia ya ha llevado ha enmarcar el cuadro.

1. Carmen siempre ha querido tener un gran espejo.
2. El lavabo ha quedado bonito con el espejo.
3. Es un presumido siempre mirándose en el espejo.

1. Me gustaría ahorrar para comprarme un buen ordenador.
2. José pasa todo el día delante del ordenador.
3. Es imposible conectarse a internet desde este ordenador.

1. Ese punto en el cielo es un avión.
2. Óscar nunca ha visto de cerca un avión.
3. Todavía no he subido nunca en un avión.

1. Es muy sano comer a diario una manzana.
2. De postre Paula se ha comido una manzana.
3. Los expulsaron del paraíso por comer una manzana.

1. Pedro tiene una gran cicatriz en el brazo.
2. El perro mordió a Cristina en el brazo.
3. No podrás cogerlo si no estiras el brazo.

1. En toda la casa no hay ningún cenicero.
2. En clase de cerámica he hecho un cenicero.
3. Voy a apagar el cigarro en el cenicero.

1. Hoy para desayunar he tomado batido de plátano.
2. Antes de comértelo quítale la piel al plátano.
3. La fruta típica de Canarias es el plátano.

1. A Carolina le dan mucho miedo las abejas.
2. No lo toques o te picarán las abejas.
3. La miel la tenemos gracias a las abejas.

1. No puedo llevar este traje sin un cinturón.
2. En esta tienda de ropa no venden cinturones.
3. Se me caen los pantalones sin el cinturón.

1. Cada día Luís va al colegio en bicicleta.
2. Se rompió el brazo cayendo de la bicicleta.
3. Tengo que cambiar los pedales de la bicicleta.

1. Juan le ha regalado a Arancha un libro.
2. Me he dejado en la biblioteca el libro.
3. ¿Quién ha mojado las hojas de este libro?.

1. Pepa ha metido en el horno el pan.
2. Para mantener la línea intenta no comer pan.
3. Cada día suele comprar dos barras de pan.

1. Como Lola es diabética no puede comer pastel.
2. Iré a la confitería a comprar un pastel.
3. Mi madre preparó para mi cumpleaños un pastel.

1. Cuidado Carlos, no te quemes con la vela.
2. Para el mal olor mejor poner una vela.
3. Me manché con la cera de la vela.

1. En el huerto no hay plantada ninguna zanahoria.
2. A esta ensalada le falta poner una zanahoria.

3. Esta verdura de color naranja debe ser zanahoria.

1. María detesta mucho el olor de los cigarros.
2. Paco ve a comprar un paquete de cigarros.
3. Después de comer casi siempre fumo dos cigarros.

1. Juan siempre se deja en casa el reloj.
2. Se me ha roto la correa del reloj.
3. Mañana tengo que atrasar una hora el reloj.

1. En medio de la carretera había una vaca.
2. En toda la granja solo hay una vaca.
3. El granjero atendió el parto de una vaca.

1. Carol, no deberías poner al sol esta flor.
2. Me gustaría comprar una planta que de flor.
3. No queda ni un pétalo en esta flor.

1. Para colgar el cuadro es necesario un martillo.
2. En la caja de herramientas está el martillo.
3. Me he golpeado el dedo con el martillo.

1. El fuerte viento se ha llevado su sombrero.
2. No se suele ver a nadie con sombrero.
3. Protégete la cabeza del sol con este sombrero.

1. Un animal que me gusta es el canguro.
2. Ir saltando es como se desplaza el canguro.
3. Cuando fui a Australia no vi ningún canguro.

1. Mañana para la fiesta me pondré este collar
2. Pedro me gustaría que me regalases un collar.
3. Podrías ponerte en el cuello este precioso collar.

1. Debes tener cuidado en donde dejas la aguja.
2. Has olvidado sacar de la camisa una aguja.
3. Mi abuela ya no puede enhebrar la aguja.

1. Voy a ir al supermercado a comprar cebollas.
2. A Lucía le encanta la hamburguesa con cebolla.
3. Le lloran los ojos siempre que pela cebollas.

1. Sacó el monedero lleno de billetes del bolso.
2. Patricia nunca olvida llevar con ella su bolso.
3. María siempre lleva de todo dentro del bolso.

1. Esta tarde me traen a casa la nevera.
2. Voy a bajar la temperatura de la nevera.
3. La bebida debe estar enfriándose en la nevera.

1. Me parece que es demasiado grande esta maleta.
2. Todo no va a caber en una maleta.
3. Al llegar al aeropuerto habían perdido mi maleta.

1. Le ha regalado a su hijo una pelota.
2. Es imposible jugar si no conseguimos una pelota.
3. El portero fue capaz de atrapar la pelota.

1. Ayer al ir al zoo vimos muchos osos.
2. ¡Ten cuidado! en este bosque viven muchos osos.

3. En los dibujos Yoggi y Bubú eran osos.

1. Es una gran aficionada a observar los pájaros.
2. En invierno no se suelen ver muchos pájaros.
3. En este árbol hay un nido de pájaros.

1. Ha ido a la tienda a pedir cajas.
2. Es imposible poner tantos libros en estas cajas.
3. Para la mudanza mejor ponerlo todo en cajas.

1. Carlos ha vuelto a perder el último autobús.
2. A esta hora ya no pasa ningún autobús.
3. Estuve media hora en la parada del autobús.

1. En el museo hay una exposición de mariposas.
2. Todos los insectos son asquerosos menos las mariposas.
3. Las orugas se acaban convirtiendo en bonitas mariposas.

1. No te lo puedo arreglar sin el botón.
2. En la caja de costura habrá algún botón.
3. Pepe, a esta camisa le falta un botón.

1. Mario siempre olvida donde ha dejado el coche.
2. Ha salido muy cara la reparación del coche.
3. Ha vuelto a pinchar la rueda del coche.

1. Después del temporal tuvo que cambiar la puerta.
2. Acabamos de pintar, intenta no tocar la puerta.
3. Fuimos a verte pero estaba cerrada la puerta.

1. Le da mucho respeto entrar en una iglesia.
2. Hace 500 años se construyó esta magnífica iglesia.
3. Aunque es creyente nunca va a la iglesia.

1. Sin querer se me ha roto una taza.
2. No me gusta tomar la leche en taza.
3. Elena quiere tomar el té en una taza.

1. Por su cumpleaños Juan le regaló un casco.
2. Si quieres ver las obras debes llevar casco.
3. Para ir en moto es obligatorio ponerse casco.

1. María no puede permitirse comprarse un nuevo vestido.
2. Ves a la tintorería a buscar el vestido.
3. Cuando se casó se diseñó ella el vestido.

1. Para ganar el juego debes coger la bandera.
2. Debes saber que cada país tiene su bandera.
3. En lo alto del castillo ondeaba una bandera.

1. El veterinario dijo que no tocaras los peces.
2. A Pablo se le murieron todos los peces.
3. Ayer me regalaron una pecera llena de peces.

1. En África viven la mayoría de los elefantes.
2. El otro día en el circo vi elefantes.
3. Los mamuts eran los antepasados de los elefantes.

1. Imposible, Carlos nunca aprenderá a utilizar la plancha.
2. Manolito, vigila no te quemes con la plancha.

3. Cuando se seque la camisa, pásale la plancha.

1. En nuestra calle ya han puesto otro semáforo.
2. Tuvo el accidente porque no vio el semáforo.
3. Los coches pasarán cuando esté verde el semáforo.

1. En casa de María no tienen ningún televisor.
2. El técnico vendrá mañana a reparar el televisor.
3. No pudo sintonizar ningún canal en este televisor.

