

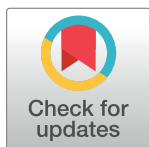
RESEARCH ARTICLE

# Individual differences in associative/semantic priming: Spreading of activation in semantic memory and epistemically unwarranted beliefs

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**Data Availability Statement:** Data, analysis code (R scripts) and fitted models (Bayesian LMEMs) that support the findings of this study are openly available in Open Science Framework (OSF) repository at <https://doi.org/10.17605/OSF.IO/G62ST>. Data analysis details document (more detailed account of our analytical and technical decisions, along with relevant code) and LMEMs complete reporting document (full results for each model with all relevant estimates) are available as [Supporting Information](#) files.

## Abstract

Starting from the *enhanced spreading of activation through semantic memory* (one of the explanatory mechanisms attempting to explain some manifestations observed in schizophrenia) and the *psychosis continuum* (a dimensional approach to psychotic disorders, where ‘normality’ and ‘psychopathology’ are not qualitatively different in nature but placed on varying levels of the same continuum), the main aim of the present research was to explore whether there are individual differences in associative/semantic priming in people with different levels of epistemically unwarranted beliefs (EUB). Participants varying in para-normal, pseudoscientific and conspiracy endorsement completed a primed lexical decision task containing related prime-target words (e.g., bulb-light) and unrelated prime-target words (e.g., sock-light). Bayesian linear mixed-effects models over response times (RTs) revealed a main direct priming effect (faster RTs in related pairs than in unrelated ones), a main facilitatory effect for some EUB scores (i.e., the higher the value for EUB score, the faster RTs), and an interactive effect between the experimental manipulation and some EUB scores (the higher the EUB score, the smaller the direct priming effect). These results are consistent with predictions made from the enhanced spreading of activation explanatory mechanism, but other alternative accounts are also discussed.

## Introduction

Schizophrenia is a diagnostic label used to designate a heterogenous combination of symptoms in perception (e.g., hallucinations, delusions), language and communication (e.g., disorganized speech, poverty of speech), affect (e.g., anhedonia, amotivation, flat emotional expression), and social behaviour (e.g., disorganized behaviour, social withdrawal), which cannot be attributed to other causes (e.g., direct effects of a drug) and that significantly impair a person’s everyday

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functioning [1–3]. From the very beginning, the term *loosening of associations* has been used to describe one of the key underlying disturbances in schizophrenia [4], that is, a disruption in how concepts, thoughts and pieces of information are connected in a logical, warranted, and coherent way [5]. This associative disturbance could explain some manifestations of schizophrenia, such as disorganised speech (i.e., jumping incoherently from one word or idea to another) and delusions (i.e., associating pieces of information that are, in fact, not connected). Evidence supporting this loosening of associations in schizophrenia comes from observations including derailment and tangentiality in speech (see [6]), production of infrequent words in verbal fluency tasks (e.g., [7]) and word-association tests (e.g., [8]), and increased associative/semantic priming effects (e.g., [9]), among others.

One of the main explanatory mechanisms that attempts to account for the loosening of associations is the *enhanced spreading of activation through semantic memory* (e.g., [6,10–13]). According to localist network accounts, semantic memory can be understood as a network of interconnected concept nodes (S4.1 in S4 File) word that denominates it), part of its activation spreads through its links to other nodes [14,15 Chapter two]. Nodes reached by this spread activation will be pre-activated to some extent and, accepting that activation level is what determines memory accessibility [16], these nodes' concepts would be more easily evoked. Of note, this activation is not propagated equally but depends on the characteristics of the connections such as directedness or distance (directly linked, linked through one intermediate node, linked through two intermediate nodes, etc.) and strength (some relationships are stronger than others) [14,15 Chapter eleven]. These characteristics, in turn, depend on factors like the degree of lexical co-occurrence and the amount of shared semantic features [6,17]. In this context, people diagnosed with schizophrenia may show loose associations because their semantic memory networks would exhibit an enhanced spreading of activation (e.g., [6,10–13]) in comparison to people without such a diagnosis. This would lead to co-activation of nodes that are distantly or weakly related.

Experimental evidence for the loosening of association phenomenon has also been obtained in non-clinical individuals scoring high in schizotypal personality traits (see [10]), with results analogous to those observed in schizophrenia. For instance, Kiang and Kutas [18] observed that schizotypal personality scores were positively correlated with an index on the atypicality of words produced in a verbal fluency task. This commonality with loosening of associations in schizophrenia is not be entirely surprising following a dimensional perspective of psychopathology, where 'normality' and 'psychopathology' are not qualitatively different in nature but placed on varying levels of the same continuum (e.g., [19,20]; see also [21] for an example of dimensional nosology of psychopathology). Indeed, several proposals exist about a *psychosis continuum* where schizotypal personality can be accommodated (for an overview, see [22,23]). The psychosis continuum framework opens the possibility of studying schizophrenia-related issues in non-clinical populations: instead of comparing people diagnosed with schizophrenia with people without such diagnosis, these issues can be indirectly studied by examining individuals with varying levels of schizotypal or other related traits. This approach makes it possible to avoid some problems associated with studies with people diagnosed with schizophrenia, such as difficulty in finding and recruiting participants, and the confounding effects of variables like primary and secondary effects of medication [10,24].

Starting from the psychosis continuum framework, the present investigation focuses on the extent to which loosening of associations can be observed in non-clinical individuals during semantic processing, in particular, in an associative/semantic priming paradigm. A typical trial of this paradigm involves the sequential presentation of a pair of stimuli: the first is the *prime*, the second is the *target*. While the prime stimulus only needs to be attended, participants are usually required to perform a task with regards to the target stimulus, such as lexical decision

(LDT; to decide whether it is a real word or a string of letters that does not correspond to an existing word) and naming (to read it aloud) [15 Chapter one]. The *associative/semantic priming effect* refers to the consistently observed result that response times (RTs) and/or response accuracy for the target word (e.g., water) are facilitated when the prime word is associatively or semantically related (S4.2 in [S4 File](#)) (e.g., glass) in comparison to when it is unrelated (e.g., class). This effect can be understood as a consequence of the by-default functioning of semantic memory: the evocation of a target word is facilitated when preceded by a related prime (but not by an unrelated prime) because its concept node would be pre-activated, as a consequence of the spreading activation coming from the concept node of the prime word ([15 Chapter two, 25]). It should be mentioned that associative/semantic priming effects have been attributed not only to automatic processes (e.g., spreading activation), but also to controlled and strategic processes (e.g., expectancy, semantic matching) (for more details, see [15 Chapter nine, 26]).

Our study is motivated by inconsistencies in the evidence regarding associative/semantic priming effects in individuals diagnosed with schizophrenia or with high levels of schizotypal traits: exacerbated priming effects (hyperpriming); diminished priming effects (hypopriming); and non-significant differences have been reported in comparison to their respective control groups (for overviews, see [10,12,17]). These inconsistencies can be explained, in part, by methodological differences between studies regarding how the experimental priming paradigm has been implemented (see [10,12,17]). A first experimental variable that can modulate associative/semantic priming effects is the directness of relationship: prime-target words can be directly related (i.e., glass-water) or they can be indirectly related through one or more intermediate word/s (i.e., plate-water through glass) [15 Chapter eleven, 26]. Indirect priming seems to be more difficult to detect than direct priming in behavioural measures [27]. A second experimental variable that can modulate associative/semantic priming effects is stimulus-onset asynchrony (SOA; time between the beginning of the prime word and the beginning of the target word): short SOAs have been associated mainly with automatic processes, while the longer the SOA is, the more likely that controlled and strategic processes come into play [15 Chapter nine, 26]. A third experimental variable that can modulate associative/semantic priming effects is relatedness proportion (proportion of related prime-target trials out of the total word-word trials): especially in long SOAs, priming tends to increase in absolute size as the relatedness proportion increases [15 Chapter nine, 28].

