Functional Neuroanatomy of Contextual Acquisition of Concrete and Abstract Words

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Abstract

■ The meaning of a novel word can be acquired by extracting it from linguistic context. Here we simulated word learning of new words associated to concrete and abstract concepts in a variant of the human simulation paradigm that provided linguistic context information in order to characterize the brain systems involved. Native speakers of Spanish read pairs of sentences in order to derive the meaning of a new word that appeared in the terminal position of the sentences. fMRI revealed that learning the meaning associated to concrete and abstract new words was qualitatively different and recruited similar brain regions as the processing of real concrete and abstract words. In particular, learning of new concrete words selectively boosted the activation of the ventral anterior fusiform gyrus, a region driven by imageability, which has previously been implicated in the processing of concrete words. ■

INTRODUCTION

To build a theory of the representation of concrete and abstract words[1] it may be helpful to consider how these different types of words are learned. Children's first vocabularies comprise mostly concrete words, as they are restricted to the information that is accessible through sensory experience with the material world (Bloom, 2000; Gillette, Gleitman, Gleitman, & Lederer, 1999). 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 define the meaning of these words (Bloom, 2000). It has been proposed on the basis of neuropsychological and neuroimaging evidence (see below) that there might be a relationship between the manner in which these words are learned and the format in which they are stored (Martin, Ungerleider, & Haxby, 2000; Saffran & Sholl, 1999). Whereas abstract concepts appear to be stored in a propositional representational format, concrete words might be represented in auditory, visual, tactile, and sensorimotor formats.

Behavioral, Neuropsychological, and Neuroimaging Evidence

From behavioral studies, it has been demonstrated that concrete words have a processing advantage over abstract words (concreteness effect). Typically, abstract words are processed more slowly (Kroll & Merves, 1986; Schwanenflugel & Shoben, 1983), remembered worse (Paivio, 1971), and take longer to read (Schwanenflugel & Stowe, 1989; Schwanenflugel & Shoben, 1983) than concrete words.

Several neuropsychological studies have provided evidence for dissociations between the representation of abstract and concrete concepts that may reflect qualitative differences in their acquisition and representational format (Crutch & Warrington, 2005). For example, numerous neuropsychological case studies have shown an amplified concreteness effect after brain damage (Martin & Saffran, 1992; Katz & Goodglass, 1990; Coltheart, Patterson, & Marshall, 1980; Goodglass, Hyde, & Blumstein, 1969). Besides, there are also several reports of patients who showed a reversal of the concreteness effect (Marshall, Pring, Chiat, & Robson, 1996; Breedin, Saffran, & Coslett, 1994; Warrington & Shallice, 1984; Warrington, 1975, 1981). These patients are characterized by selective impairment for concrete words while showing a relative preservation of abstract words.

This double dissociation of concrete and abstract word processing suggests that the brain regions that sustain concrete and abstract words representations might be different as well. These lesions in different regions which

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produce impairment of different types of words led Allport (1985) to propose 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 model, the loss of perceptual aspects of word meaning has been found to cause the reversed concreteness effect (Marshall et al., 1996; Breedin et al., 1994).

Functional imaging studies have also provided evidence for the implication of different brain regions in the processing of concrete and abstract words. The processing of abstract words has been associated with greater activation in areas such as the middle and superior temporal gyrus and the left inferior frontal gyrus (IFG), which are thought to be involved in semantic processing (Pexman, Hargreaves, Edwards, Henry, & Goodyear, 2007; Fliessbach, Weis, Klaver, Elger, & Weber, 2006; Binder, Westbury, McKiernan, Possing, & Medler, 2005; Sabsevitz, Medler, Seidenberg, & Binder, 2005; Wallentin, Ostergaard, Lund, Ostergaard, & Roepstorff, 2005; Fiebach & Friederici, 2004; Noppeney & Price, 2004; Whatmough, Verret, Fung, & Chertkow, 2004; Grossman et al., 2002; Friederici, Opitz, & von Cramon, 2000; Jessen et al., 2000; Wise et al., 2000; Kiehl et al., 1999; Perani et al., 1999; Mellet, Tzourio, Denis, & Mazoyer, 1998). By contrast, concrete words show greater activity in regions associated with higher levels of visual processing, such as the ventral anterior part of the fusiform gyrus (Bedny & Thompson-Schill, 2006; Fliessbach et al., 2006; Sabsevitz et al., 2005; Wallentin et al., 2005; Fiebach & Friederici, 2004; Giesbrecht, Camblin, & Swaab, 2004; Whatmough et al., 2004; Wise et al., 2000; Mellet et al., 1998; D'Esposito et al., 1997; Fletcher et al., 1995). However, other studies have failed to find greater activations for concrete words in these areas (e.g., Binder et al., 2005; Jessen et al., 2000) or in any other brain regions (Noppeney & Price, 2004; Friederici et al., 2000; Kiehl et al., 1999; Krause et al., 1999; Perani et al., 1999).

Theoretical Proposals for the Concreteness Effects

Several theories have been proposed to account for the concreteness effect. The dual-coding theory (Paivio, 1971, 1986) proposes that there are two cognitive symbolic systems, an ''imagery'' system specialized for the representation and processing of nonverbal objects/events and a ''verbal system'' dealing with linguistic representations. The nonverbal symbolic system is composed of modality-specific internal structures (visual, auditory, haptic, and motor) that map onto the sensorimotor attributes of the represented objects. This subsystem has some similarities with the more recent proposal of perceptual symbol systems, which can construct specific simulations (similar to a mental image) of an entity or event using representations derived from perceptual–motor experiences (Barsalou, 1999). According to this qualitative account, the main difference between concrete and abstract words is that image representations are stored only for concrete words. Whereas abstract words predominantly activate verbal representations, the processing of concrete words coactivates linguistic *and* imagery (sensorimotor) representations leading to facilitated processing of concrete words.

In contrast to this view, the context availability theory (Schwanenflugel & Shoben, 1983) argues that the difference between concrete and abstract words is only quantitative. When presented in isolation, concrete words are thought to activate more contextual information in semantic memory than abstract words (Schwanenflugel & Stowe, 1989; Schwanenflugel & Shoben, 1983) because the latter tend to appear within a wider range of contexts and are, therefore, less likely to recruit specific pieces of information, and thus, are more difficult to process (Schwanenflugel & Shoben, 1983). This processing disadvantage disappears if abstract words are presented within a context, such as a sentence. This 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 account of the concreteness effect postulates that it arises from the fact that concrete words are supported by more semantic features than abstract words (Plaut & Shallice, 1993). This hypothesis agrees with previous findings which showed that normal participants produced more associates for concrete than abstract words (de Groot, 1989).

The three theoretical approaches agree that the representation of concrete concepts entails some additional component that facilitates access, activation, and further remembering, but differ in their explanation of the nature of this component. Furthermore, the dual-coding and the context availability theories have difficulties in explaining the reversal of the concreteness effect in certain neurological patients. In fact, the loss of the additional component that gives concrete words a processing advantage should level the difference between concrete and abstract words, which is clearly not the case in some patients. However, Paivio (2006) has recently argued that damage to perceptual components of word meaning in previous patients (Breedin et al., 1994) might be the key to understanding the reversal of the concreteness effect in the context of the dual-coding theory. The possible disruption of normal imaginary processes and/or their respective association with their verbal and well-preserved representations might predict impoverished concrete word processing. Furthermore, whereas certain ''lesions'' to a connectionist model of deep dyslexia developed by Plaut and Shallice (1993) lead to a selective impairment of concrete words, this model does not account for the most fundamental distinction between concrete and abstract words, that is,

the perceptual properties which are essential for the representation of concrete but not abstract words (Breedin et al., 1994).