1. Para mi cumpleaños necesito comprarme un nuevo paraguas.
2. Con ese viento era imposible abrir el paraguas.
3. Va a llover, mejor que cojas el paraguas.

1. Joaquín ya ha cambiado otra vez de móvil.
2. He tenido que cambiar la batería del móvil.
3. He olvidado el código PIN de mi móvil.

1. Mañana o pasado iré a comprar un regalo.
2. Aunque eran sus padres solo trajeron un regalo.
3. Es mi cumpleaños seguramente me traerán un regalo.

1. El gran sueño de Carolina es ser médico.
2. Al llegar había muchísima gente esperando al médico.
3. Me duele mucho la barriga, iré al médico.

1. Si vas fuera, mejor búscate un buen hotel.
2. No se si hay piscina en este hotel.
3. Carmen prefirió las cuatro estrellas de este hotel.

1. Luís se pasa el día en el bar.
2. Debajo de mi casa han abierto un bar.
3. Mañana iremos a tomar algo a aquel bar.

1. Esta tarde Juan se ha comprado un microondas.
2. La cocina es pequeña, no cabe un microondas.
3. Tengo la leche caliente enseguida gracias al microondas.

1. Fernando siempre toma por las noches un café.
2. A Luisa nunca le ha gustado el café.
3. Toda esta cafetera, si solo yo tomaré café.

1. En casa de María aún no tienen horno.
2. Llamaré para que vengan a reparar el horno.
3. Antes de meter la pizza calienta el horno.

1. Juan le ha regalado a Nieves una guitarra.
2. Pablo se ha apuntado a clases de guitarra.
3. Santana es de los mejores tocando la guitarra.

1. Aunque parezca imposible Juan no soporta el fútbol.
2. Mario se pone nervioso cuando ve el fútbol.
3. El Barça es un gran equipo de fútbol.

1. La otra noche Carmen lucía un precioso anillo.
2. María estaba triste porque había perdido el anillo.
3. No se puede sacar del dedo el anillo.

1. Han decidido que van a cambiar el grifo.
2. No se quién siempre deja abierto el grifo.

3. Después de beber tienes que cerrar el grifo.

1. Antonio todavía no sabe como funciona la calculadora.
2. Para el curso que viene necesitaré una calculadora.
3. Esta división es muy complicada utilizaré la calculadora.

1. Busca en ese cajón si encuentras una pila.
2. Esto no funciona porque le falta una pila.
3. Este reloj está parado, mejor cambiaré la pila.

1. María olvidó poner su nombre en el buzón.
2. Alguien me ha robado las cartas del buzón.
3. No sé el piso, míralo en el buzón.

1. Carmen está deseando poderse comprar una nueva casa.
2. Iba tan borracho que no encontró su casa.
3. Después del trabajo me voy directamente a casa.

1. Iba paseando y me encontré con una cabra.
2. A José le encanta el queso de cabra.
3. Hay leche de vaca pero también de cabra.

1. A Cristina se le ha estropeado el despertador.
2. Mario odia el ruido que hace su despertador.
3. Mario siempre se despierta sin necesidad del despertador.

1. Esto es un peligro, deberían arreglar esta escalera.
2. He tenido que pedir a Carmen una escalera.
3. El ascensor no funciona sube por la escalera.

1. Al caer se rompió un par de uñas.
2. María tiene unas manchas blancas en las uñas.
3. El gato se defendió arañándole con las uñas.

1. Suerte que se dio cuenta que había fuego.
2. Se me acercó misteriosamente y me pidió fuego.
3. Vigila, te puedes quemar si juegas con fuego.

1. Pablo tendrás que aprender a utilizar la lavadora.
2. Mi gato se metió dentro de la lavadora.
3. Esta camiseta no puede ponerse en la lavadora.

1. El coche que me he comprado lleva termómetro.
2. Solo llegar el médico le puso un termómetro.
3. Que calor, nunca había marcado tanto el termómetro.

1. Vigila, no te hagas daño con la grapadora.
2. Encima de mi escritorio podrás encontrar la grapadora.
3. No queda ni una grapa en esta grapadora.

1. Jesús no sabe donde ha metido su tarjeta.
2. Al irnos del hotel nos dieron una tarjeta.
3. En esta tienda no me aceptaron la tarjeta.

1. Pídele a la vecina un poco de chocolate.
2. Paula no puede hacer el pastel sin chocolate.
3. A partir del cacao se hace el chocolate.

1. Déjalo ya, no te van bien estos calcetines.
2. Mañana en el mercadillo me compraré unos calcetines.

3. Antes de ponerte los zapatos ponte los calcetines.

1. Vigila, Luisa, se te ha caído una gota.
2. De este medicamento debes tomarte solo una gota.
3. Está lloviendo, me acaba de caer una gota.

1. Pedro se ha dejado en casa la toalla.
2. En la playa alguien me robó la toalla.
3. Después de ducharte sécate bien con la toalla.

1. A Esther no le vendrán bien estos zapatos.
2. Juan no ha querido comprarse unos nuevos zapatos.
3. Esta zapatería no tiene mucha variedad de zapatos.

1. Primero de todo se fija en sus dientes.
2. En una pelea se le rompieron dos dientes.
3. Después de comer debes cepillarte bien los dientes.

1. A Carmen no le gusta nada su nariz.
2. Este niño siempre se está tocando la nariz.
3. No puede oler nada, tiene tapada la nariz.

1. José siempre lleva en el bolsillo un lápiz.
2. Jaimito necesita para el colegio un nuevo lápiz.
3. Lo podrás borrar si lo escribes en lápiz.

1. Baja a la ferretería a comprar una bombilla.
2. Si quieres luz tendrás que poner otra bombilla.
3. Para ahorrar luz, compra este tipo de bombilla.

1. Los niños en la granja vieron un avestruz.
2. El pájaro más grande existente es el avestruz.
3. Este huevo tan grande debe ser de avestruz.

1. En un reportaje vi como vivían los leones.
2. Mañana en el zoo veremos a muchos leones.
3. Los reyes de la selva son los leones.

1. Mi hijo solo quiere juguetes que sean dinosaurios.
2. Juan sabe mucho de como vivían los dinosaurios.
3. En la película Jurassic Park salían muchos dinosaurios.

1. Juanito se pasaría todo el día comiendo queso.
2. Voy a la tienda a por un queso.
3. En los dibujos los ratones siempre comen queso.

1. Víctor es un gran estudioso de las pirámides.
2. Todavía no saben como se construyeron las pirámides.
3. Navegando por el Nilo pude ver las pirámides.

1. En este mundo cada vez hay menos árboles.
2. Desde casa de Juan se ven muchos árboles.
3. En este bosque ya han talado demasiados árboles.

1. Ayer José se fue a comprar una raqueta.
2. No podemos jugar si no tienes la raqueta.
3. Para jugar a tenis necesitas tener una raqueta.

1. Es muy difícil sacar las manchas de aceite.
2. En el supermercado estaba de oferta el aceite.

3. Para freír los calamares debes poner abundante aceite.

1. El padre de Juan tiene un gran bigote.
2. El novio de María ha decidido dejarse bigote.
3. El gran pintor Dalí tenía un característico bigote.

1. Iba paseando y se cayó en un río.
2. Detrás de esta montaña hay un gran río.
3. Te pueden multar si pescas en este río.

1. Encima de la mesa pequeña había una rosa.
2. Que pena ya se ha marchitado la rosa.
3. Por San Jordi Carlos me regaló una rosa.