Rodríguez-Ferreiro et al. [12] identified other methodological issues that may contribute to the between-studies variation in findings. Firstly, the comparison of categorical groups (e.g., high schizotypy vs. low schizotypy) instead of keeping the variable continuous (e.g., schizotypy score) usually leads to decreased statistical power to detect effects [12]. Secondly, the usage of difference scores as the dependent variable (priming effect = mean RT of the unrelated prime condition – mean RT of the related prime condition) may increase statistical noise [12]. Moreover, when these difference scores are the only measures reported (i.e., no RTs per condition), the amount of information provided is importantly reduced: for instance, a larger priming (i.e., greater RT difference between the unrelated and related conditions) can be due to both a reduction of RTs in the related condition and an increase of RTs in the unrelated condition [15 Chapter eight]. Thirdly, the traditional analytical approach in psycholinguistics has been to conduct separated by-participant (collapsing/averaging over items) and by-item (collapsing/averaging over participants) statistical analysis, as in ANOVA and linear regression. However, this statistical approach has several limitations, such as increased rates of faulty statistical inference (i.e., both false positives and false negatives; see [29–31]). Fortunately, better alternatives are now available: linear mixed-effects models (LMEMs; for an accessible introduction, see [30]). Finally, literature inconsistencies for associative/semantic priming in schizophrenia and

schizotypy could also be due to *within-diagnostic heterogeneity*, one of the intrinsic problems associated to categoric nosological systems. Indeed, two individuals diagnosed with schizophrenia can be very different in their symptomatology and underlying psychopathological mechanisms [32,33]. Therefore, it is possible that some individuals diagnosed with schizophrenia have a semantic network with enhanced spreading activation (e.g., those with predominantly positive symptoms, such as delusions), while others do not (e.g., those with predominantly negative symptoms, such as anhedonia). A similar logic can be applied to high-schizotypy individuals, since the underlying structure of manifestations of this construct is similar to schizophrenia [23]. To overcome this limitation, instead of starting from generic categoric labels (e.g., schizophrenia, schizotypy) or symptoms clusters (e.g., positive, negative or disorganized symptoms), one possibility is to focus on specific traits (e.g., unusual beliefs, [32]) which may be specifically related with the cognitive processes which are the focus of this research (spreading of activation through semantic networks).

## The present study

Epistemically unwarranted beliefs (EUB; [34]) is a term used to encompass beliefs that are not logically or empirically grounded [35], being paranormal phenomena (e.g., certain numbers giving good/back luck), pseudoscientific speculations and practices (e.g., lie detection through polygraph), and conspiracy theories (e.g., COVID-19 ‘pandemic’) three popular instances in contemporary societies (see [34,36]). In a similar vein to schizotypal personality traits, there is evidence that EUB may be placed within the psychosis continuum (e.g., see [37–39]). Therefore, we might expect people with high levels of EUB to have some similarities with people diagnosed with schizophrenia, like an enhanced spreading activation in semantic networks, which would be reflected in the associative/semantic priming paradigm.

To the best of our knowledge, there are no studies directly evaluating this hypothesis in relation to pseudoscientific or conspiracy beliefs, although there are a few preceding associative/semantic priming studies in relation to paranormal and magical beliefs [40–42]. These three studies have in common that at least two groups of non-clinical individuals (high paranormal/magical beliefs vs. low paranormal/magical beliefs) performed an associative/semantic priming experimental procedure which contained related and unrelated prime-target word pairs. Nevertheless, they also differed in several aspects: how related pairs were defined (category-associated vs. category-unassociated vs. function-associated vs. function-unassociated in [40]; directly related vs. indirectly related in [41,42]); which was the main task (naming [40] vs. lexical decision [41,42]); or the inclusion of additional independent variables (e.g., stimulus lateralized presentation [41,42], substance administration [42]). Kerns and Berenbaum [40] found a significant main effect of prime-target relationship (“overall semantic priming” [40, p. 729] effect), with faster RTs to related than to unrelated prime-target pairs. Unfortunately, it is unclear whether there is a significant main effect of group or not, and a direct test of the interactive effect group x prime-target relationship is not available. However, groups were compared on the size of the priming effect, which can be understood as an approximation of the interactive effect of interest (but keep in mind that, given the aforementioned issues of using difference scores [12], a direct test of the interaction over raw RTs would be needed). This analysis revealed that believers showed a significantly increased priming effect in comparison to non-believers “for all prime conditions” and “averaging across all prime conditions” [40, p. 729]. Pizzagalli et al. [41], also found a significant main effect of prime-target relationship (directly related pairs had faster RTs than indirectly related pairs and unrelated pairs, and, in turn, indirectly related pairs had faster RTs than unrelated pairs). However, the main effect of group was not significant. Moreover, a triple interaction was found between the

independent variables of the study: paranormal believers and disbelievers only differed in indirectly related pairs when they were presented in the left visual field, with faster RTs for believers. Mohr et al. [42] had a complex design with four independent variables. Focusing on the analyses carried out with the placebo group (results without the interference of any psychoactive substance) and which collapsed the distinction of lateralized presentation (which is not of interest) [42, p. 78], the significant main effect of prime-target relationship was found again (directly related pairs had faster RTs than indirectly related pairs and unrelated pairs, and, in turn, indirectly related pairs had faster RTs than unrelated pairs). Additionally, a significant main effect of group was also found (believers produced faster RTs than non-believers). No interaction was found between these two variables.

Taking the three studies together [40–42], the only systematic result is the typical priming effect: faster RTs were produced to related pairs than to unrelated ones. However, they are not consistent with each other either in the main effect of group (believers with faster RTs than non-believers in [42], but without significant differences in [41]) or the group  $\times$  prime-target relationship interactive effect (believers had an overall larger priming effect than non-believers in [40], believers had a stronger indirect—but not direct—priming effect than non-believers in [41], without significant differences in priming effects between believers and non-believers in [42]). In this context, our main aim was to explore whether there are individual differences in associative/semantic priming depending on participants' EUB level. With this purpose in mind, participants whose EUB levels were measured through self-report psychometric instruments performed a primed LDT. With this study we intended to contribute to resolving the inconsistencies in the literature regarding associative/semantic priming effects with respect to the psychosis continuum. Apart from focusing on a psychosis-related specific trait (i.e., unusual beliefs) to circumvent the within-diagnostic heterogeneity limitation, the methodological considerations and limitations previously identified were also taken into account in our study, in order to both examine the desired processes (i.e., automatic spreading activation) and to maximise statistical power. Firstly, we focused on direct rather than indirect priming: directly related and unrelated prime-target pairs were tested (from here on, this experimental manipulation will be referred to as Relatedness). Secondly, we used a short SOA (200 ms) stimuli presentation. Thirdly, the relatedness proportion was 50% (following [26]). Fourthly, individual differences in EUB were kept as a continuous variable (instead of dichotomizing to high vs. low groups). Fifthly, we did not focus on difference scores (i.e., the analysed data were raw RTs for related and unrelated prime-target pairs). Finally, we analysed our data through LMEMs (instead of conducting separate by-participant and by-item analyses).

We expected to replicate the typical direct priming effect, that is, a main effect of Relatedness with faster RTs for related prime-target pairs than for unrelated prime-target pairs. More importantly for our concerns, we hypothesised that if EUB believers generally experience a faster/greater and further reaching spreading of activation through semantic memory (e.g., [6,11]) compared to people with low levels of EUB, a main facilitatory effect of EUB would be expected. That is, high scores in EUB should be associated with shorter RTs in both related (faster/greater spreading to close associates; see [10]) and unrelated (further reaching spreading, which results in the activation of remote associates; see [10]) conditions. We supposed that, alternatively, if EUB facilitatory effects only occur in one of these two conditions (exclusively in related pairs or in unrelated pairs), that would suggest that only one of two possible mechanisms are in place: faster/greater spreading to close associates or further reaching spreading activating remote associates. This would be indicated by an interaction between EUB and Relatedness.

## Method

### Participants

Ninety-nine undergraduate Psychology students from Universitat Rovira i Virgili (URV, Tarragona, Spain) participated voluntarily (convenience sampling) in exchange for extra academic credits. One participant was removed from data analysis because that person exceeded the error rate limit (25%). The 98 valid participants were aged between 18–49 years ( $M = 19.61$ ,  $SD = 3.65$ ), with a sex distribution of 74 females and 24 males. The study was performed in accordance with the Declaration of Helsinki, and it was approved by the *Comitè Ètic d'Investigació en Persones, Societat i Medi Ambient* of URV (reference: CEIPSA-2021-TD-0023). Participants gave their informed written consent before starting the study.