Objectives

As there is no previous neuroimaging evidence on the learning of concrete and abstract new words, we investigated the neurophysiological correlates underlying learning new words, and how these are modulated by word concreteness. As a working hypothesis, we predicted that the same regions that store the representation of concrete and abstract words and its semantic features (see above) will support the association of new words to their appropriate concepts. To test this hypothesis, a new word learning task was used in which adults were engaged in discovering the meaning of new concrete and abstract words presented repetitively across several sentences (Mestres-Missé, Rodriguez-Fornells, & Münte, 2007). Notice, however, that the meanings corresponding to the new words already exist in the learner's semantic memory. Thus, the present contextual learning task mimics the process of learning the meaning of a new word in a foreign language. This process of inferring meanings from contexts is very important not only in second-language research but also in first-language acquisition, where it is supposed to be the principal source of learning of new words in school (Nation, 2001). In the present experiment, differences in learning concrete and abstract words from context were studied in adults using a variant of the human simulation paradigm of vocabulary learning (Gillette et al., 1999). Finally, the paradigm was also designed to control for the amount of contextual information provided for learning each type of new words.

METHODS

Participants

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

Stimuli and Tasks

While in the scanner, participants silently read pairs of sentences. In the critical conditions, the two sentences ended in a new word (standing for either an abstract word, henceforth Nwa for new-word abstract, or a concrete word, henceforth Nwc for new-word concrete) and participants had to discover the meaning of the hidden word. Hidden words were nouns of medium frequency.

In addition, as a control, sentence pairs ending in existing concrete (Rwc for real-word concrete) or abstract (Rwa for real-word abstract) words were also presented. An example for the *Nwc* condition (all materials were in Spanish, examples are translated) was:

1. ''She likes people with nice and clean *tankies*''
2. ''After the meals you should brush your *tankies*''
Hidden word: teeth.

An example for the *Nwa* condition was:

1. ''She didn't want to tell me her *golmet*''
2. ''Don't tell this to anybody, it is a *golmet*'' Hidden word: secret.

Sentences were systematically counterbalanced across the two critical conditions by creating different sentence lists. Sentences uniformly had a length of eight words. New words respected the phonotactic rules of Spanish and were created by changing one or two letters of an existing word.

The hidden words were 80 concrete words and 80 abstract words (see Appendices A and B for the complete list). Concrete words were selected from previous word-learning experiments (Mestres-Missé et al., 2007) (mean frequency of 62.7 per million occurrences) (Sebastian-Gallés, Martí, Carreiras, & Cuetos, 2000). Moreover, all of the selected words were highly imaginable, concrete, and familiar, as rated on scales ranging from 1 (*low*) to 7 (*high*); mean familiarity was 6.3, mean imageability was 6.2, and mean concreteness was 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 real-word abstract (Rwa) sentence pairs (control condition), and 40 real-word concrete (Rwc) sentence pairs (control condition). Concrete sentences were chosen from previous word-learning experiments (Mestres-Missé et al., 2007). The cloze probability of each sentence was assessed in pilot studies. The cloze probability of a word in a given context refers to the proportion of people who would choose to complete that particular sentence fragment with that particular word (Taylor, 1953). Mean cloze probability for the final pool of concrete sentences was: first sentence (low constraint) 15.6% ($SD = 13.6$) and second sentence (high constraint) 85.8% ($SD = 8.4$). The probability of meaning discovery after reading both sentences sequentially was 97.6% ($SD = 3.8$). Abstract sentences were built and tested in the same way as concrete ones (Mestres-Missé et al., 2007). Mean cloze probability for 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 discovery reading both sentences sequentially was 94.5% (*SD* = 6.6).

The two lists were matched in frequency, familiarity, concreteness, and imageability for the hidden word; abstract words were matched to abstract words and the same for concrete words. 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. Contexts were rotated systematically over real and new words for concrete and abstract conditions separately. This procedure ensures that, across the group of participants, each context occurred equally often in conjunction with real or new words. Each list of 160 sentence pairs was divided into eight experimental runs comprising five sentence pairs per condition as well as five additional fixation trials of 8 sec.

Each run 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 msec, then sentence stems (seven words) were presented centrally for 2000 msec. After a variable interval between 1 and 2 sec, the terminal words or new words were presented for 500 msec. After a variable interval of 1 to 6 sec during which the screen remained dark, the second sentence was presented in the same fashion. After the second sentence, participants were required to think about the hidden word or, in the case of a real word, about a semantically related word. The order of the four experimental conditions within an experimental run 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 msec. 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, 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 eight experimental runs, each lasting about 7 min. A short rest was given between runs.

As the fMRI design did not allow direct testing for *correct meaning assignment*, a short behavioral two-alternative forced-choice task was performed during breaks between functional runs. Participants were shown a new word together with a correct or an incorrect word. The correct word referred to the meaning that participants had to discover in the learning task. The incorrect word referred to the meaning of another new word that had appeared in the same learning run. These stimuli were presented visually in a pyramid arrangement with the new word positioned at the top center of the display and two word choices (actual meaning of the new word–meaning of another new word) on either side of the bottom of the display. Participants indicated the appropriate meaning for the particular new word by pressing one of the two buttons (10 trials after each block; random SOA of 1000–2000 msec). Subsequently, participants performed an old/new-word recognition task, in which 20 words were presented (5 from the Rwa and 5 from the Rwc condition, and 10 new real words), and the participants had to indicate by pressing one of two buttons whether they had seen a particular word in the preceding block. This task served to induce participants to attend to the Rwc and Rwa sentences (which otherwise could have been neglected).

After the scanning session, a new-word recognition test was carried out. Participants were presented with a list of 160 new words (80 learned new words, half concrete and half abstract, and 80 fillers) with the participants' task being to mark those new words that had occurred during the scanning session and to recall their meaning. Data from only 14 participants were collected for this test.

fMRI Data Acquisition

Images were acquired on a 3-T whole-body MRI system (Siemens Magnetom Trio, Erlangen, Germany). Whole-brain T2*-weighted fMRI images were obtained (200 scans per run) using axially oriented echo-planar imaging (TR = 2 sec; TE = 30 msec; 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 msec; TE = 4.77 msec; TI = 1100 msec; flip angle = 7°; 192 slices; 1 mm^3 isotropic voxels). The sentences were back-projected on a screen mounted on the head coil, allowing the participants to read them through a mirror.

fMRI Data Preprocessing

Data were analyzed using standard procedures implemented in SPM2 (www.fil.ion.ucl.ac.uk/spm). 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, Williams, Howard, Frackowiak, & Turner, 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 nonlinear normalization was applied using discrete cosine basis functions by which brain warps are expanded in SPM2 (Ashburner & 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 mm³ voxels and then spatially smoothed with an 8-mm full-width half-maximum isotropic Gaussian kernel to minimize effects of intersubject anatomical differences.

fMRI 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, Josephs, Rees, & Turner, 1998). Specifically, the event-related design matrix included all conditions of interest, that is, first sentence new-word concrete (1Nwc; new-word concrete embedded in the first-sentence context) and, analogously, 2Nwc (new-word concrete second sentence), 1Nwa (new-word abstract first sentence), 2Nwa, 1Rwc, 2Rwc, 1Rwa, 2Rwa. The data were 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 second-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 × Imageability for Rw and Nw conditions, and Word Type × Imageability in the comparison between Rw and Nw conditions) were calculated accordingly. Unless mentioned otherwise, contrasts were thresholded at $p < .001$ with a cluster extent of more than 20 contiguous voxels, and only clusters with a significant $p < .05$, corrected for multiple comparisons, are reported and interpreted (Worsley & 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, Kollokian, Kwan, & Evans, 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 new words. 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 participant 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 two-way repeated measures ANOVAs conducted separately for new-word and real-word conditions with the following factors: word exposure (first vs. second sentence) and imageability (concrete vs. abstract). Further statistical analyses with planned comparisons (two-sided, paired-sample *t* tests) were used to test differences ($p < .05$) between the parameter estimates from the different conditions.