1. A Carmen le regalaron un juego de sábanas.
2. Juan se disfrazó poniéndose por encima unas sábanas.
3. José, a tu cama toca cambiarle las sábanas.

1. Era un paisaje precioso todo lleno de girasoles.
2. Me han regalado unas cuantas semillas de girasoles.
3. Las pipas son las semillas de los girasoles.

1. Los padres de Mario tienen un nuevo barco.
2. Este verano Carlos tendrá que viajar en barco.
3. Como adora navegar se ha comprado un barco.

1. Ayer tarde su padre le regaló una película.
2. Han elegido a Carmen para hacer una película.
3. En la cartelera no hay ninguna buena película.

1. A Carlos le gustaría vivir en una isla.
2. Este verano iremos de vacaciones a una isla.
3. Hoy he aprendido que Menorca es una isla.

1. Esta mañana temprano se ha estropeado el ascensor.
2. Se compró un piso que no tenía ascensor.
3. Ves por las escaleras no funciona el ascensor.

1. A mi padre no le gusta este chiste.
2. Que memoria, siempre se acuerda de algún chiste.
3. No puedo parar de reír, cuéntame otro chiste.

1. Por favor cuando vengas podrías traerme una almohada.
2. Tendrías que comprar una funda para esta almohada.
3. Me duele el cuello de dormir sin almohada.

1. Sus padres le han regalado la nueva cocina.
2. Carmen está ahorrando para poder reformar la cocina.
3. Después de hacer la cena limpia la cocina.

1. No puedo acabar el trabajo no tengo pegamento.
2. Manolo baja a la papelería a comprar pegamento.
3. Si quieres que te lo pegue tráeme pegamento.

1. Te has dejado en el coche el mapa.
2. Para el viaje no olvides coger un mapa.
3. No se dónde estamos, míralo en el mapa.

1. Los niños no deberían jugar con las tijeras.
2. No se dónde Juana ha metido las tijeras.

3. No cortan nada, lleva a afilar las tijeras.

1. Al cruzar no vio que venía un taxi.
2. A Carlos le fue imposible encontrar un taxi.
3. Cuando quieras irte, avísame que llamaré un taxi.

1. A María le encanta trabajar en la panadería.
2. Si quieres un bocadillo baja a la panadería.
3. Está muy bueno el pan de esta panadería.

1. Nos dimos cuenta que le faltaba una pierna.
2. Al caerse Juan se lastimó en una pierna.
3. Se rompió el fémur, le enyesaron la pierna.

1. Joaquín sueña tener de mascota a dos serpientes.
2. Tiene en un terrario un par de serpientes.
3. En India podemos encontrar muchos encantadores de serpientes.

1. Hoy vendrá el técnico a instalarme el teléfono.
2. A Marcos no le gusta hablar por teléfono.
3. Vi a Juan y me pidió tu teléfono.

1. No se pude salir después de la campana.
2. Arriba en el campanario podemos ver una campana.
3. ¿Entramos a clase? Ya ha sonado la campana.

1. Laura había trabajado en una fábrica de azúcar.
2. Esta tarta no sabe bien, hay demasiado azúcar.
3. El pastel quedará demasiado dulce, échale menos azúcar.

1. Miriam ha empezado a trabajar en un restaurante.
2. Luisa me recomendó que fuéramos a este restaurante.
3. Para cenar mejor reservar mesa en el restaurante.

Appendix B: Stimulus Material for Chapters 4 and 5

Experiment 5

A. Novel words – corresponding Spanish word

Afima – vergüenza; alcazo – silencio; areo – dolor; atual – error; camira – magia; cartuno – milagro; cinca – reserva; coreto – tiempo; cunto – ejemplo; decasa – culpa; demosa – razón; desuba – educación; diera – presión; difo – infinito; diper – gusto; espel – deseo; etudo – futuro; findo – sueño; gamila – fuerza; herno – miedo; imgeo – amor; madida – idea; masuo – humor; milaca – diferencia; miloma – fe; motra – sed; murada – solución; neceita – esperanza; oviro – valor; pepo – control; pesea – verdad; pusofa – paz; ralida – política; recea – cultura; risuta – sociedad.

B. Sentences

1. Me gustan las películas que tratan del futuro.
2. No le gusta nada pensar en el futuro.
3. Los coches irán sin ruedas en el futuro.

1. Dolores está triste porque no encuentra el amor.
2. Con los años siempre se acaba el amor.
3. Siempre me está deseando salud, dinero y amor.

1. Una gran casa siempre ha sido su deseo.
2. Al final se ha acabado cumpliendo mi deseo.
3. Antes de soplar las velas pide un deseo.

1. No me gustan nada las series de humor.
2. A menudo me dicen que tengo mal humor.
3. Siempre está riendo, tiene mucho sentido del humor.

1. Mañana temprano le preguntaré a Esther la verdad.
2. Todavía no sé si esto puede ser verdad.
3. Juan es muy mentiroso nunca dice la verdad.

.

1. A Carlos le gustaría poder estudiar el tiempo.
2. No sé si iré, todo depende del tiempo.
3. Parece mentira que ya haya pasado tanto tiempo.

1. Juan es una persona con muy poca fuerza.
2. Carlos es muy delgado pero tiene mucha fuerza.
3. Podrá levantar la piedra alguien con mucha fuerza.

1. Decidió venir con nosotros aunque tenía mucho miedo.
2. Las casas viejas siempre me han dado miedo.
3. A Carlos las serpientes le dan mucho miedo.

1. No puedo creer como Marcos todavía tiene esperanza.
2. Con tantos problemas ya no tenía ninguna esperanza.
3. Lo último que se pierde es la esperanza.

1. María tiene en el pie un gran dolor.
2. No podía ni moverse a causa del dolor.
3. Me dieron un calmante para aliviar el dolor.

1. Ayer supe que te habían robado la idea.

2. A ver si se te ocurre alguna idea.
3. No sé que escribir no tengo ninguna idea.

1. A Juan le regalaron un juego de magia.
2. Para su cumpleaños hicieron un número de magia.
3. Fue increíble, desapareció como por arte de magia.

1. Clara lleva unos días que siempre tiene sueño.
2. Todas las mañanas me dice que tiene sueño.
3. Me voy a dormir que tengo mucho sueño.

1. Procura que entre nuestros hijos haya más paz.
2. Después de la absurda guerra llegó la paz.
3. Muchas ciudades se movilizaron para pedir la paz.

1. Mireia ya ha llamado para buscar una solución.
2. Mire como lo mire no veo ninguna solución.
3. Jorge, este problema es imposible, no tiene solución.

1. No sé como puedes tener aún tanta sed.
2. Tuvimos que parar de andar porque tenía sed.
3. Buscaremos una fuente que Pablo tiene mucha sed.

1. En casa de mis padres nunca hay silencio.
2. Me gusta estar sola y disfrutar del silencio.
3. ¡Podéis estar callados! Necesito un poco de silencio.

1. No lo sé seguro, pero quizá tenga razón.
2. Al final se enfadaron, pero ignoro la razón.
3. Al final Carlos pudo demostrar que tenía razón.

1. Es difícil saber el valor, tiende a infinito.
2. La vieja carretera parecía alargarse hasta el infinito.
3. Las teorías dicen que el universo es infinito.

1. Hizo todo este esfuerzo para demostrar su fe.
2. Creer que sucederá es un acto de fe.
3. Creer en Dios es una cuestión de fe.

1. Esto es imposible de arreglar sin un milagro.
2. Las posibilidades son muy remotas necesito un milagro.
3. El accidente fue grave, se salvaron de milagro.