### Materials and instruments

**Primed LDT.** In the following, the psycholinguistic properties of the words used in this study (i.e., selected primes and targets) and their sources are listed: age of acquisition [43–45]; arousal [44,46–49]; bigram frequency (mean, token-absolute) [50 subtitle tokens database]; concreteness [44,46–48,50 subtitle tokens database]; contextual diversity (logarithmic scale) [50 subtitle contextual diversity database]; familiarity [44,45–47,50 subtitle tokens database]; Levenshtein distance between Spanish-Catalan translations (S4.3 in S4 File) [51]; mean Levenshtein distance of the 20 closest words [50 subtitle tokens database]; number of higher frequency orthographic neighbours [50 subtitle tokens database]; number of letters [50 subtitle tokens database]; number of orthographic neighbours [50 subtitle tokens database]; trigram frequency (mean, token-absolute) [50 subtitle tokens database]; valence [44,46–49]; word frequency (logarithmic scale) [50 subtitle tokens database]; and word prevalence (natives from Spain) [52]. Some of the normative values for some subjective variables (age of acquisition, concreteness, familiarity, valence, arousal) were accessed through EmoFinder [53].

**Critical trials.** 200 Spanish word triplets were selected. Each triplet contained a target word (e.g., *luz* [light]), and two possible prime words: one related to the target word (e.g., *bombilla* [bulb]) and another unrelated to it (e.g., *calcetín* [sock]). That is, there were two alternative prime-target pairings with the same target word (Relatedness: related vs. unrelated). We created two experimental lists (A vs. B) with one prime-target version in each list, so each participant only saw one prime-target version for each target word, either the related or the unrelated. This resulted in each list containing 100 related and 100 unrelated prime-target pairs.

Related prime-target pairs were obtained from the NALC free association norms [54–56]. The developers of the database provided us a file with all the cue-target pairs together with its forward associative strength (FSG, i.e., proportion of people producing the target word as the first thing that came into mind after being exposed to the cue word). We considered as candidate stimulus only those word pairs for which data were available for all the relevant word properties for both cue and target words. We ordered the list of candidates cue-target word pairs by descending FSG and selected those candidates for which the following restrictions were fulfilled: (1) no reference to proper nouns (e.g., *pantera-rosa* [Pink Panther]); (2) no word pairs that act as a single concept (e.g., *panda-oso* [panda bear]); (3) no shared lexeme between prime and target (e.g., *deshacer-hacer* [undo-do]); (4) no initial orthographic overlap between prime and target (e.g., *enojo-enfado* [annoyance-anger]); (5) no probably unknown words as primes; (6) no Spanish-Catalan false friends (e.g., *cama* [bed in Spanish, leg in Catalan]); and (7) no exact or very similar words in their lexical form to those already present in

Table 1. Descriptive statistics of properties of the words used in critical and filler trials.

	Critical trials									Filler trials		
	Related primes			Unrelated primes			Target words			Primes		
	M	SD	Range (min-max)	M	SD	Range (min-max)	M	SD	Range (min-max)	M	SD	Range (min-max)
Age of acquisition	6.75	1.92	1.74-10.68	6.82	1.97	2.42-10.78	4.63	1.63	1.12-9.98	6.76	1.95	2.32-10.60
Concreteness	4.93	0.97	1.99-6.63	4.90	0.96	2.39-6.68	5.07	1.01	2.15-6.72	4.89	0.93	2.35-6.64
Familiarity	5.33	0.92	2.74-6.84	5.30	1.01	2.44-6.88	6.18	0.60	3.15-7.00	5.31	0.94	2.32-7.00
Valence	5.49	1.40	1.20-8.60	5.52	1.37	1.45-8.25	5.83	1.60	1.45-8.70	5.42	1.34	1.35-8.35
Arousal	5.20	0.94	2.30-7.75	5.22	0.96	2.20-7.50	5.25	1.13	2.28-8.45	5.14	1.07	2.05-7.95
NLD Spanish-Catalan	0.71	0.29	0.00-1.00	0.71	0.28	0.00-1.00	0.64	0.30	0.00-1.00	0.71	0.27	0.00-1.00
Prevalence (in z-scores)	2.36	0.23	1.63-2.58	2.34	0.26	1.26-2.58	2.40	0.19	1.96-2.58	2.34	0.25	1.58-2.58
Word frequency (in logarithmic scale)	1.03	0.61	0.02-3.69	1.03	0.61	0.01-3.04	1.85	0.57	0.35-3.13	1.03	0.61	0.03-3.11
Length (in letters)	6.61	1.90	3-12	6.61	1.87	4-12	5.78	1.59	3-11	6.62	1.83	4-12
N	4.92	5.56	0-29	5.74	7.25	0-32	7.51	8.38	0-40	5.28	6.70	0-33
NHF	0.71	1.59	0-10	0.87	1.87	0-13	0.45	1.07	0-8	0.75	1.52	0-9
Lev_N	1.82	0.62	1.00-3.95	1.80	0.60	1.00-4.05	1.64	0.50	1.00-3.45	1.84	0.61	1.00-4.20
Bigram frequency (mean, token-absolute)	27124.38	11768.69	4234.40-66073.05	25408.93	10832.95	3057.30-61194.14	25729.68	11716.45	2099.43-64490.91	25892.75	11051.66	4986.46-55073.17
Trigram frequency (mean, token-absolute)	2723.67	2413.36	3.90-13668.18	2544.84	2304.73	57.96-12249.64	2488.85	2120.57	157.52-13647.86	2652.59	2517.68	23.16-15769.89
Contextual diversity (in logarithmic scale)	0.72	0.47	0.02-2.00	0.71	0.47	0.00-1.97	1.30	0.42	0.19-1.97	0.72	0.47	0.02-1.97

Note. NLD = normalised Levenshtein distance between Spanish–Catalan translations; N = orthographic neighbours; NHF = orthographic neighbours of higher frequency; Lev\_N = mean Levenshtein distance of the 20 closest words.

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previously selected pairs. In all the selected pairs the target word was the first associate of the prime, with FSG values ranging from .43 to .94 ( $M = .56$ ,  $SD = .11$ ).

Unrelated primes were selected using the Match software [57]. Subsequently, the potential unrelated word prime candidate was checked to ensure that it was not: (1) related with the target word (i.e., not listed as an associate in NALC, plus a subjective validation performed by the authors); (2) equal or very similar to other previously selected words (either related primes, targets, or other unrelated primes); or (3) orthographically overlapped in its initial letters with the target word (e.g., *polen-potasio* [pollen-potassium]). The search-validation process was repeated as many times as necessary to find a word that was suitable to act as unrelated prime. Independent samples t-tests (JASP, version 0.18.2.0, [58]) (S4.4 in S4 File) indicated that unrelated primes did not significantly differ from related primes in their group means in any word property (all  $p \geq .130$ , all 95% CI for means difference containing the 0, all  $BF_{01} \geq 2.98$ , all 95% CrI (S4.5 in S4 File) for effect size containing the 0; see Table 1). Furthermore, word properties' distributions did not significantly differ between related and unrelated pairs, as indicated by two-sample independent Kolmogorov-Smirnov tests (all  $p \geq .327$ ) (SPSS, version

29.0, [59]). Finally, the related and unrelated primes of each target were matched in grammatical category: the two primes of a given triplet were both verbs (restricted to infinitive forms) or names/adjectives (considered together because it is quite frequent to have words that can behave both as noun and as adjective).

**Filler trials.** In order to have the same number of ‘yes’ and ‘no’ responses in the LDT, it was also necessary to create 200 word-pseudoword pairs (the pairing was performed randomly). These 200 filler trials were the same in both experimental lists.