RESULTS
Behavioral Performance

Meaning recognition for Nwc and Nwa did not differ significantly (71 ± 15.3% vs. 65 ± 15.1%, respectively, $t = 1.96$, $p = .069$) and was significantly different from chance [Nwc: $t(14) = 17.93$, $p < .0001$; Nwa: $t(14) = 16.65$, $p < .0001$]. Although the false alarm rate did not differ (Nwc: 21.1 ± 10.8% vs. Nwa: 24.2 ± 10.6%, $t = -1.2$, $p = .24$), fewer omissions were observed for Nwc [7.9 ± 7.8% vs. 10.7 ± 8.5%, $t(14) = -2.2$, $p < .044$].

Reaction times (RTs) were significantly shorter for Nwc [1674 ± 187 msec vs. 1809 ± 233 msec, $t(14) = -3.38$, $p < .004$], which may explain the higher omission rate for abstract new words, as an RT deadline of 3000 msec was used.

In the old/new-word recognition task the overall hit rate was 85.1% ($SD = 13.1$) and false alarms occurred in 10.8% ($SD = 11.3$), indicating that participants paid attention to the real-word sentence conditions. No differences between concrete and abstract words were found for hits (Rwc: 86 ± 14.7%, Rwa: 84.2 ± 12.8%; $t < 1$), false alarms (Rwc: 10.5 ± 13.7%, Rwa: 11.1 ± 10%; $t < 1$) and omitted responses (Rwc: 3.7 ± 4%, Rwa: 4.7 ± 4.8%; $t < 1$). However, participants were faster to judge concrete words [Rwc: 1188 ± 202 msec; Rwa: 1365 ± 206 msec, $t(14) = -5.2$, $p < .0001$].

In the new-word recognition test carried out after the scanning session, participants correctly recognized 13.4 ($SD = 7.4$) of 40 Nwc and 11.6 ($SD = 7.8$) of 40 Nwa ($t = 1.5$, $p = .14$). Of those new words correctly recognized, meaning was correctly recalled only for 3.5 ($SD = 2.8$) concrete and 1.9 ($SD = 2.8$) abstract new words [$t(13) = 2.70$, $p < .018$].

fMRI Data

Real-word Analysis

The contrast first-sentence real word versus second-sentence real word (word exposure effect) yielded acti- vations in the left fusiform gyrus (Brodmann's area [BA] 37), visual word form area (VWFA), right middle occip- ital gyrus (BA 18), left cuneus (BA 17), right precuneus/ superior parietal lobe (BA 7), left IFG (BA 45), right inferior/middle frontal gyrus (BA 45/46), and left middle temporal gyrus (BA 21) (Table 1, Figure 1A). There were no areas with significant activation for the opposite con- trast. This pattern is consistent with the repetitive sup- pression phenomenon (Grill-Spector, Henson, & Martin, 2006; Wheatley, Weisberg, Beauchamp, & Martin, 2005) due to priming on the second occurrence of the word (Ganel et al., 2006; Schacter, Dobbins, & Schnyer, 2004; Dehaene et al., 2001; Wiggs & Martin, 1998).

Regarding the imageability effect, neither for the con- trast Rwc > Rwa nor for the opposite contrast did sig- nificant activations emerge at the chosen threshold. However, when the threshold was lowered ($p < .005$, cluster extent 20 voxels), a significant activation was re- vealed in the right middle temporal gyrus (BA 21; coor- dinates: 52, −24, −8; $t = 4.02$, $p < .005$) for the latter contrast. No significant interaction was found between word exposure and imageability.

New-word Analysis

The contrast first-sentence new word versus second- sentence new word (word exposure effect) did not yield any significant activation. The opposite contrast showed significant activation in the left claustrum, left middle

Table 1. Activation Clusters for Main Effects (Word Exposure and Imageability) and Interaction on Real Words

| Brain Region | ~BA | Coordinates | | | | p Corrected |
		x	y	z	t	
Word Exposure Effect (1Rw > 2Rw)						
L Fusiform gyrus	37	−36	−52	−20	8.89	.0001*
R Middle occipital gyrus	18	24	−96	0	7.53	.0001*
L Cuneus (SCA)	17	−12	−88	0	6.45	.0001*
R Precuneus/superior parietal lobe	7	28	−56	52	6.48	.001
L Inferior frontal gyrus	45	−52	32	16	6.04	.0001
R Inferior/middle frontal gyrus	45/46	56	24	32	4.10	.0001
L Middle temporal gyrus	21	−52	−40	−4	5.37	.005
Word Exposure Effect (2Rw > 1Rw)		No significant activations				
Imageability Effect (Rwc > Rwa)		No significant activations				
Imageability Effect (Rwa > Rwc)		No significant activations				
Interaction		No significant activations				

MNI coordinates and t value for the peak location in a particular identified anatomical cluster ($p < .001$, 20 voxels spatial extent) for the statistically significant differences in the corresponding activated regions. Note that only clusters that were significant on a cluster level of $p < .05$ (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).

*$p < .0001$.

Figure 1. Brain areas that were found active in real-word and new-word analysis. (A) Group-average comparisons between first sentence and second sentence for real words (word exposure effect). 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. L = left; VWFA = visual word form area. (B) Views in standard stereotactic space of the group-average comparison between second and first sentence for new word (word exposure effect). (C) Average comparisons between new-word concrete and new-word abstract for new-word conditions (imageability effect). (D) Group-average interaction between word exposure and imageability. L = left; R = right; FFG = fusiform gyrus.
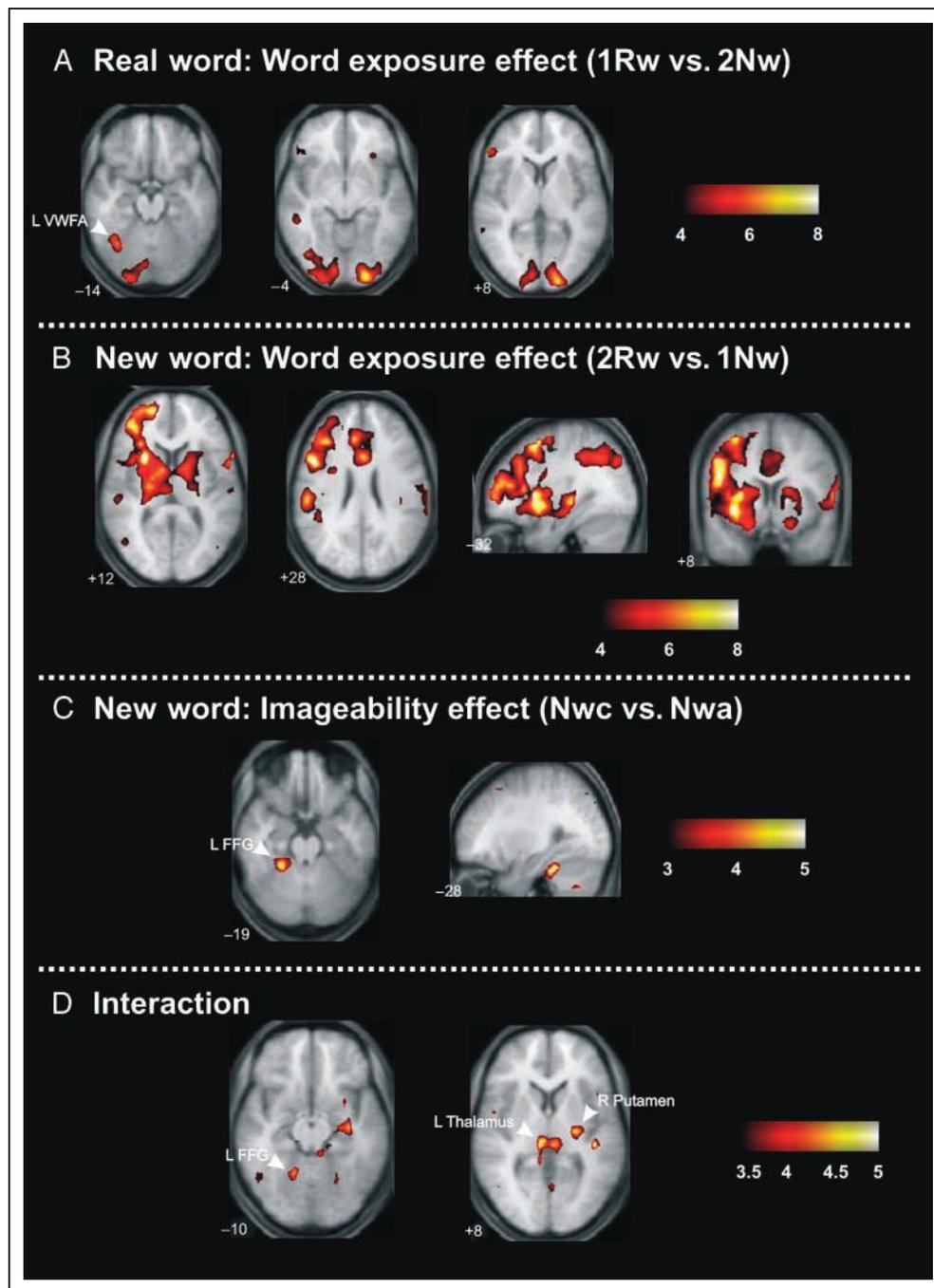
frontal gyrus (BA 46), right anterior cingulate gyrus (BA 32), left middle temporal gyrus (BA 21), right precentral gyrus (BA 4), left inferior parietal lobe (BA 40), right putamen, right caudate body, left IFG (BA 45), left putamen, and left caudate body (Table 2, Figure 1B).