1. Mi prima Carmen es una persona sin gusto.
2. Juan dijo que lo haría con mucho gusto.
3. María debería ser decoradora tiene muy buen gusto.

1. Estos dos grupos siempre compiten por el control.
2. El esquiador bajaba por la ladera sin control.
3. No te preocupes tanto, todo está bajo control.

1. No entiende lo importante que es la educación.
2. Quiere que su nieto tenga una buena educación.
3. Es un grosero, no tiene nada de educación.

1. No debería existir enfermedad alguna que provocase vergüenza.
2. No va a la playa porque tiene vergüenza.
3. Cuando llegó Sara se puso rojo de vergüenza.

1. Ahora mismo no se me ocurre ningún ejemplo.

2. Esther siempre pone a su hermana de ejemplo.
3. No lo acabo de entender ponme un ejemplo.

1. Manuel ha demostrado que tiene un gran valor.
2. Se encontró una moneda antigua pero sin valor.
3. Por suerte no te robaron nada de valor.

1. En su último viaje descubrió toda una cultura.
2. La televisión se encarga de difundir nuestra cultura.
3. Cada país tiene su propia lengua y cultura.

1. El colchón se puede romper con tanta presión.
2. La manguera se rompió por la fuerte presión.
3. Es difícil ganar la final bajo tanta presión.

1. No puedes saltarte una norma de la sociedad.
2. Hicieron una gran fiesta para presentarlas en sociedad.
3. Iré a una fiesta de la alta sociedad.

1. Un tema que preocupa mucho es la seguridad.
2. La empresa no tomó suficientes medidas de seguridad.
3. Carlos ha encontrado trabajo como guarda de seguridad.

1. Seguro que se han confundido en la reserva.
2. Mario casi nunca juega siempre está de reserva.
3. Al llegar al hotel habían anulado nuestra reserva.

1. A simple vista no se ve la diferencia.
2. Por más que los compare no encuentro diferencia.
3. Aunque son gemelos se nota una gran diferencia.

1. Siempre me aparece el mismo tipo de error.
2. No funcionó a causa de un pequeño error.
3. Marcaron gol porque el portero cometió un error.
.
1. María odia todo lo relacionado con la política.
2. Carlos nunca se pierde los debates de política.
3. No voto porque no me gusta la política.

1. Sabes que no es de nadie la culpa.
2. Lo siento mucho pero no fue mi culpa.
3. No puede dejar de sentir parte de culpa.

Experiment 6

A. Novel concrete words – corresponding Spanish word

Apina – bufanda; atigo – pez; batate – dedo; camolo – botón; derento – ordenador; efeto –café; enima – bicicleta; igal – fútbol; litano – aceite; marpo - ascensor; memra – escalera; metepo – oído; otena – nariz; prical – cuchillo; relca – película; sanre – mapa; sela - abeja; subio – cine; tucalo – cinturón; vorlo – anillo.

B. Novel abstract words – corresponding Spanish word

Abula – mentira; anduna – vergüenza; balloro – plan; butea – presión; cabio – destino; cupeta – adopción; deseto – humor; edao – trozo; epecia – diferencia; ferte – milagro; grafa – versión; ibaja – reserva; larso – infinito; mucaco – significado; pefeto – curso; polica – magia; proca – sed; saria – culpa; sencio – error; vermo – ejemplo.