Prime words for the filler trials were also selected with Match [57]. We selected these primes under the restriction that they should not be too similar in their lexical form to any of the words already selected as the critical items (either related primes, unrelated primes, or targets) or to other filler primes. Independent samples t-tests revealed that this word set did not significantly differ in their group mean in any word property from either the related primes (all  $p \geq .281$ , all 95% CI for means difference containing the 0, all  $BF_{01} \geq 5.15$ , all posterior distribution 95% CrI for effect size containing the 0) or the unrelated primes (all  $p \geq .417$ , all 95% CI for means difference containing the 0, all  $BF_{01} \geq 6.57$ , all posterior distribution 95% CrI for effect size containing the 0) of the critical trials (see Table 1). Two-sample independent Kolmogorov-Smirnov tests indicated that word properties’ distributions for filler primes did not significantly differ from the distributions of either the related (all  $p \geq .220$ ) or the unrelated critical primes (all  $p \geq .142$ ). Furthermore, the proportion of words of different grammatical categories (number of verbs vs. number of nouns/adjectives) was the same for prime words in filler trials as for prime words in critical trials.

Target pseudowords of the filler trials were generated with Wuggy [60] starting from the target words of the critical trials. Pseudowords were matched to critical target words on syllabic structure, length, and transition frequencies. Spanish and Catalan pseudohomophones were avoided, and accents were added to some pseudowords.

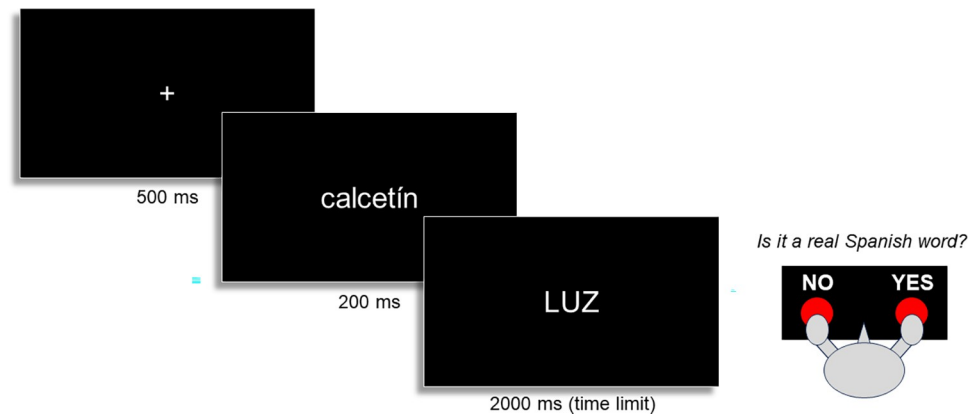
**Popular Epistemically Unwarranted Beliefs Inventory (PEUBI).** PEUBI is a psychometric instrument developed to measure EUB [36]. It consists of 36 items on a 5-point scale (1 = *Fully disagree*, 5 = *Fully agree*) loading in five correlated factors: Superstitions (PEUBI-S); Occultism and Pseudoscience (PEUBI-OP); Traditional Religion (PEUBI-TR); Extraordinary Life Forms (PEUBI-ELF); and Conspiracy Theories (PEUBI-CT).

**Pseudoscientific Belief Scale, revised version (PSEUDO-R).** Given that pseudoscientific beliefs included in PEUBI are somewhat limited (i.e., only related to New Age movement and occultism), PSEUDO-R was included as it is a psychometric instrument developed to measure this specific subgroup of EUB more extensively [61]. It consists of 19 items on a 5-point scale (1 = *Strongly disagree*, 5 = *Strongly agree*) loading on a single factor.

## Procedure

The study was conducted in sessions in which groups of up to three participants were tested, from 13/April/2023 to 22/May/2023. Participants were first instructed to read and complete the informed written consent form. They were then asked to complete the primed LDT. After they completed the task, they were asked to complete PEUBI and PSEUDO-R questionnaires (in this order). Finally, participants were debriefed if they wanted to.

**Primed LDT.** The structure of a primed LDT trial can be seen in Fig 1. Each trial started with a fixation cross (+) which was presented in the centre of the screen for 500 ms. Then the fixation cross was replaced by the prime word (Arial font, size 11, lowercase), which was presented on screen for 200 ms. Participants were instructed not to respond to the prime stimulus but just to read it silently. Immediately after the prime offset, the prime word was replaced by the target stimulus (Arial font, size 11, uppercase). Participants had to indicate, as quickly and



**Fig 1. Example of a trial in the primed lexical decision task.**

<https://doi.org/10.1371/journal.pone.0313239.g001>

as accurately as possible, if the target stimulus was a real Spanish word ('yes' button pressed with the index finger of the dominant hand) or not ('no' button pressed with the index finger of the other hand). The target remained on screen until the participant produced a response or until the time limit of 2,000 ms was reached. Participants did not receive any feedback either on RT or accuracy. After an intertrial interval of 750 ms the next trial started automatically. Breaks were included every 100 trials. Participants pushed a foot pedal to finish the break and continue the experiment. Before starting the experimental trials, there were 10 practice trials during which the experimenter was present to help them if necessary. We used DMDX software [62] to present stimuli and record responses.

**EUB assessment.** Both PEUBI and PSEUDO-R were implemented in the computer. Participants only saw one item per screen, and they had to respond by clicking the desired option on the 5-point scale (option-button response format).

## Data analysis

**EUB scores.** The value for each EUB score was obtained by summing its corresponding items (appropriately treating reverse scoring items). For each of these EUB scores, descriptive statistics (i.e., *M*, *SD*, range, skewness) and reliability estimates (McDonald's  $\omega$  and Cronbach's  $\alpha$ , with their corresponding 95% CI) were calculated in JASP. Additionally, pairwise Pearson correlation coefficients and their 95% CI between EUB scores were also calculated in JASP.

**Primed LDT.** Analyses were performed in RStudio (version 2023.12.0, [63]; R version 4.3.2, [64]) using the following libraries: *bayestestR* (version 0.13.1.2, [65]), *BayesTools* (version 0.2.16, [66]), *brms* (version 2.20.4, [67]), *datawizard* (version 0.9.1, [68]), *emmeans* (version 1.9.0, [69]), *ggeffects* (version 1.3.4, [70]), *ggplot2* (version 3.4.4, [71]), *LMERConvenienceFunctions* (version 3.0, [72]), *performance* (version 0.10.8; [73]), *psych* (version 2.3.12, [74]), *readxl* (version 1.4.3, [75]) *rethinking* (version 2.40, [76]), *splithalf* (version 0.8.2; [77]). (S4.6 in [S4 File](#)).

For brevity, many analytical and technical decisions are identified but not described in detail in the present report. A more detailed account of our analytical and technical decisions (along with relevant code) can be found in the [S1 File](#) document at (see [S2 File](#) document for a Spanish translation).

**Data trimming.** The original dataset had 39,600 trial-level RTs (400 items x 99 participants). However, several data trimming criteria were applied to prepare these data for analysis. First, participants with an overall task error rate of >25% were excluded: the 400 observations of

one participant were not included in the analysis under this rule. Second, only data from critical trials were included in the analyses: the 19,600 observations corresponding to filler trials were not analysed. Third, we checked that none of the items had a mean error rate of  $>70\%$ . No critical item had to be excluded for this reason. Fourth, we removed observations with either display or visualization errors or incorrect responses: 517 observations were excluded for this reason. Fifth, RTs  $< 300$  ms or that reached the 2,000 ms time limit were removed: 37 observations were excluded for this reason. Finally, we excluded, for each participant, RTs observations beyond  $\pm 2.5$  SD of the participant's mean RT: 610 observations were excluded for this reason. In sum, we conducted our analysis of primed LDT performance using 18,436 observations.

Reliability estimates were obtained for RTs after the data trimming procedure. More concretely, Spearman-Brown corrected split-half reliabilities (and their 95% CI) were estimated with a permutation-based computation in the *splithalf* package [77] for average RTs of the two Relatedness conditions with 5,000 random splits.

*Variables adjustment.* We retrieved  $\log_{10}$ -transformed word frequency and contextual diversity measures from the EsPal database [50]. We retrieved raw sublexical frequency measures (bigram frequency and trigram frequency) from EsPal, calculating the  $\log_{10}$ -transformed values for use in our LMEMs analyses (for a rationale for using log-transformed frequencies, see [78,79 Chapter five]).

Categorical predictors were sum-coded: previous error was coded as  $-1 = \text{yes}$  and  $+1 = \text{no}$ ; Relatedness was coded as  $-1 = \text{unrelated}$  and  $+1 = \text{related}$ ; list was coded as  $-1 = \text{list B}$  and  $+1 = \text{list A}$ . Continuous interval scale predictors were standardized.