The comparison Nwc versus Nwa (imageability effect) yielded significant activation in the left fusiform gyrus (BA 37) (Figure 1C, Table 2). The opposite contrast did not show any significant activation. Interactions between word exposure and imageability were found in the left thalamus, right putamen, and left fusiform gyrus (BA 20/37) (Figure 1D, Table 2). These interactions reflected

the increased activation in Nwc for the second sentence (see parameter estimates analysis of these regions in Figure 2B and Figure 3).

New-word vs. Real-word Comparison (Second Sentence)

The contrast second-sentence real word versus second-sentence new word (word-type effect) revealed anterior and posterior cingulate cortex activation (Table 3). The opposite contrast yielded large activations in various regions of the left hemisphere, including the left IFG (BA 45),

Table 2. Activation Clusters for Main Effects (Word Exposure and Imageability) and Interaction on New Words

| Brain Region | ~BA | Coordinates | | | | p Corrected |
		x	y	z	t	
Word Exposure Effect (1Nw > 2Nw)		No significant activations				
Word Exposure Effect (2Nw > 1Nw)						
L Claustrum		−28	12	12	11.83	.0001*
L Middle frontal gyrus	46	−40	44	16	9.96	.0001*
R Anterior cingulate cortex	32	8	24	40	7.50	.0001*
L Middle temporal gyrus	21	−60	−32	−4	7.67	.0001**
R Precentral gyrus	4	60	12	4	7.39	.0001**
L Inferior parietal lobe	40	−44	−40	52	7.17	.0001**
R Putamen (lentiform)		20	−4	16	6.65	.0001**
R Cerebellum		12	−80	−28	6.51	.0001**
R Caudate body		16	4	12	6.10	.0001**
L IFG	45	−36	36	8	7.80	.0001
Left Putamen		−20	−8	12	6.70	.0001
Left Caudate body		−8	0	12	6.60	.0001
Left Brainstem (midbrain)		0	−40	−20	5.19	.0001
Imageability Effect (Nwc > Nwa)						
L Fusiform gyrus	37	−24	−40	−24	6.36	.001***,a
Imageability Effect (Nwa > Nwc)		No significant activations				
Interaction						
R Brainstem (pons)		8	−32	−32	5.35	.040
L Thalamus (pulvinar)		−8	−28	8	5.05	.006
R Putamen (lentiform)		28	−16	8	4.86	.048
L Fusiform gyrus	20/37	−32	−32	−28	4.77	.034

MNI coordinates and *t* value for the peak location in a particular identified anatomical cluster (*p* < .001; 20 voxels spatial extent) for the statistically significant differences of the corresponding activated regions.

[a]Small volume correction.

*p < .00001.

**p < .0001.

***p < .0005.

the left middle frontal gyrus (BA 46), fusiform gyrus bilaterally (BA 37, VWFA), anterior cingulate cortex/presupplementary motor area (ACC/pre-SMA, BA 32/6), left inferior parietal lobe (BA 40), the caudate body bilaterally, the thalamus bilaterally, and the left superior temporal gyrus (BA 22) among other regions (see Table 3, Figure 2A).

The concrete versus abstract contrast (imageability effect) showed activation in the left fusiform gyrus (BA 37) (Figure 2B, Table 3). This region matched with the activation in the fusiform gyrus observed in the previous contrast between Nwc and Nwa (see imageability effect in the previous section). There were no areas displaying

significant activation for the opposite contrast. No significant interaction was found between word type and imageability.