C. Concrete words sentences

1. Esta mañana temprano se ha estropeado el ascensor.
2. Ves por las escaleras no funciona el ascensor.

1. María estaba triste porque había perdido el anillo.
2. No se puede sacar del dedo el anillo.

1. He olvidado comprar las entradas para el cine.
2. Comprar, palomitas antes de entrar en el cine.

1. Has olvidado poner en la mesa mi cuchillo.
2. Se ha cortado el dedo con un cuchillo.

1. He tenido que pedir a Carmen una escalera.
2. El ascensor no funciona sube por la escalera.

1. Para el viaje no olvides coger un mapa.
2. No sé donde estamos míralo en el mapa.

1. A Carmen no le gusta nada su nariz.
2. No puede oler nada tiene tapada la nariz.

1. Han elegido a Carmen para hacer una película.
2. En la cartelera no hay ninguna buena película.

1. En la caja de costura habrá algún botón.
2. Pepe a ésta camisa le falta un botón.

1. Es muy difícil sacar las manchas de aceite
2. Para freiré los calamares debes poner abundante aceite.

1. A Carolina le dan mucho miedo las abejas.
2. La miel la tenemos gracias a las abejas.

1. Nada más llegar María se quitó la bufanda.
2. En invierno protejo mi garganta con una bufanda.

1. A Luisa nunca le ha gustado el café
2. Toda esta cafetera si sólo yo tomar, café

1. No puedo llevar este traje sin un cinturón.
2. Se me caen los pantalones sin el cinturón.

1. Mario se pone nervioso cuando ve el fútbol.
2. El Barça es un gran equipo de fútbol.

1. De noche caí y me corte mi dedo.
2. Al cerrar la puerta se pilló el dedo.

1. A Pablo se le murieron todos los peces.
2. Ayer me regalaron una pecera llena de peces.

1. Desde ayer Pepe tiene dolor en un oído.
2. De pequeño tuve una infección en el oído.

1. Me gustaría ahorrar para comprarme un buen ordenador.
2. Es imposible conectarse a internet desde este ordenador.

1. Cada día Luís va al colegio en bicicleta.
2. Tengo que cambiar los pedales de la bicicleta.

D. Abstract words sentences

1. Esta tarde María no podrá venir al curso.
2. Lo ha suspendido todo no pasará de curso.

1. Hace meses que está en trámites de adopción.
2. En China hay muchas niñas entregadas en adopción.

1. María no cree en la existencia del destino.
2. No saben si fue coincidencia o el destino.

1. A menudo me dicen que tengo mal humor.
2. Siempre está riendo tiene mucho sentido del humor.

1. El premio que gané era sólo una mentira.
2. Al final me enteré que todo era mentira.

1. Antes de empezar deberíamos tener un buen plan.
2. Pudieron fugarse porque habían ideado un buen plan.

1. No sé como puedes tener aún tanta sed.
2. Buscaremos una fuente que Pablo tiene mucha sed.

1. Carmen todavía no me ha contado su versión.
2. De ésta película han hecho una segunda versión.

1. Ahora mismo no se me ocurre ningún ejemplo.
2. No lo acabo de entender ponme un ejemplo.

1. Es difícil saber el valor tiende a infinito.
2. Las teorías dicen que el universo es infinito.

1. Sabes que no es de nadie la culpa.
2. No puede dejar de sentir parte de culpa.

1. El colchón se puede romper con tanta presión.
2. Es difícil ganar la final bajo tanta presión.

1. Mario casi nunca juega siempre está de reserva.
2. Al llegar al hotel habían anulado nuestra reserva.

1. Han descubierto unas inscripciones pero desconocen su significado.
2. No sé busca en el diccionario su significado.

1. Al final sólo pudo conseguir un pequeño trozo.
2. El jarrón nuevo se rompió en muchos trozos.

1. A simple vista no se ve la diferencia.

2. Aunque son gemelos se nota una gran diferencia.

1. Siempre me aparece el mismo tipo de error.
2. Marcaron gol porque el portero cometió un error.

1. A Juan le regalaron un juego de magia.
2. Fue increíble desapareció como por arte de magia.

1. Esto es imposible de arreglar sin un milagro.
2. El accidente fue grave se salvaron de milagro.

1. No va a la playa porque tiene vergüenza.
2. Cuando llegó Sara se puso roja de vergüenza.

Experiment 7

A. Novel concrete words – corresponding Spanish word

Adarato – coche; alacro – cigarro; areo – sol; atelo – queso; bilsa – iglesia; bisaco – aceite; bisno – colegio; brande – llave; bupido – suelo; capino – cine; cartuno – zapato; catebia – escalera; centiño – barco; cerino – papel; cija – uña; cilso – cuadro; clita – bandera; conua – guitarra; coparo – médico; curteno – otoño; desuba – isla; diero – bar; difo – pan; duta – boca; enrate – café; faleto – calendario; falito – diente; fiamba – estrella; flesta – película; foba – nube; fostico – amigo; gepo – plato; geria – sangre; herno – teléfono; ilero – mar; imgeo – león; insata – vela; lertico – pez; lianto – corazón; libeso – aeropuerto; lineto – sombrero; mabrona – naranja; madida – nariz; masuo – espejo; matreño – botón; mesato – azúcar; miloma – ventana; minto – periódico; motra – cocina; nalosa – gota; nilecas – gafas; nilopo – cuchillo; obeto – árbol; ofa – mosca; omblón – pantalón; onito – brazo; oprisa – tarjeta; paceto – anillo; pecuas – manchas; pieto – paraguas; pilso – gato; pisal – fútbol; pruba – leche; pune – ojo; ralida – cama; rasiño – hotel; recea – canción; restate – ordenador; rotiro – fuego; seomo – río; sibrano – televisor; sionte – oído; tarra – mesa; tilapo – ascensor; trepto – cinturón; tulso – casco; valo – mapa; varosa – silla; vatesa – ciudad; viato – dedo.

B. Novel abstract words – corresponding Spanish word

Adrema – solución; ango – principio; astino – plan; astiro – milagro; atual – titular; belinca – cultura; belto – volumen; beste – turno; biteco – tamaño; bofín – rastro; camira – noticia; canduta – teoría; casel – acuerdo; cipita – importancia; crosna – denuncia; cucheno – efecto; cunto – ejemplo; denería – venganza; desala – prueba; dicamo – significado; ditena – curiosidad; emsa – imaginación; espel – pecado; espimo – fracaso; esruba – presión; etudo – destino; fimeta – duda; findo – motivo; flata – edad; gaena – seguridad; gamila – suerte; gasba – descripción; graenta – generación; guna – reserva; gurato – tratamiento; hareta – oportunidad; idona – influencia; imbra – broma; infaco – control; isama – inteligencia; lapio – eco; leco – curso; macito – misterio; mampo – límite; midoga – diferencia; milso – secreto; motefa – fe; nacal – mito; niepa – tradición; nilata – adopción; nosa – talla; oleta – experiencia; oleto – final; olusna – información; oviro – cuidado; pesmola – norma; piloma – intención; pinocas – ganas; puca – pausa; pusofa – conclusión; queseja – crítica; rasinta – dificultad; recerdo – valor; recola –

posición; refia – decisión; remoca – personalidad; rinaca – vergüenza; ristro – perdón; rolantre – paro; sileca – combinación; silopa – espera; silta – ayuda; sito – resultado; tacela – duración; teba – energía; tería – culpa; tesca – conciencia; tezo – error; tromo – reto; ulina – justicia.

C. Concrete words sentences

1. En el supermercado estaba de oferta el aceite.
2. Para freír los calamares debes poner abundante aceite.

1. Ésta vez debemos hacer escala en otro aeropuerto.
2. Su avión sale a las siete del aeropuerto.