Proxies of the same construct were expected to be collinear: the two variables of lexical frequency; the three variables of lexical neighbourhood; and the two variables of sublexical frequency. Therefore, a preventive removal of variables was performed: only one of each of these variables was finally included in the analyses. We selected a priori the proxy of each construct that subjectively felt most often used in the literature: word frequency as the lexical frequency measure; number of orthographical neighbours as the lexical neighbourhood measure; and bigram frequency as the sublexical frequency measure.

*Analysis specifications.* Raw RTs were analysed with Bayesian LMEMs using the *brms* package ([67]; for accessible introductions, see [80,81]). Given the typical right/positive skewness of RTs, the Ex-Gaussian function was used as the reference distribution. We specified the somewhat informative prior distribution  $\alpha \sim \text{Normal}(700, 200)$  for the intercept, the weakly informative prior  $\beta \sim \text{Normal}(0, 50)$  for the slopes of fixed effects, the weakly informative prior  $\sigma \sim \text{Normal}_+(0, 50)$  for standard deviations of random effects, and the weakly informative prior  $\rho \sim \text{LKJ}(2)$  for correlations between random effects. A total of four sampling chains were run in parallel, with 10,000 samples each (including 2,000 for the warm-up phase).

We specified fixed-effects structure based on our theoretical assumptions. Critical predictors were set based on our aims and predictions: Relatedness (we expect to replicate the typical direct priming effect); EUB (a main facilitatory effect is expected if semantic networks of EUB believers generally experience an enhanced spreading of activation); and Relatedness x EUB (if EUB facilitation occurs either only for related prime-target pairs or only for unrelated prime-target pairs). Control predictors were specified based on the identification of potential confounding variables in the literature (see [29,78,82–84]). The maximal random-effects structure was motivated by experimental design [85], with participants and target words as grouping units. Therefore, the model formula was the following:

RTs  $\sim 1 + \text{prime word Age of acquisition} + \text{prime word Concreteness} + \text{prime word Familiarity} + \text{prime word Valence} + \text{prime word Arousal} + \text{prime word NLD Spanish-Catalan} + \text{prime word Prevalence} + \text{prime word Frequency} + \text{prime word Length} + \text{prime word}$

Number of orthographic neighbours + prime word Bigram frequency + target word Age of acquisition + target word Concreteness + target word Familiarity + target word Valence + target word Arousal + target word NLD Spanish-Catalan + target word Prevalence + target word Frequency + target word Length + target word Number of orthographic neighbours + target word Bigram frequency + Trial order + Previous RT + Previous error + Relatedness + List + EUB + Relatedness:List + Relatedness:EUB + (1 + Relatedness | Participant) + (1 + Relatedness + EUB | Target)

We performed a separate analysis incorporating each possible EUB score on its own (PEU-BI-S, PEUBI-OP, PEUBI-TR, PEUBI-ELF, PEUBI-CT, PSEUDO-R).

**Model checks.** First, we computed variance inflation factor (VIF) values to check that there were no important degrees of collinearity between predictors (all predictors had  $VIF \leq 2.44$ ). Second, posterior predictive checks were performed to ensure that the Ex-Gaussian distribution was appropriate to model our RTs data. Third, some diagnostics were inspected to check whether the MCMC procedure had any convergence or efficiency issue [86 Chapter five, 87]: trace and trunk plots (all chains for each estimate had appropriate visual pattern);  $\hat{R}$  Gelman-Rubin convergence diagnostic (all estimates had  $\hat{R} < 1.01$ ); and effective sample size (all estimates had EES > 100 times the number of chains).

**Sample size and sensitivity/power.** Starting from the rule of thumb of having a minimum of 30-50 participants and 30-50 items (i.e., 900-2,500 observations; see [88]), the number of observations finally analysed in this study (i.e., 18,436) was deemed to be enough.

## Results

### EUB scores

Descriptive statistics and reliability estimates for each EUB score can be found in Table 2, and the intercorrelations between EUB scores are presented in Table 3.

### Primed LDT

For the sake of brevity, only a qualitative summary of the Bayesian LMEMs results is provided here. For a complete report of these analyses, please see the S3 File.

**Reliability.** Reliability estimates for RTs were  $r_{SB} = .98$ , 95% CI [.97, .99] for the related condition and  $r_{SB} = .98$ , 95% CI [.97, .99] for the unrelated condition.

**Critical predictors.** Posterior distribution estimates for Relatedness were consistently negative (95% CrI). This provides evidence for a main effect of this predictor: we observed

**Table 2. Descriptive statistics and reliability estimates of epistemically unwarranted beliefs' scores for the 98 final participants of the primed lexical decision task.**

	Descriptive statistics				Reliability estimates	
	<i>M</i>	<i>SD</i>	Range (Min-Max)	Skewness	McDonald's $\omega$ [95% CI]	Cronbach's $\alpha$ [95% CI]
PEUBI-S	15.78	6.47	7-32	0.50	.89 [.85, .92]	.88 [.84, .91]
PEUBI-OP	29.09	8.98	11-52	0.24	.90 [.86, .93]	.89 [.86, .92]
PEUBI-TR	11.01	5.50	6-27	0.97	.91 [.89, .94]	.91 [.88, .93]
PEUBI-ELF	10.55	3.88	6-23	0.73	.75 [.68, .83]	.75 [.66, .81]
PEUBI-CT	18.58	4.30	7-29	-0.05	.79 [.72, .85]	.77 [.69, .83]
PSEUDO-R	56.56	8.73	38-79	-0.26	.81 [.75, .86]	.79 [.73, .85]

Note. PEUBI-S = superstitions; PEUBI-OP = occultism and pseudoscience; PEUBI-TR = traditional religion; PEUBI-ELF = extraordinary life forms; PEUBI-CT = conspiracy theories; PSEUDO-R = pseudoscience.

<https://doi.org/10.1371/journal.pone.0313239.t002>

Table 3. Correlation matrix between epistemically unwarranted beliefs' scores for the 98 final participants of the primed lexical decision task.

	PEUBI-S	PEUBI-OP	PEUBI-TR	PEUBI-ELF	PEUBI-CT	PSEUDO-R
PEUBI-S	—					
PEUBI-OP	.57*** [.42, .69]	—				
PEUBI-TR	.32** [.13, .48]	.20 [-.00, .38]	—			
PEUBI-ELF	.55*** [.39, .68]	.68*** [.56, .77]	.30** [.10, .47]	—		
PEUBI-CT	.26** [.07, .44]	.45*** [.27, .59]	.28** [.09, .45]	.39*** [.21, .55]	—	
PSEUDO-R	.46*** [.29, .60]	.64*** [.51, .75]	.26** [.07, .44]	.49*** [.33, .63]	.41*** [.23, .57]	—

Note. Pearson correlation coefficient (95% CI in brackets). PEUBI-S = superstitions; PEUBI-OP = occultism and pseudoscience; PEUBI-TR = traditional religion; PEUBI-ELF = extraordinary life forms; PEUBI-CT = conspiracy theories; PSEUDO-R = pseudoscience.

\*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ .

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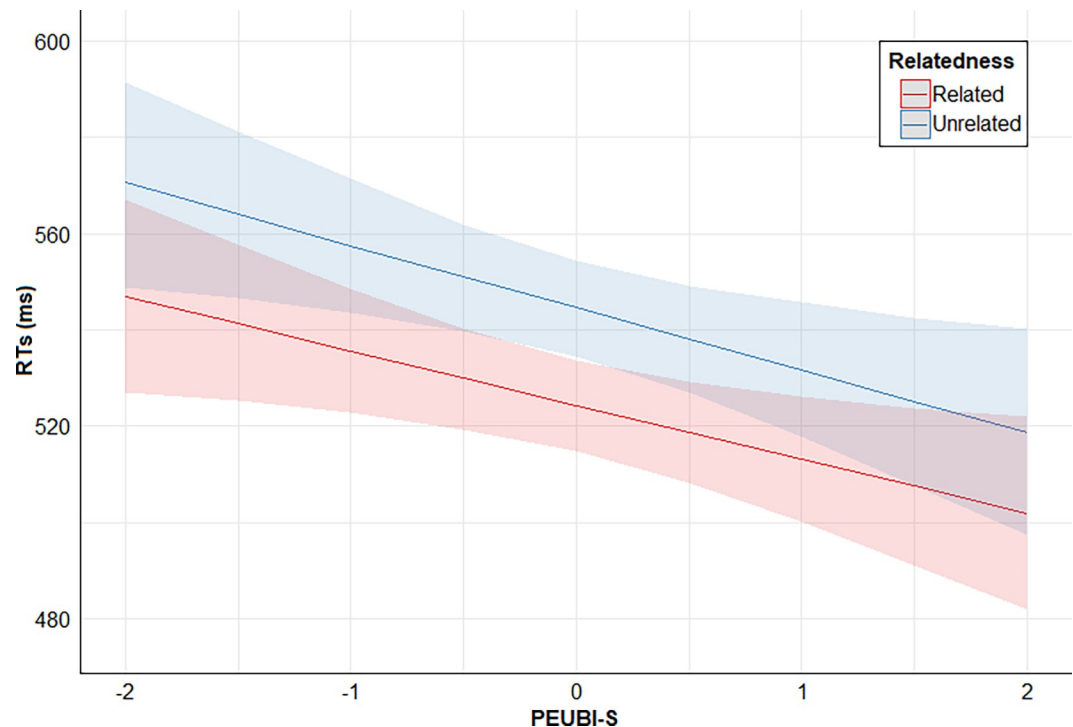
faster RTs in the related condition than in the unrelated condition, that is, a direct priming effect. (S4.7 in [S4 File](#)).

Posterior distribution estimates for PEUBI-S, PEUBI-OP and PEUBI-TR were consistently negative (95% CrI). This provides evidence for a facilitatory main effect of these predictors: the higher the value for scores on these EUB dimensions, the faster RTs. However, posterior distribution estimates for PEUBI-ELF, PEUBI-CT and PSEUDO-R encompassed the zero (95% CrI). This implies that the data are compatible with null or near-null main effects of these predictors.

Finally, posterior distribution estimates for Relatedness x PSEUDO-R were consistently positive (95% CrI). This provides evidence for the effect of an interaction between these two predictors: the higher the PSEUDO-R score, the lower the direct priming effect (smaller RTs difference between related and unrelated conditions). However, posterior distribution estimates for Relatedness x PEUBI-S, Relatedness x PEUBI-OP, Relatedness x PEUBI-TR, Relatedness x PEUBI-ELF, and Relatedness x PEUBI-CT encompassed the zero (95% CrI). This implies that the data are compatible with null or near-null interactions between Relatedness and the remaining EUB dimensions. Figs 2–7 show the marginal effects (S4.8 in [S4 File](#)) of the critical predictors of the present study.

**Control predictors.** Posterior distribution estimates for some control predictors were consistently negative (95% CrI). This provides evidence for a facilitatory main effect of the following predictors: prime familiarity (i.e., the higher the familiarity of the prime word, the faster RTs); target familiarity (i.e., the higher the familiarity of the target word, the faster RTs); target frequency (i.e., the higher the frequency of the target word, the faster RTs); and trial (i.e., faster RTs as the task progresses).

Posterior distribution estimates for some control predictors were consistently positive (95% CrI). This provides evidence for a inhibitory main effect of the following predictors: prime age of acquisition (i.e., the higher the age of acquisition of the prime word, the slower RTs); prime number of orthographic neighbours (i.e., the higher the number of orthographic neighbours of the prime word, the slower RTs); target age of acquisition (i.e., the higher the age of acquisition of the target word, the slower RTs); with the exception of the model with PEUBI-TR as EUB score, in which the posterior distribution 95% CrI encompassed the zero and, therefore, was compatible with null main effects); target length (i.e., the higher the number of letters of



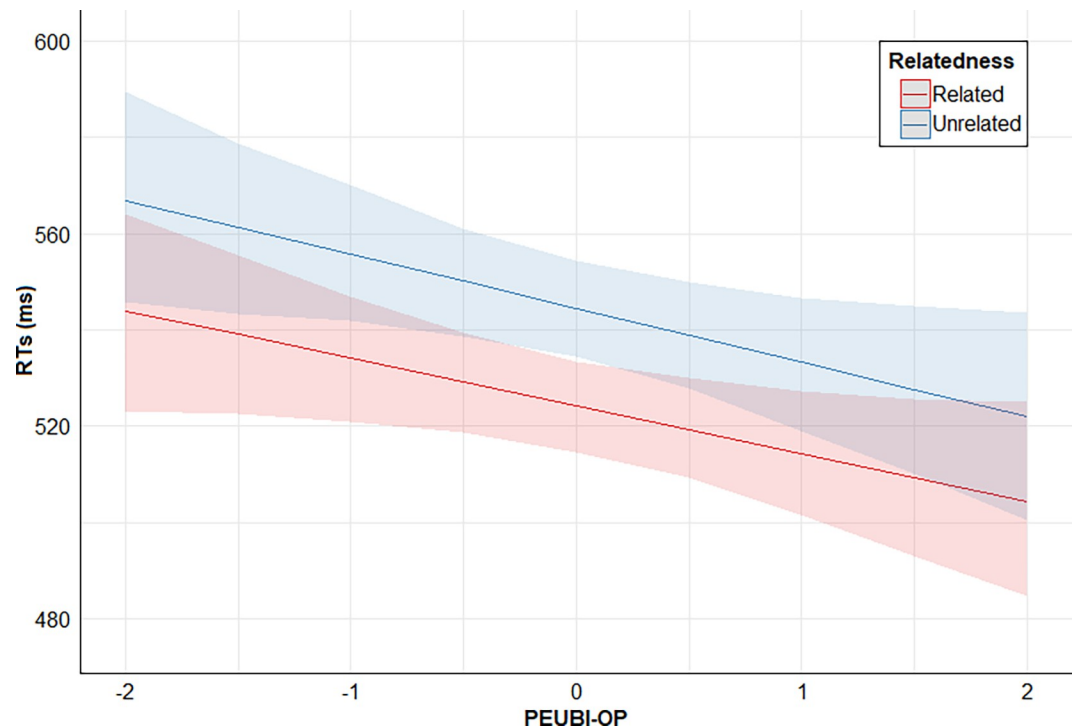
**Fig 2. Marginal effects (estimated marginal medians with 95% CrI) for the interaction between Relatedness and PEUBI-S.** *Note.* Relatedness = associative/semantic relationship between prime-target words (related [e.g., bulb-light] vs. unrelated [e.g., sock-light]); PEUBI-S = superstitions (epistemically unwarranted beliefs' score).

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the target word, the slower RTs); and previous RT (i.e., the slower the RT of the previous trial, the slower the RT of the current trial).

Posterior distribution estimates for some control predictors encompassed the zero (95% CrI). This implies that the data are compatible with null or near-null main effects for the following predictors: prime concreteness (with the exception of the model with PEUBI-TR as EUB score, in which posterior distribution 95% CrI was consistently positive and, therefore, provided evidence for an inhibitory main effect); prime valence; prime arousal; prime NLD Spanish-Catalan; prime prevalence; prime word frequency; prime length; prime bigram frequency; target concreteness; target valence; target arousal; target NLD Spanish-Catalan; target prevalence; target number of orthographic neighbours; target bigram frequency; previous error; and list.

Posterior distribution estimates for Relatedness x List were consistently negative (95% CrI). This provides evidence for an interactive effect between these two predictors. Though there was a direct priming effect in both lists, this effect was a bit larger in list A than in list B. This seems to be mainly driven by a between-lists difference in unrelated prime-target pairs (i.e., in list A they produced slower RTs than in list B), while the between-lists differences for related prime-target pairs is tiny (S4.9 in [S4 File](#)). However, we do not consider the Relatedness x List interaction to be a threat to the validity of our results. First, the pattern of priming effects was similar in both lists and differences were small. Second, this interactive effect is included (and controlled for) in the models. Third, EUB scores were similar between lists (independent samples t-tests: all  $p \geq .394$ , all 95% CI for means difference containing the 0, all  $BF_{01} \geq 3.39$ , all posterior distribution 95% CrI for effect size containing the 0; two-samples Kolmogorov-Smirnov tests: all  $p \geq .640$ ).