Analysis of the Areas Modulated by Word Imageability

To further pinpoint the effects of imageability, ANOVAs were performed on the parameter estimates at the peak coordinates of the following regions: left fusiform gyrus (including anterior fusiform gyrus and VWFA) and right middle temporal gyrus. The regions were selected because they have been implicated in previous studies (Bedny & Thompson-Schill, 2006; Fliessbach et al., 2006;
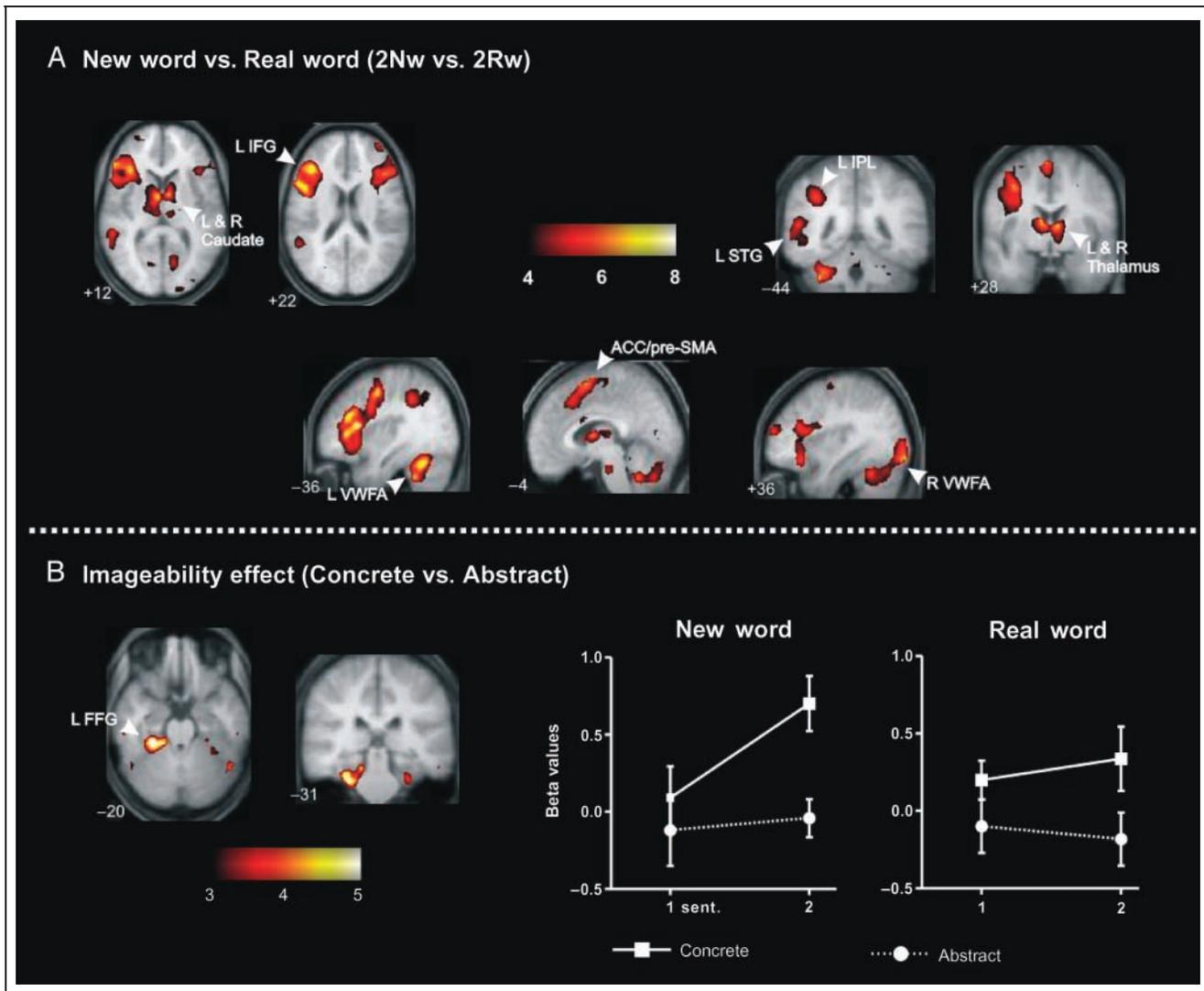
Figure 2. Activation of the anterior ventral fusiform gyrus in learning new concrete words. (A) Group-average comparisons between new word and real word (word-type effect). (B) Group-average comparison between concrete and abstract (imageability effect). Group-average beta values for first and second sentence of new word and real word (abstract–concrete) in the left fusiform gyrus (BA 37, coordinates −28, −36, −24). Error bars indicate standard error of the mean. L = left; R = right; IFG = inferior frontal gyrus; IPL = inferior parietal lobe; STG = superior temporal gyrus; VWFA = visual word form area; ACC/pre-SMA = anterior cingulate cortex/pre-supplementary motor area; FFG = fusiform gyrus; sent. = sentence.

Sabsevitz et al., 2005; Wallentin et al., 2005; Giesbrecht et al., 2004; Whatmough et al., 2004; Noppeney & Price, 2002). The results of the ANOVA analysis are summarized in Table 4.

For the anterior left fusiform gyrus (BA 37) (Figure 2B, Table 3), concrete stimuli evoked greater activation than abstract stimuli. Interestingly, concrete stimuli were associated with greater activation than abstract stimuli in both the first and second sentences. Moreover, during the second sentence, Nwc showed greater activation than Rwc [$t(14) = 2.31, p < .036$]. A more posterior portion of the fusiform gyrus, corresponding to the VWFA (see Figures 1A, 2A, and 3), showed a different pattern: Nwc showed an increase in activation from the first to second sentence, whereas Nwa showed no differences.

For real words, a deactivation was seen for the second sentence. The same pattern of activation was observed on the right VWFA. Thus, the ventral anterior fusiform gyrus was modulated by imageability in general, whereas the VWFA showed modulation only for new words.

The right middle temporal gyrus (BA 21) showed effects of imageability for real words. We observed that this region showed greater activation for 1Rwa compared to 1Rwc (see Table 4 and Figure 3). Although new-word conditions did not show imageability effects in this region, Rwa showed a greater level of activity than Rwc during both the first and second 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 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.

DISCUSSION

This experiment used fMRI to study the association of new words to an existing meaning derived from sentential context. In particular, it was asked how this process differs depending on a word's concreteness. The main finding of the present study is that the left fusiform gyrus plays a differential role depending on a word's imageability. This region was only involved in learning new concrete words while practically no activation was observed for new abstract words. Whereas no region showed differential involvement in learning the meaning of abstract new words, the right middle temporal gyrus (BA 21) was more activated for real abstract words. We

will further discuss the learning effects (behaviorally) obtained, the involvement of the fusiform and the middle temporal gyrus in learning concrete and abstract new words and, finally, the implication of other regions activated during the learning task.

Word Learning Behavioral Effects

The correct meaning assignment task conducted after each experimental run indicated that both concrete and abstract words were successfully learned from contextual information (Chaffin, Morris, & Seely, 2001). The mean percentage of correct meaning assignment obtained was 68%, very similar to our previous results using only concrete words (Mestres-Missé, Camara, Rodriguez-Fornells, Rotte, & Munte, 2008). Although both types of new words were successfully learned, concrete words were associated with faster RTs and fewer omissions than abstract words. The present results replicate previous findings showing that concrete words are easier to learn and to remember than abstract words in second-language learning (de Groot, 2006; de Groot & Keijzer, 2000; van Hell & Candia-Mahn, 1997). Effects of word concreteness have not only been found in novice learners of a second language but also in fluent bilinguals who translated concrete words more quickly and accurately than abstract
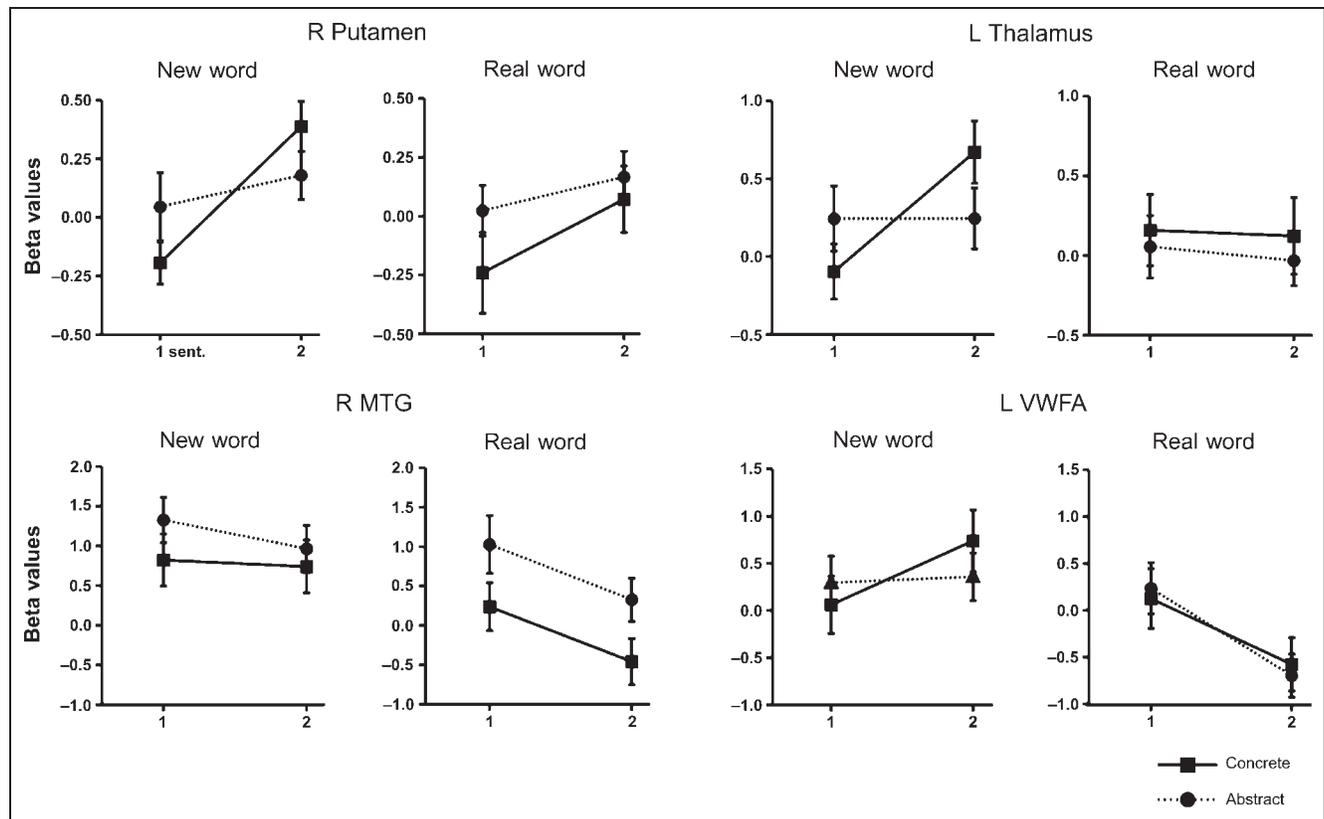