1. He buscado pero no he encontrado tu amigo.
2. Siempre me ayuda, Pedro es mi mejor amigo.

1. María estaba triste porque había perdido el anillo.
2. No se puede sacar del dedo el anillo.

1. Desde casa de Juan se ven muchos árboles.
2. En este bosque ya han talado demasiados árboles.

1. Esta mañana temprano se ha estropeado el ascensor.
2. Ves por las escaleras no funciona el ascensor.

1. Mi madre trabaja en una fábrica de azúcar.
2. El pastel quedará demasiado dulce échale menos azúcar.

1. Debes saber que cada país tiene su bandera.
2. En lo alto del castillo ondeaba una bandera.

1. Luís se pasa el día en el bar.
2. Mañana iremos a tomar algo a aquel bar.

1. Este verano Carlos tendrá que viajar en barco.
2. Como adora navegar se ha comprado un barco.

1. Carlos me dio un beso en la boca.
2. Se lavó los dientes y enjuagó la boca.

1. En la caja de costura habrá algún botón.
2. Pepe a tu camisa le falta un botón.

1. Pedro tiene una gran cicatriz en el brazo.
2. Felipe es manco pues le falta un brazo.

1. A Luisa nunca le ha gustado el café.
2. Toda esta cafetera, si solo yo tomaré café.

1. Para no olvidarte, mejor márcalo en el calendario.
2. Ya es septiembre, pasa la hoja del calendario.

1. En esta tienda hay grandes ofertas en camas.
2. Cada mañana se va sin hacer la cama.

1. Pablo le ha escrito a María una canción.
2. En el colegio aprendió a cantar esta canción.

1. Por su cumpleaños Juan le regaló un casco.

2. Para ir en moto es obligatorio ponerse casco.

1. María detesta mucho el olor de los cigarros.
2. Después de comer casi siempre fumo dos cigarros.

1. He olvidado comprar las entradas para el cine.
2. Compraré palomitas antes de entrar en el cine.

1. No puedo llevar este traje sin un cinturón.
2. Se me caen los pantalones sin el cinturón.

1. Mis tíos todavía viven en la misma ciudad.
2. La gente de campo no soporta la ciudad.

1. Mario siempre olvida donde ha dejado el coche.
2. Ha vuelto a pinchar la rueda del coche.

1. Carmen está ahorrando para poder reformar la cocina.
2. Carlos lleva los platos sucios a la cocina.

1. Carlitos siempre espera en la puerta del colegio.
2. La conozco, de pequeñas íbamos al mismo colegio.

1. Su padre tuvo un grave ataque de corazón.
2. Un trasplante muy difícil es el de corazón.

1. A Laura le encantan los colores del cuadro.
2. Patricia ya ha llevado ha enmarcar el cuadro.

1. Has olvidado poner en la mesa mi cuchillo.
2. Se ha cortado el dedo con un cuchillo.

1. De noche, caí y me corte mi dedo.
2. Al cerrar la puerta se pilló el dedo.

1. Primero de todo se fija en sus dientes.
2. Después de comer debes cepillarte bien los dientes.

1. He tenido que pedir a Carmen una escalera.
2. El ascensor no funciona sube por la escalera.

1. Carmen siempre ha querido tener un gran espejo.
2. Es un presumido siempre mirándose en el espejo.

1. Esta noche no se ve ni una estrella.
2. No sabía que el sol es una estrella.

1. Suerte que se dio cuenta que había fuego.
2. Vigila, te puedes quemar si juegas con fuego.

1. Mario se pone nervioso cuando ve el fútbol.
2. El Barça es un gran equipo de fútbol.

1. Esta mañana he ido a comprar unas gafas.
2. Para leer o ver la televisión necesito gafas.

1. Desde pequeña, Luisa tiene alergia a los gatos.
2. Como tiene ratones se ha comprado un gato.

1. De este medicamento debes tomarte solo una gota.

2. Está lloviendo, me acaba de caer una gota.

1. Pablo se ha apuntado a clases de guitarra.
2. Santana es de los mejores tocando la guitarra.

1. Si vas fuera, mejor búscate un buen hotel.
2. Resulta que nos alojamos en el mismo hotel.

1. Hace quinientos años se construyó esta magnífica iglesia.
2. Aunque es creyente nunca va a la iglesia.

1. A Carlos le gustaría vivir en una isla.
2. Hoy he aprendido que Menorca es una isla.

1. En la nevera no queda nada de leche.
2. Me apetece un bol de cereales con leche.

1. Mañana vamos al circo a ver los leones.
2. Los reyes de la selva son los leones.

1. Me gusta el ruido metálico de las llaves.
2. Pedro está buscando en su bolsillo las llaves.

1. Iré al médico que me mire estas manchas.
2. Ponte otra camisa, esta está llena de manchas.

1. Para el viaje no olvides coger un mapa.
2. No se dónde estamos, míralo en el mapa.

1. Desde el balcón se puede ver el mar.
2. Me gustaría un hotel con vistas al mar.

1. Al llegar había muchísima gente esperando al médico.
2. Me duele mucho la barriga, iré al médico.

1. No vamos a caber todos en ésta mesa.
2. Creo que lo he dejado encima la mesa.

1. El insecto que menos gusta es la mosca.
2. La Tsé-tsé es un tipo especial de mosca.

1. Una de mis frutas preferidas son las naranjas.
2. De mañana me apetece un zumo de naranja.

1. A Carmen no le gusta nada su nariz.
2. No puede oler nada, tiene tapada la nariz.

1. Es muy relajante poder quedarse mirando las nubes.
2. Lloverá, el cielo está todo lleno de nubes.

1. Desde ayer, Pepe tiene dolor en un oído.
2. De pequeño tuve una infección en el oído.

1. Desde ayer que me duele mucho este ojo.
2. Me han recetado unas gotas para los ojo.

1. Me gustaría ahorrar para comprarme un buen ordenador.
2. Es imposible conectarse a internet desde este ordenador.

1. La época que más me gusta es otoño.

2. Verano, invierno, primavera y me falta el otoño.

1. Para mantener la línea intenta no comer pan.
2. Cada día suele comprar dos barras de pan.

1. Carmen tiene que coserte otra vez el pantalón.
2. Sin el cinturón se me cae el pantalón.

1. Marta se ha dejado de firmar éste papel.
2. Escríbeme tu dirección en éste trozo de papel.

1. Con ese viento era imposible abrir el paraguas.
2. Va a llover, mejor que cojas el paraguas.

1. A Pablo se le murieron todos los peces.
2. Ayer me regalaron una pecera llena de peces.

1. Han elegido a Carmen para hacer una película.
2. En la cartelera no hay ninguna buena película.

1. Me gusta pasar el rato con el periódico.
2. Pablo cada día compra y lee el periódico.

1. Ten cuidado no se te caigan los platos.
2. Después de cenar te toca lavar los platos.

1. Voy a la tienda a por un queso.
2. En los dibujos los ratones siempre comen queso.

1. Iba paseando y se cayó en un río.
2. Te pueden multar si pescas en este río.

1. No te rasques más o te harás sangre.
2. Ésta mañana María ha ido a donar sangre.

1. En el piso nuevo todavía no tengo sillas.
2. Esta mesa no hace conjunto con las sillas.

1. No le gusta pasar mucho rato al sol.
2. En verano se pasa horas tomando el sol.

1. El fuerte viento se ha llevado su sombrero.
2. Protégete la cabeza del sol con este sombrero.

1. En casa ya han puesto el nuevo suelo.
2. No me gusta que tires papeles al suelo.

1. Al irnos del hotel nos dieron una tarjeta.
2. En esta tienda no me aceptaron la tarjeta.

1. Hoy vendrá el técnico a instalarme el teléfono.
2. Vi a Juan y me pidió tu teléfono.

1. El técnico vendrá mañana a reparar el televisor.
2. No pudo sintonizar ningún canal en este televisor.

1. Al caer se rompió un par de uñas.
2. El gato se defendió arañándole con las uñas.

1. Para el mal olor mejor poner una vela.

2. Me manché con la cera de la vela.

1. Cuando compramos la casa cambiamos todas las ventanas.
2. Hay demasiado ruido fuera, puedes cerrar las ventanas.

1. A Esther no le vendrán bien estos zapatos.
2. No sabe abrocharse los cordones de los zapatos.

D. Abstract words sentences

1. Hasta ahora la cosa quedaba en un acuerdo.
2. Trabajadores y empresa han llegado a un acuerdo.

1. Hace meses que está en trámites de adopción.
2. En China hay muchas niñas entregadas en adopción.

1. Al final no se atrevió a pedir ayuda.
2. No podré acabarlo a tiempo sin tu ayuda.

1. No te lo creas sólo es una broma.
2. No puede ser, te habrán gastado una broma.

1. Esta camisa y falda hacen una buena combinación.
2. Alcohol y pastillas puede ser una mala combinación.