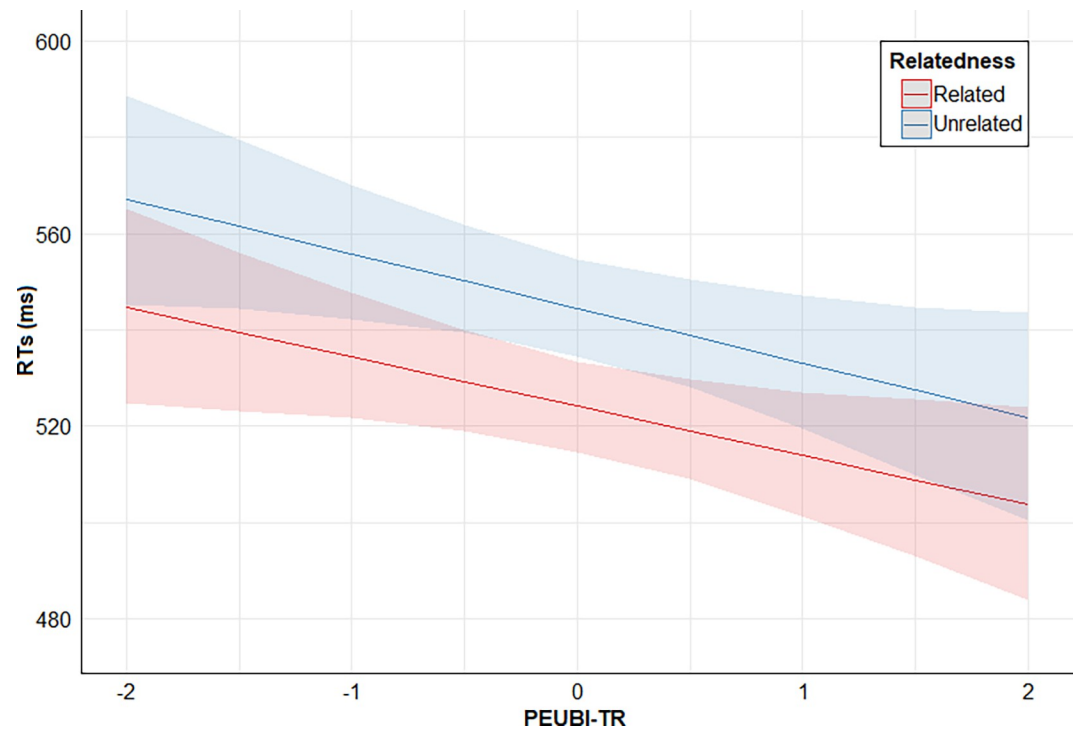
**Fig 3. Marginal effects (estimated marginal medians with 95% CrI) for the interaction between Relatedness and PEUBI-OP.** *Note.* Relatedness = associative/semantic relationship between prime-target words (related [e.g., bulb-light] vs. unrelated [e.g., sock-light]); PEUBI-OP = occultism and pseudoscience (epistemically unwarranted beliefs' score).

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## Discussion and conclusions

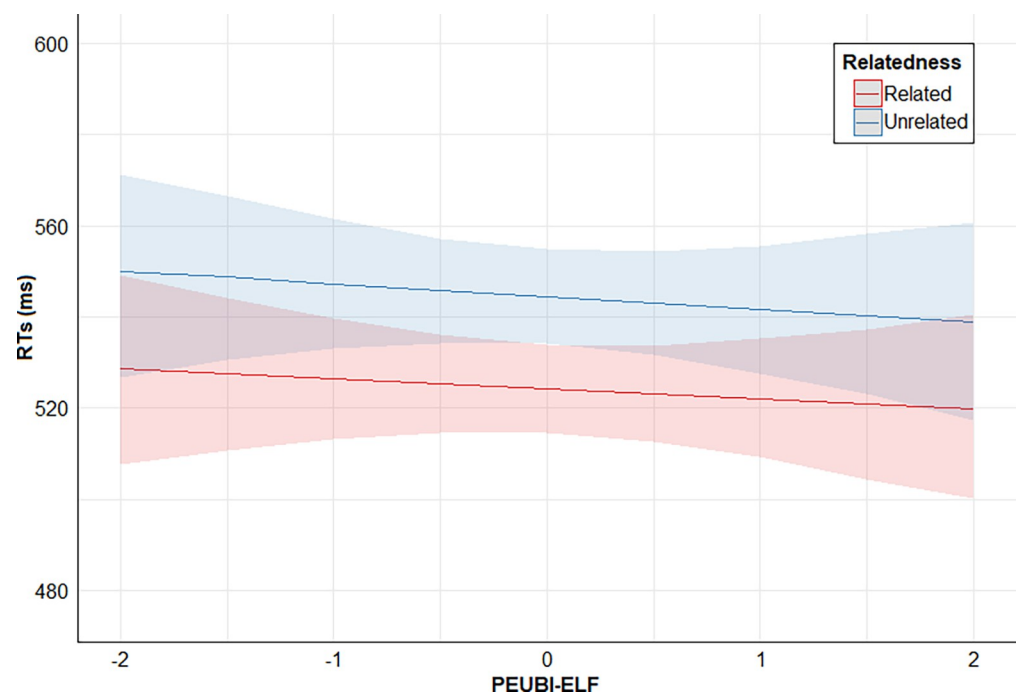
Loosening of associations is considered to be as a key underlying disturbance in schizophrenia [5]. One of the explanatory mechanisms that attempts to account for this phenomenon is based on how semantic networks are activated: people diagnosed with schizophrenia would perform illogical or unwarranted associations because of an enhanced spreading of activation through semantic memory (e.g., [6,10–12]), which would lead to co-activation of nodes that are distantly or weakly related. Evidence for this explanatory mechanism partly comes from studies of associative/semantic priming, although there are inconsistencies in the literature [10,12,17]. Grounded in a dimensional approach to psychopathology ([19]; psychosis continuum, [23,38]), the main purpose of the present research was to explore if there are individual differences in associative/semantic priming in people with different levels of EUB. To do so, participants completed a primed LDT containing both related and unrelated prime-target pairs and filled two EUB questionnaires. Bayesian LMEDs over RTs revealed main effects of Relatedness (direct priming effect: faster RTs in the related condition than in the unrelated condition), facilitatory main effects for some EUB scores (i.e., the higher the PEUBI-S, PEUBI-OP or PEUBI-TR scores, the faster RTs) but null main effects for the others (PEUBI-ELF, PEUBI-CT, PSEUDO-R), and an interactive Relatedness x EUB effect for PSEUDO-R only (the higher the PSEUDO-R score, the smaller the priming effect) (S4.10 in S4 File).

As reviewed in the Introduction, we are not aware of previous research to which our results can be directly compared concerning pseudoscientific and conspiracy beliefs, but we can compare our results to those from a small set of prior associative/semantic priming studies concerned with paranormal and magical beliefs [40–42]. Firstly, the direct priming effect we



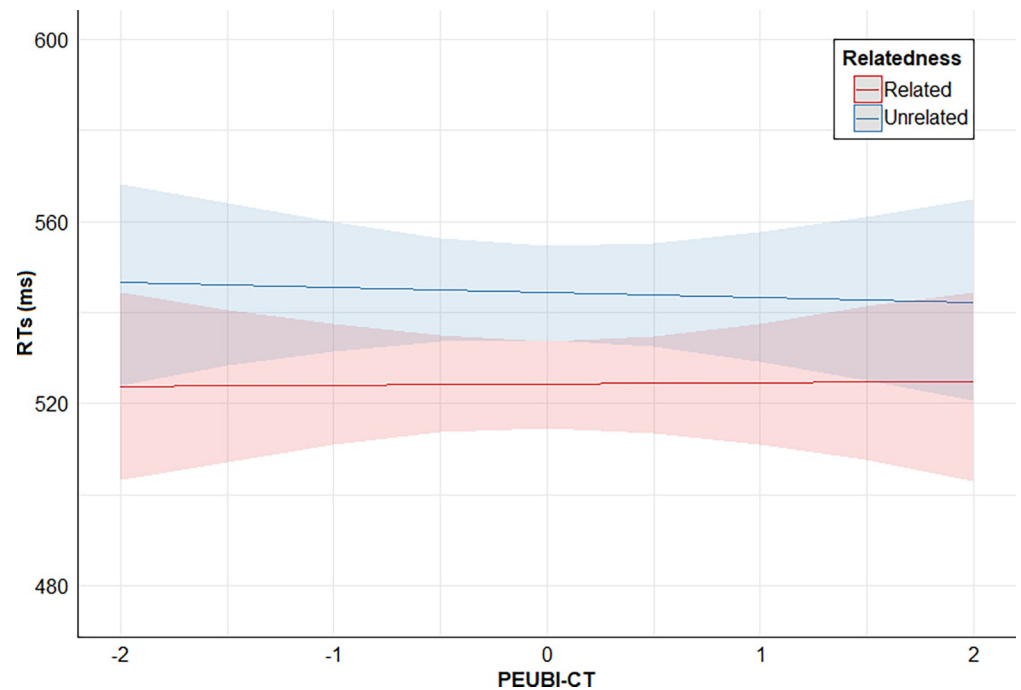
**Fig 4. Marginal effects (estimated marginal medians with 95% CrI) for the interaction between Relatedness and PEUBI-TR.** *Note.* Relatedness = associative/semantic relationship between prime-target words (related [e.g., bulb-light] vs. unrelated [e.g., sock-light]); PEUBI-TR = traditional religion (epistemically unwarranted beliefs' score).