Figure 3. Parameter estimates analysis for concrete and abstract new words and real words. Group-average beta values for first and second sentence of new-word and real-word condition (abstract–concrete) in the right putamen (coordinates 28, −16, 8), left thalamus (−8, −28, 8), right middle temporal gyrus (52, −24, −8), and left VWFA (−36, −56, −20). Error bars indicate standard error of the mean. sent. = sentence.

Table 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

| Brain Region | ~BA | Coordinates | | | | p Corrected |
		x	y	z	t	
Word Type Effect (2Rw > 2Nw)						
Anterior cingulate cortex	32	0	28	−8	7.84	.0001
L Posterior cingulate gyrus	31	−4	−52	32	4.88	.017
Word Type Effect (2Nw > 2Rw)						
L Insula/IFG	13	−36	20	16	9.15	.0001*
L IFG	45	−36	32	8	8.19	.0001*
L IFG	44	−48	8	24	8.09	.0001*
L Fusiform gyrus	37	−36	−56	−20	7.58	.0001**
R Middle occipital gyrus	18	40	−88	−8	7.25	.0001**
L Middle frontal gyrus	46	−36	−4	48	7.19	.0001**
R Fusiform gyrus	37	32	−52	−24	6.81	.0001**
R Inferior frontal gyrus	45	44	24	20	6.83	.0001**
L Anterior cingulate cortex/pre-SMA	32/6	−4	4	64	6.55	.0001**
L Caudate body		−8	−4	16	7.40	.0001
R Caudate body		8	0	12	7.33	.0001
L Superior temporal gyrus	22	−60	−52	16	6.72	.0001
L Cuneus	18	−24	−96	−8	5.83	.003
L Inferior parietal lobe	40	−40	−44	44	5.77	.0001
L Brainstem (pons)		−4	−20	−24	5.27	.035
R Thalamus (medial dorsal)		8	−20	12	4.92	.0001
L thalamus		−8	−20	16	4.88	.0001
R Middle frontal gyrus	6	32	−8	68	4.73	.030
R Thalamus		20	−16	16	4.72	.0001
L Cuneus (SCA)	17	−12	−76	4	4.38	.019
Imageability Effect (C > A)						
L Fusiform gyrus	37	−28	−36	−24	5.74	.002
Imageability Effect (A > C)		No significant activations				
Interaction		No significant activations				

MNI coordinates and *t* value for the peak location in a particular identified anatomical cluster (*p* < .001; 20 voxels spatial extent) for the statistically significant differences of the corresponding activated regions. A = abstract; C = concrete.

*$p < .00001$.

**$p < .0001$.

words (van Hell & de Groot, 1998a, 1998b; de Groot & Poot, 1997).

Interestingly, in the new-word recognition test carried out after the scanning session, approximately 31% of the new words were correctly recognized with no differences between concrete and abstract words. When recalling the meaning of the recognized words, concrete meanings were better recalled than abstract meanings albeit the small percentage of new-word meanings that were recalled. It is important to bear in mind that the focus of the present vocabulary learning simulation is on the process of inferring the meaning of a new word from a verbal context (Frantzen, 2003; Nation, 2001; Nagy & Gentner, 1990; Nagy, Anderson, & Herman, 1987). Therefore, the

Table 4. Parameter Estimates Analysis

	Peak Coordinates	New Word			Real Word		
		WE	I	WE × I	WE	I	WE × I
L aFFG	−28, −36, −24	5.2*	28.04***	10.02***	ns	12.8**	ns
L VWFA	−36, −56, −20	ns	ns	13.03**	54.05***	ns	ns
R MTG	52, −24, −8	ns	ns	ns	10.3**	19.4***	ns

Pairwise ANOVAs restricted to new word and real word, respectively, comparing the different conditions and regions of interest. WE = word exposure (first vs. second sentence); I = imageability; L aFFG = left anterior fusiform gyrus; L VWFA = left visual word form area; R MTG = right middle temporal gyrus; ns = nonsignificant. Degrees of freedom = 1, 14.

*p < .05.

**p < .01.

***p < .001.

correct meaning assignment task used within the scanning runs and the new-word recognition task used at the end of the fMRI session should only be considered indirect indexes of the meaning discovery process. In previous studies using similar materials and the same paradigm, the percentage of correct meaning extraction was approximately 91% when directly evaluated after the presentation of the verbal context (Mestres-Missé et al., 2007). The lack of correct recall of the meanings at the end of the experiment can easily be explained by taking into account that participants had to remember the meaning of 80 new words in roughly 1 hr and 15 min, each presented only in one trial without repetitions. Further training would likely lead to a gradual increase of recalled meanings. It is also important to stress that the memory tests we used were focused on the evaluation of the association between the new word and an already existing concept. Other psycholinguistic tasks (e.g., semantic priming, lexical decision, naming tasks, picture–word interference) would be needed as well as longitudinal designs in order to evaluate how the new words are integrated in the mental lexicon. Whereas several studies have investigated how new words are integrated in the lexicon in this way, they do not provide information as to the neural networks involved (Tamminen & Gaskell, 2008; Clay, Bowers, Davis, & Hanley, 2007; Dumay & Gaskell, 2007; Gaskell & Dumay, 2003).

Imageability Effects in the Fusiform and Middle Temporal Gyrus

Several regions were modulated by word imageability. The activation found in the ventral anterior fusiform gyrus for concrete items in the present study is consistent with earlier studies (Bedny & Thompson-Schill, 2006; Fliessbach et al., 2006; Sabsevitz et al., 2005; Wallentin et al., 2005; Giesbrecht et al., 2004; Whatmough et al., 2004; Wise et al., 2000; Mellet et al., 1998; D'Esposito et al., 1997; Fletcher et al., 1995). This part of the fusiform gyrus is a region of the inferotemporal cortex associated with high-level visual processing (Ishai, Ungerleider, & Haxby, 2000; Chao, Haxby, & Martin, 1999; Mellet et al., 1998; D'Esposito et al., 1997). Activation of this region has been reported in studies of word reading (Cohen et al., 2002; Dehaene, Le, Poline, Le, & Cohen, 2002; Buchel, Price, & Friston, 1998), object categorization (Gerlach et al., 2002; Gerlach, Law, Gade, & Paulson, 2000; Martin et al., 2000; Gerlach, Law, Gade, & Paulson, 1999; Martin, Wiggs, Ungerleider, & Haxby, 1996), semantic association (Vandenberghe, Price, Wise, Josephs, & Frackowiak, 1996), object naming (Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996; Martin et al., 1996; Price, Wise, & Frackowiak, 1996), encoding of pictures (Stern et al., 1996) and words (Wagner et al., 1998), and word concreteness (Bedny & Thompson-Schill, 2006; Sabsevitz et al., 2005; Wallentin et al., 2005; Fiebach & Friederici, 2004; Mellet et al., 1998; D'Esposito et al., 1997; Fletcher et al., 1995). 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 (Hoenig & Scheef, 2005; Ryan et al., 2001). Moreover, neuropsychological studies of patients with lesions in the inferior temporal cortex tend to show a selective preservation of abstract compared to concrete concepts (Marshall et al., 1996; Breedin et al., 1994; Warrington & Shallice, 1984; Warrington, 1975, 1981).