1. No le riñas tanto aún no tiene conciencia.
2. No hizo la mili, fue objetor de conciencia.

1. Carlos todavía no ha llegado a ninguna conclusión.
2. Tras estudiar el caso detenidamente sacó ésta conclusión.

1. Estos dos grupos siempre compiten por el control.
2. No te preocupes tanto, todo está bajo control.

1. Se sorprendió por la dureza de la crítica.
2. La película italiana ha recibido muy buena crítica.

1. La próxima vez intenta hacerlo con más cuidado.
2. Cuando cojas al bebé debes tener mucho cuidado.

1. Sabes que no es de nadie la culpa.
2. No puede dejar de sentir parte de culpa.

1. En su último viaje descubrió toda una cultura.
2. Cada país tiene su propia lengua y cultura.

1. Algunos vinieron por convicción otros sólo por curiosidad.
2. Cuéntamelo ya que me está picando la curiosidad.

1. Esta tarde María no podrá venir al curso.
2. Lo ha suspendido todo, no pasará de curso.

1. Ayer nadie estaba de acuerdo con la decisión.
2. Nata o chocolate pero toma ya una decisión.

1. Antonio recibió ayer en su casa una denuncia.
2. Fue a la policía a poner una denuncia.

1. Un testigo del robo pudo facilitar una descripción.

2. El hombre detenido no coincidía con la descripción.

1. María no cree en la existencia del destino.
2. No saben si fue coincidencia o el destino.

1. A simple vista no se ve la diferencia.
2. Aunque son gemelos se nota una gran diferencia.

1. Mi hijo leyó todo el libro sin dificultad.
2. Creo que lo encontrarás aunque con cierta dificultad.

1. Este tema es difícil siempre hay alguna duda.
2. Lo he entendido perfectamente no tengo ninguna duda.

1. Debido al gran éxito han alargado la duración.
2. Compré estas pilas porque son de larga duración.

1. Escuchó una segunda voz que era el eco.
2. En la cueva pudimos oír nuestro lejano eco.

1. Marta y yo somos de la misma edad.
2. Esta es una residencia para la tercera edad.

1. No creo que éste plan tenga mucho efecto.
2. Éste medicamento no me ha hecho ningún efecto.

1. Ahora mismo no se me ocurre ningún ejemplo.
2. No lo acabo de entender ponme un ejemplo.

1. Lee éstas recomendaciones para el ahorro de energía.
2. Durante la fusión de átomos se desprende energía.

1. Siempre me aparece el mismo tipo de error.
2. Marcaron gol porque el portero cometió un error.

1. Nos informaron que hay un año de espera.
2. Actualmente numerosos enfermos aguardan en lista de espera.

1. Le dieron el trabajo aunque no tenía experiencia.
2. En el anuncio piden alguien con amplia experiencia.

1. Hizo todo ese esfuerzo para demostrar su fe.
2. Creer en Dios es una cuestión de fe.

1. Ignoraba que todas las cosas tienen un final.
2. Pudimos ver toda la película hasta el final.

1. Todos sus esfuerzos desembocaron en un gran fracaso.
2. La poca asistencia al recital augura un fracaso.

1. Al final acudió a la fiesta sin ganas.
2. Iré aunque se me han quitado las ganas.

1. En éste bar encuentro gente de mi generación.
2. Las tradiciones se transmiten a la siguiente generación.

1. Me recomendó este juego para estimular la imaginación.
2. Todo aquello sólo fue producto de su imaginación.

1. Lo que Carlos dijo ayer no tiene importancia.

2. No sé por qué le das tanta importancia.

1. Este programa tiene un gran impacto e influencia.
2. Tus amigos del barrio son una mala influencia.

1. Al final Sara ha conseguido toda la información.
2. Ahora la policía está recopilando toda la información.

1. Éste juego ayuda estimula la creatividad e inteligencia.
2. Aprendió que el coeficiente intelectual mide la inteligencia.

1. Le ha faltado capacidad para cumplir su intención.
2. No te enfades lo dice sin mala intención.

1. El ladronzuelo tiene cuentas pendientes con la justicia.
2. De mayor quiere ser juez para repartir justicia.

1. Con los adolescentes hay que establecer un límite.
2. Dejó claro que su paciencia tenía un límite.

1. Esto es imposible de arreglar sin un milagro.
2. El accidente fue grave, se salvaron de milagro.

1. El origen de la nota era un misterio.
2. Como se construyeron las pirámides es un misterio.

1. Tras quince victorias se convirtió en un mito.
2. La existencia de drácula es sólo un mito.

1. Han reconocido que no había ningún buen motivo.
2. Se enfadó conmigo pero no sé el motivo.

1. Odia que algo se salga de la norma.
2. Éste caso es una excepción a la norma.

1. Antonia cogió la revista y consultó la noticia.
2. La revista del corazón publicó una sorprendente noticia.

1. Los jóvenes no tienen ni han tenido oportunidad.
2. Todos tenemos derecho a tener una segunda oportunidad.

1. Mi padre lleva muchos años en el paro.
2. La empresa dejó muchos trabajadores en el paro.

1. Estoy inquieta mejor continuo después de la pausa.
2. Reemprenderemos las noticias internacionales tras ésta breve pausa.

1. Muchos siguen creyendo que el sexo es pecado.
2. Antes de comulgar con Dios confesó su pecado.

1. Ayer vino a mi casa a pedirme perdón.
2. Fue su culpa yo no pienso pedirle perdón.

1. Las drogas te acabarán por alterar la personalidad.
2. Ser introvertido es un rasgo de la personalidad.

1. Para estar bien organizados debemos tener un plan.
2. Pudieron fugarse porque habían ideado un buen plan.

1. El niño se siente cómodo en ésta posición.

2. El atleta español ha llegado en tercera posición.

1. El colchón se puede romper con tanta presión.
2. Es difícil ganar la final bajo tanta presión.

1. Juan ha llegado a tiempo para el principio.
2. Ahora no puedes retirarte aceptaste desde un principio.

1. María ha decidido que hará la última prueba.
2. Entrará en los bomberos si supera esta prueba.

1. A ciegas es completamente imposible encontrar su rastro.
2. Los ladrones del banco desaparecieron sin dejar rastro.

1. Mario casi nunca juega siempre está de reserva.
2. Al llegar al hotel habían anulado nuestra reserva.

1. Las constantes presiones ejercidas no obtuvieron ningún resultado.
2. Una vez hecha la suma dime el resultado.

1. Le atraía la idea de aceptar el reto.
2. Aún sabiendo que no ganaría aceptó el reto.

1. Ayer María no me quiso contar su secreto.
2. No lo cuentes a nadie es un secreto.

1. Un tema que preocupa mucho es la seguridad.
2. Carlos ha encontrado trabajo como guarda de seguridad.

1. Han descubierto unas inscripciones pero desconocen su significado.
2. No sé, busca en el diccionario su significado.

1. Mireia ya ha llamado para buscar una solución.
2. Jorge este problema es imposible no tiene solución.

1. La familia de Cristina siempre ha tenido suerte.
2. Siempre le pasan cosas, tiene muy mala suerte.

1. El vestido verde no es de mi talla.
2. Me encanta el pantalón pero necesito otra talla.

1. No me gusta, lo prefiero de otro tamaño.
2. Con el microscopio puedes verlo aumentado de tamaño.

1. Mañana estudiaremos las aplicaciones reales de tu teoría.
2. Me gusta más la práctica que la teoría.

1. Las recientes informaciones obligaron a cambiar el titular.
2. Hoy los periódicos abren con el mismo titular.

1. La sidra en Asturias tiene una gran tradición.
2. Se casó por la iglesia siguiendo la tradición.

1. Por tercera vez le han cambiado el tratamiento.
2. Las personas mordidas deben comenzar inmediatamente el tratamiento.

1. Ahora no puedo salir que es mi turno.
2. La gente hace largas colas esperando su turno.

1. Manuel ha demostrado que tiene un gran valor.

2. Se encontró una moneda antigua pero sin valor.

1. Los hermanos de María están planeando una venganza.
2. Los padres de la víctima han jurado venganza.

1. No va a la playa porque tiene vergüenza.
2. Cuando llegué Sara se puso roja de vergüenza.

1. Al acercarnos el ruido iba aumentando de volumen.
2. No puedo escuchar nada puedes subir el volumen.

Appendix C: Review of the literature comparing concrete and abstract words processing