Our results extend these previous findings by showing that this region is involved in learning the meaning associated to concrete new words. Indeed, prior research has shown that retrieving information about object attributes engages the same areas that mediate their perceptual processing, suggesting the existence of distributed semantic representations (Martin, 2001; Martin et al., 2000; Barsalou, 1999; Kosslyn et al., 1999; Damasio, 1989; Allport, 1985). Crutch and Warrington (2005) have recently proposed that representations of concrete words can be thought of in terms of a well-organized hierarchical structure (categorical organization), whereas abstract words have a shallower (associative) organization.

This categorical organization of superordinate and sub-ordinate representations for concrete words allows the sharing of features with overlapping concepts, which might have allowed the participants to easily infer the meaning of the concrete new words. This might explain the greater activation of the anterior ventral fusiform gyrus in Nwc compared to Rwc. In the search for the matching concept, several candidates associated to the underlying hidden concept might be activated. If only the conceptual representation of the hidden (target) word had been activated in the Nwc condition, a difference between real and new-word conditions should not have been obtained (see Figure 2B). This is in line with previous suggestions that this region is involved in conceptual and/or lexical processing and not only related to stimulus feature processing (Martin, 2007; Simons, Koutstaal, Prince, Wagner, & Schacter, 2003; Koutstaal et al., 2001).

The selective activation of the ventral anterior fusiform gyrus for concrete words and new-word learning in the present study is consistent with one of the most important predictions of the dual-coding theory (Paivio, 2006). The activation of the nonverbal imagery symbolic system in concrete words predicts the activation of several areas of the ventral visual or ''object properties processing'' pathway, as it was the case in the present study. Previous studies also support the involvement of these regions in visual imagery (see meta-analysis in Thompson & Kosslyn, 2000). In contrast, the context availability theory (Schwanenflugel & Shoben, 1983) proposes the activation of a single-amodal system, represented by a general neural network or region, which could be only modulated due to the differential contextual availability in concrete and abstract words. As virtually no activation of the ventral anterior fusiform gyrus was seen for abstract words, the present results do not support this model. Importantly, we presented the words and new words in very supportive sentence contexts which, if anything, should have mitigated any concreteness effects according to the contextual availability theory.

As the conceptual representations associated to abstract words are more disperse and branched in semantic memory due to their associative structure (Crutch & Warrington, 2005; Schwanenflugel & Shoben, 1983), one should expect abstract words to activate regions involved in deeper semantic processing. Indeed, our results showed middle temporal gyrus involvement in the processing of abstract real words (see also Pexman et al., 2007), but no differential activation was found for the learning of abstract new words compared to concrete new words. However, the activation in the middle temporal gyrus might be confounded with the task of meaning extraction, as both new-word conditions have high semantic processing demands (see also Mestres-Missé et al., 2008). A further explanation for the lack of activations specifically reflecting the association of abstract new words to their meaning might be that this process is spatially more dispersed with a greater inter-item variability. This explanation would agree with the idea that the meanings of abstract words tend to be more variable and less redundant across contexts, frequently having related but distinct meanings.

We also found that a more posterior and dorsal region of the fusiform gyrus, known as the VWFA, showed a stronger response to the concrete new-word condition (Nwc) especially during the second sentence. The VWFA has been related to prelexical representation of visual words, responding preferentially to letter strings than to other categories of visual stimuli (for a review, see Cohen & Dehaene, 2004), and to word and word-like (pseudo-words) stimuli than consonant strings (Binder, Medler, Westbury, Liebenthal, & Buchanan, 2006; Cohen et al., 2002; Dehaene et al., 2002; Buchel et al., 1998). However, other studies have found larger activation in this region for pseudowords compared to words which challenges the view of the VWFA as limited to prelexical processing (Abutalebi et al., 2007; Kronbichler et al., 2004; Mechelli, Gorno-Tempini, & Price, 2003). The VWFA has been reported to show no differences in activation as a function of semantic category (Dehaene et al., 2002) or of word imageability (Buchel et al., 1998). Recently, Abutalebi et al. (2007) found larger activation in this region in a task where participants had to link known semantic and phonological information to a new orthographic word form. Therefore, the larger activation found in this study for new words might be attributed to the retention and storage of visual word forms. At present, and considering the previous literature, we do not have a clear explanation about the increased activation seen in this region when learning concrete new word forms. Further research might be needed in order to understand the differences in activation found between concrete and abstract new words and the role of this region in word learning.

Other Brain Regions Involved in Word Learning

A distributed brain network was involved in word learning that includes the left IFG (BA 45), middle and superior temporal gyrus (BA 21/22), ACC/pre-SMA (BA 32/6), and several subcortical areas. This network corroborated the pattern observed in an earlier study (Mestres-Missé et al., 2008).

In relation to the basal ganglia, it has been shown that these regions play an important role in human learning (Seger, 2006; Seger & 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 & Strick, 2000). Prefrontal cortex and the striatum are often simultaneously active during learning (Seger & Cincotta, 2006). The thalamus has been shown to be involved in object recall and lexical retrieval (Crosson et al., 2003; Kraut et al., 2002; Crosson et al., 1999).

Figure 4. New-word abstract induced greater activation than new-word concrete during the first sentence in ACC/pre-SMA. Group-average beta values for first and second sentence of new-word and real-word condition (abstract–concrete) in left ACC/pre-SMA (−4, 4, 64). Error bars indicate standard error of the mean. sent. = sentence.
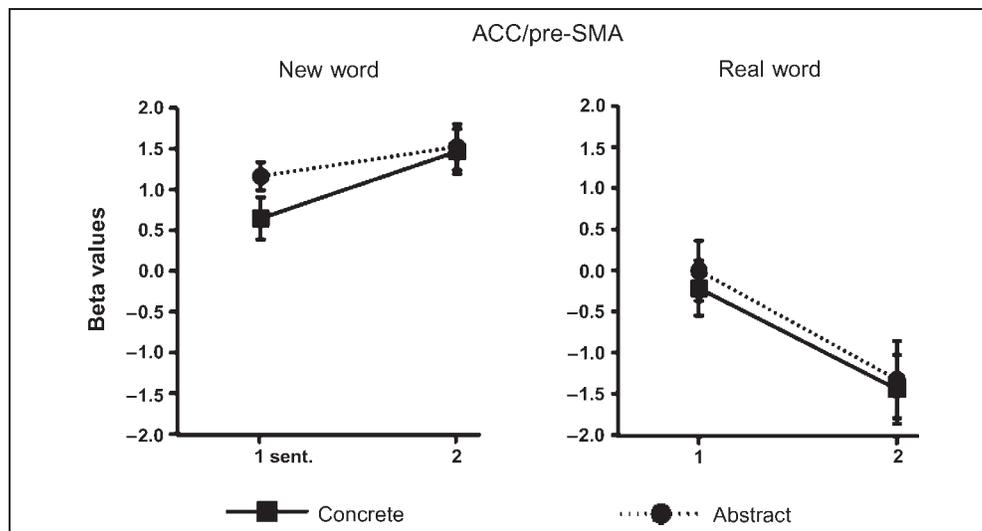
In our previous study (Mestres-Missé et al., 2008), we hypothesized that the coupling between ACC and subcortical structures might be involved in facilitating the retrieval of lexical items from preexisting stores during language generation. The basal ganglia might induce and maintain a processing bias toward the selection of a candidate meaning. Once an appropriate lexical item has been selected, the bias may be overridden allowing further processing of the selected item by frontal structures (Crosson et al., 2003), and later storage in medial-temporal regions. Similarly, Ullman (2006) has proposed the existence of a frontal–subcortical circuit involving the anterior IFG (pars triangularis, BA 45) and basal ganglia, which might subserve the retrieval of lexical/semantic knowledge.

One important finding is that we observed greater activation during the association of concrete but not abstract new words to their meaning in some regions of this loop (the basal ganglia, thalamus, and ACC/pre-SMA). Importantly, these regions are not directly linked to high-level visual processing (i.e., the imageability aspect of concrete words). Nwa induced greater activation than Nwc during the first sentence in ACC/pre-SMA [$t(14) = -2.2$, $p < .038$; see Figure 4]. The basal ganglia and the thalamus showed the pattern of greater activation for new-word conditions compared to real-word ones during the second sentence (Figure 2A, Table 3). In contrast, in the left thalamus and right putamen, only Nwc was associated with an increase on activation in the second sentence when compared to Nwa (see Figure 3). We propose that the greater activation for concrete new words reflects faster and easier selection of a candidate meaning, allowing greater activity to accrue in this network. This activation can thus be viewed as the neural counterpart of the behavioral finding that concrete words are learned easier, faster, and better than abstract words (de Groot, 2006; de Groot & Keijzer, 2000; van Hell & Candia-Mahn, 1997).

Finally, learning of new words also led to activation of inferior parietal cortex, which has previously been shown to reflect learning of new words through association (Breitenstein et al., 2005), learning new labels for new tools (Cornelissen et al., 2004), second-language proficiency (Mechelli et al., 2004), and recently, the size of the vocabulary in adolescents (Lee et al., 2007). Further studies are required to understand the exact function of this region in word learning.

Conclusions

To summarize, the present study showed the differential involvement of some regions in the meaning assignment to new concrete and abstract words. The most important finding is that the ventral anterior fusiform gyrus is exclusively engaged in the association of new concrete words to their meaning. This provides further evidence for the existence of qualitative differences in learning, storing, and processing concrete and abstract words.

APPENDIX A: NOVEL CONCRETE WORDS–CORRESPONDING SPANISH WORDS (ENGLISH TRANSLATION)

Adarato–coche (car); alacro–cigarro (cigarette); areo–sol (sun); atelo–queso (cheese); bilsa–iglesia (church); bisaco–aceite (oil); bisno–colegio (school); brande–llave (key); bupido–suelo (floor); capino–cine (movie theater); cartuno–zapato (shoe); catebia–escalera (stair/ladder); centiño–barco (boat/ship); cerino–papel (paper); cija–uña (nail); cilso–cuadro (painting); clita–bandera (flag); conua–guitarra (guitar); coparo–médico (doctor); curteno–otoño (fall); desuba–isla (island); diero–bar (bar); difo–pan (bread); duta–boca (mouth); enrate–café (coffee); faleto–calendario (calendar); fato–diente (tooth); fiamba–estrella (star); flesta–película (movie); foba–nube

(cloud); fostico–amigo (friend); gepo–plato (plate); geria–sangre (blood); herno–teléfono (telephone); ilero–mar (see); imgeo–león (lion); insata–vela (candle); lertico–pez (fish); lianto–corazón (heart); libeso–aeropuerto (airport); lineto–sombrero (hat); mabrona–naranja (orange); madida–nariz (nose); masuo–espejo (mirror); matreño–botón (button); mesato–azúcar (sugar); miloma–ventana (window); minto–periódico (newspaper); motra–cocina (kitchen); nalosa–gota (drop); nilecas–gafas (glasses); ilopo–cuchillo (knife); obeto–árbol (tree); ofa–mosca (fly); omblón–pantalón (trousers); onito–brazo (arm); oprisa–tarjeta (card); paceto–anillo (ring); pecua–mancha (stain); pieto–paraguas (umbrella); pilso–gato (cat); pisal–fútbol (soccer); pruba–leche (milk); pune–ojo (eye); ralida–cama (bed); rasiño–hotel (hotel); recea–canción (song); restate–ordenador (computer); rotiro–fuego (fire); seomo–río (river); sibrano–televisor (television); sionte–oído (ear); tarra–mesa (table); tilapo–ascensor (elevator); trepto–cinturón (belt); tulso–casco (helmet); valo–mapa (map); varosa–silla (chair); vatesa–ciudad (city); viato–dedo (finger).

APPENDIX B: NOVEL ABSTRACT WORDS–CORRESPONDING SPANISH WORD (ENGLISH TRANSLATION)

Adrema–solución (solution); ango–principio (beginning); astino–plan (plan); asiro–milagro (miracle); atual–titular (holder); belinca–cultura (culture); belto–volumen (volume); beste–turno (turn); biteco–tamaño (size); bofín–rastro (trace); camira–noticia (a piece of news); canduta–teoría (theory); casel–acuerdo (agreement); cipita–importancia (importance); crosna–denuncia (report/complaint); cucheno–efecto (effect); cunto–ejemplo (example); denería–venganza (revenge); desala–prueba (proof); dicamo–significado (meaning); ditena–curiosidad (curiosity); emsa–imaginación (imagination); espel–pecado (sin); espimo–fracaso (failure); esruba–presión (pressure); etudo–destino (fate); fimeta–duda (doubt); findo–motivo (reason); flata–edad (age); gaena–seguridad (security); gamila–suerte (luck); gasba–descripción (description); graenta–generación (generation); guna–reserva (reservation); gurato–tratamiento (treatment); hareta–oportunidad (opportunity); idona–influencia (influence); imbra–broma (joke); infaco–control (control); isama–inteligencia (intelligence); lapio–eco (echo); leco–curso (course); macito–misterio (mistery); mampo–límite (limit); midoga–diferencia (difference); milso–secreto (secret); motefa–fe (faith); nacal–mito (myth); niepa–tradición (tradition); nilata–adopción (adoption); nosa–talla (size); oceta–experiencia (experience); oleto–final (final/ending); olusna–información (information); oviro–cuidado (care); pesmola–norma (rule); piloma–intención (intention); pinocas–ganas (to feel like doing something); puca–pausa (pause); pusofa–conclusión (conclusion); queseja–crítica (criticism); rasinta–dificultad (difficulty); recerdo–valor (value); recola–posición (position); refia–decisión (decision); remoca–personalidad (personality); rinaca–vergüenza (shame);

ristro–perdón (forgiveness); rolantre–paro (unemployment); sileca–combinación (combination); silopa–espera (wait); silta–ayuda (help); sito–resultado (result); tacela–duración (duration); teba–energía (energy); tería–culpa (fault); tesca–conciencia (conscience); tezo–error (mistake); tromo–reto (challenge); ulina–justicia (justice).

Note

1. In the present study, ''concrete and abstract word or new word forms'' are used in order to refer to the word or new word forms (existing or new lexemes) that symbolize concrete or abstract conceptual information, respectively. The terms ''abstract'' and ''concrete word forms'' have been used systematically in the literature (Paivio, 2006; Crutch & Warrington, 2005; Kroll & Merves, 1986; Schwanenflugel & Shoben, 1983) even though this distinction is only applicable to the knowledge or conceptual representations a word refers to.

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