Study	Task	Concrete > Abstract		Abstract > Concrete	
		Region	Coordinates	Region	Coordinates
D'Esposito et al. (1997)	Generate mental images to auditory presented CW vs. listen passively to AW	L FFG (37)	-33, -48, -18	R SFG (10)	19, 50, 24
		L premotor (6)	-45, -3, 31	R precuneus (7)	4, -74, 35
		L ACC (24)	-7, -3, 42		
Fletcher et al. (1995)	Recall of high and low imageable paired associates	L precuneus	-2, -54, 32	---------------	
		R precuneus	4, -52, 34		
		R STG	42, -58, 16		
		L ACC	-12, 38, 0		
		R FFG	42, -26, -16		
Mellet et al. (1998)	Mental image generator to aurally presented definitions of CW vs. passive listening of AW definitions	L IT/FFG	-42, -32, -18	R MTG	58, 2, -18
		L ITG	-52, -62, -6	R STS	54, -20, 6
		L FFG	-44, -58, -22	R STG	52, -26, 18
		R IT/FFG	52, -50, -14	L STG	-60, -22, 12
		L Prec/MFG	-40, 4, 34		
			-28, 14, 30		
		L IPL	-46, -38, 46		
		L PrecG	-42, -16, 38		
		L premotor	-36, 46, 0		
Perani et al. (1999a)	Lexical decision of CW vs. AW blocks	---------------		L IFG (47)	-44, 14, -4
				L STG (22/38)	-58, 8, -16
				R IFG (47)	52, 20, -12
				R TP (38)	42, 16, -36
				R POJ (39/19)	40, -70, 36
				R ACC (32)	6, 16, 40
				R amygdala	30, -4, -8
Kiehl et al. (1999)	Lexical decision of CW vs. AW blocks	---------------		R STG	56, 11, 0
Wise et al. (2000)	Reading, hearing and making semantic similarity judgments to words varying on imageability	L mid. FFG	-33, -45, -16	L STG	Not reported
Jessen et al. (2000)	Encoding of CW vs. AW	L PL	-39, -69, 36	R occipital	33, -78, 12
		L prefrontal	-42, 42, 9	L IFG	-57, 30, 3
		R PL	42, -63, 42		
		R precuneus	-3, -57, 45		
Friederici et al. (2000)	Abstract-Concrete judgment (visual)	---------------		L IFG (45)	-46, 21, 25
				R thalamus	4, -18, 15
Grossman et al. (2002)	Make pleasantness decisions on printed words (animals, implements, abstract)	---------------		[Abs. > Implements]	
				L Post. Lat. TL (22, 21, 37)	-60, -32, 12
				[Abs. > Animals]	
				L Post. Lat. TL (37/39/21/22)	-52, -68, 4
				L prefrontal (10/9)	-24, 44, 12
				R med. frontal (32/24)	16, 36, -4
				R Post. Lat. TL (22/21)	56, -32, 16
Fiebach & Friederici (2004)	Lexical decision task	L basal TL	-27, -41, 4	L IFG (45)	-46, 23, 7
Whatmough et al. (2004)	Semantic judgment task	L lingual G	-16, -80, -2	L STG	-43, -18, 8
		R lingual G	1, -74, 9	R mid. FFG	21, -54, -6
		L lat. FFG	-44, -57, -21		
Noppeney & Price (2004)	Synonym judgment decisions on CW and AW triads	---------------		L IFG	-54, 21, -6
				L ant. TP	-51, 14, -26
				L MTG/STS	-60, -42, -6
Giesbrecht et al. (2004)	Semantic relatedness judgments on C vs. A pairs of words	L IFG (45/47)	-56, 33, 3	---------------	
		L PrecG/IFG (44)	-48, 15, 8		
		L MTG (20/21)	-59, -51, 3		
		L med. FG (6)	-4, 38, 35		

Study	Task	Concrete > Abstract		Abstract > Concrete	
		Region	Coordinates	Region	Coordinates
Binder et al. (2005)	Lexical decision (CW vs. AW)	L angular G	-37, -74, 26	L PrecG	-48, 1, 33
		R angular G	53, -53, 28	L IFG	-40, 20, 6
		R MTG	49, -49, 14	L IFS	-48, 28, 13
		L MFG	-33, 22, 45	L STG	-49, 8, -13
		L PCG	-9, -46, 20		
		R PCG	5, -35, 38		
		L precuneus	-8, -68, 28		
		R precuneus	7, -61, 35		
Wallentin et al. (2005)	Reading and listening to C vs. A landmark sentences	L FFG/PHG (20/37)	-32, -44, -20	L IFG (47)	-45, 29, -6
		R FFG/PHG (20/37)	30, -38, -24	R IFG (47/13/45)	40, 25, -12
		L retrosplenial (30)	-16, -64, 8	L SFG (9/8)	62, 20, 16
		R retrosplenial (30)	-40, -82, 16		-11, 56, 30
		L TOP junction (19)	-40, -82, 16	L MFG (6)	-38, 6, 52
		R TOP junction (19)	42, -80, 18	R MFG (6/10)	35, 23, 40
		L & R PCG/R PostcG (5/31)	-4, -40, 40	L med. FG	-4, 0, 62
				L TP (38)	-48, 18, -22
		L precuneus (7)	-24, -74, 38	R TP (38)	52, 16, -28
		L MFG (8)	-32, 28, 44	L MTG (21)	-58, -9, -15
		R MFG (10)	10, 52, -12	R MTG (21)	49, 0, -28
				L STG (39)	-52, -61, 19
				L PCG (31)	-2, -56, 22
				Cerebellum	0, -76, -46
Sabsevitz et al. (2005)	Semantic similarity judgments on CW vs. AW triads	L PHG	-26, -30, -16	L STG	-49, 6, -14
		L ITG	-57, -49, -14	L STS	-55, -40, 5
		L FFG	-45, -52, -15	L MTG	-59, -47, 3
		R hipp/amygdala	21, -5, -14	R STG/S	47, 2, -14
		R hippocampus	25, -14, -18	L IFG	-47, 19, 2
		R PHG	26, -26, -16	L SFG	-9, 49, 33
		L angular/SOG	-28, -79, 36		
		R angular G	39, -65, 32		
		R angular/SMG	45, -47, 42		
		L I/orbital FG	-22, 26, -9		
		L I/MFG	-42, 39, 12		
		L MFG	-37, 27, 19		
		L SFG	-19, 8, 52		
		L subcallosal G	-11, 18, -12		
		R I/orbital G	32, 31, -8		
		R MFG	39, 29, 22		
		L PCG/isthmus	-14, -54, 15		
		R PCG/isthmus	4, -57, 18		
Fliessbach et al. (2006)	Encoding and retrieval of CW vs. AW in a recognition memory paradigm	[Enconding]		[Enconding]	
		---------------	---------------	L IFG (45)	-50, 21, 7
		[Recognition]		[Recognition]	
		L IPG	-36, -77, 40	L IFG (45)	-48, 24, 7
		L angular G	-50, -65, 39	[Old/new effect]	
		R angular G	45, -69, 39	---------------	---------------
		[Old/new effect]			
		L precuneus	-9, -60, 28		
		R precuneus	6, -63, 31		
		L cerebellar H	-18, -56, -21		
		L PCG	-3, -39, 41		
		R PCG	3, -33, 46		
		R ACC	3, 38, -4		
		L ACC	-6, 38, -2		
		[Corr. old/new and behavioral concreteness effect]			
		L FFG/hippocampus	-33, -10, -20		

Study	Task	Concrete > Abstract		Abstract > Concrete	
		Region	Coordinates	Region	Coordinates
Bedny & Thompson-Schill (2006)	Semantic similarity judgments on CW and AW verbs and nouns	L FFG	-31, -40, -24	L MOG (18)	-30, -99, -3
		L SFG (8)	-21, 18, 54	R lingual G	15, -90, -3
		L precuneus/SPL (19/7)	-27, -78, 39		
		R post. MTG (39)	45, -69, 24		

Note: Stereotactic coordinates as given by the authors. Mellet et al. (1998), Peranit et al. (1999a), Giesbrecht et al. (2004), Wallentin et al. (2005) and Bedny and Thompson-Schill (2006) reported MNI coordinates. The rest reported Talairach and Tournoux coordinates. CW = concrete words; AW = abstract words; Abs. = Abstract, Corr. = correlation, FFG = fusiform gyrus, ACC = anterior cingulate cortex, SFG = superior frontal gyrus, STG = superior temporal gyrus, ITG = inferior temporal gyrus, PrecG = precentral gyrus, MTG = middle temporal gyrus, STS = superior temporal sulcus, IFG = inferior frontal gyrus, TP = temporal pole, POJ = parieto-occipital junction, mid = middle, PL = parietal lobule, Post = posterior, Lat = lateral, TL = temporal lobule, I = inferior, med = medial, ant = anterior, FG = frontal gyrus, MFG = middle frontal gyrus, PCG = posterior cingulate gyrus, IFS = inferior frontal sulcus, PHG = parahippocampal gyrus, TOP = temporo-occipito-parietal, PostG = postcentral gyrus, hipp = hippocampus, SOG = superior occipital gyrus, SMG = supramarginal gyrus, IPG = inferior parietal gyrus, SPL = superior parietal lobule, MOG = middle occipital gyrus, H = hemisphere, R = right, L = left.