<https://doi.org/10.1371/journal.pone.0313239.g004>



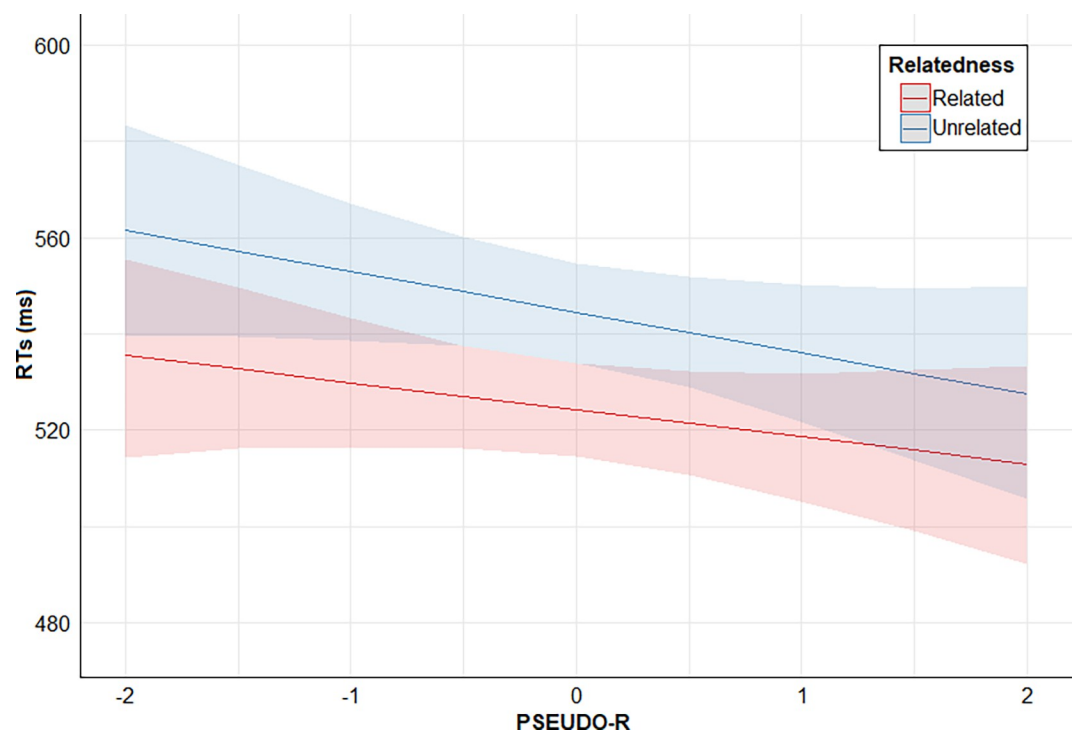
**Fig 5. Marginal effects (estimated marginal medians with 95% CrI) for the interaction between Relatedness and PEUBI-ELF.** *Note.* Relatedness = associative/semantic relationship between prime-target words (related [e.g., bulb-light] vs. unrelated [e.g., sock-light]); PEUBI-ELF = extraordinary life forms (epistemically unwarranted beliefs' score).

<https://doi.org/10.1371/journal.pone.0313239.g005>



**Fig 6. Marginal effects (estimated marginal medians with 95% CrI) for the interaction between Relatedness and PEUBI-CT.** *Note.* Relatedness = associative/semantic relationship between prime-target words (related [e.g., bulb-light] vs. unrelated [e.g., sock-light]); PEUBI-CT = conspiracy theories (epistemically unwarranted beliefs' score).

<https://doi.org/10.1371/journal.pone.0313239.g006>



**Fig 7. Marginal effects (estimated marginal medians with 95% CrI) for the interaction between prime-target Relatedness and PSEUDO-R.** *Note.* Relatedness = associative/semantic relationship between prime-target words (related [e.g., bulb-light] vs. unrelated [e.g., sock-light]); PSEUDO-R = pseudoscience (epistemically unwarranted beliefs' score).

<https://doi.org/10.1371/journal.pone.0313239.g007>

found was consistently reported in those previous studies [40–42]. Secondly, facilitatory main effects found for PEUBI-S, PEUBI-OP and PEUBI-TR are consistent with the results of Mohr et al. [42], but not with those of Pizzagalli et al. [41]. A visual inspection of the Fig 1 in Pizzagalli et al. [41] suggests that believers were faster in the three prime-target conditions (i.e., directly related, indirectly related, and unrelated). Perhaps the apparent main effect of the level of paranormal belief was not detected in that study due to lack of statistical power (in their sample there were only 12 believers and 12 disbelievers). Thirdly, the effects of the interaction between Relatedness and PSEUDO-R is not consistent with any of the previous studies [40–42]. While Pizzagalli et al. [41] and Mohr et al. [42] did not observe a modulation of the direct priming effect by the level of paranormal/magical beliefs, Kerns and Berenbaum [40] found this interactive effect but in the opposite direction (i.e., believers showed an increased –not decreased– priming effect in comparison to the control group). Of note, the Relatedness x PSEUDO-R effect in our results seems to be quite small-sized (see Fig 7). Therefore, it should be interpreted with caution and explored in future studies.

Overall, the key finding is that our results are consistent with the predictions made assuming the enhanced spreading of activation mechanism (e.g., [6,10–12]). That is, believers in certain EUB instances may have both a faster/greater spreading activation to close associates (reflected in facilitation in related prime-target pairs) and further reaching spreading activation to remote associates (reflected in facilitation in unrelated prime-target pairs) in comparison to non-believers. One could argue that the facilitatory main effects of some EUB scores could be due to faster general processing/response speed in believers than non-believers. We do not believe this to be the case for the following reasons. Firstly, by-participant random intercepts of LMEMs account/control to some extent for between-participants average/basal differences in RTs. Secondly, facilitatory EUB main effects were not present in response to pseudowords. We conducted Bayesian LMEMs over RTs of the correct responses to pseudowords (filler trials), and the data are compatible with null or near-null main effects for all EUB dimensions (i.e., all 95% CrI encompassed the zero). Thirdly, facilitatory EUB main effects have not been found when the priming paradigm is absent. Huete-Pérez and Ferré [89] performed a study where EUB levels were measured with the same psychometric instruments; the sample of participants was similar to the present one in size, education level, age, sex and EUB distributions; and participants also completed a LDT. However, in that case the LDT was non-primed (i.e., standard lexical decision over words/pseudowords, that is, without being preceded by any prime word) and no main effects for any EUB score was found over LDT RTs. Together, these three pieces of evidence lead us to believe that present EUB facilitatory main effects are specifically due to people with higher EUB levels experiencing an enhanced spreading of activation from both related and unrelated primes to the target (and not to a general faster processing/response speed) in comparison to people with lower levels of EUB. Nevertheless, we cannot fully discard this possibility, just as we cannot rule out the role of other individual differences that can modulate associative/semantic priming (e.g., attentional control and reading ability; [90]) and which may be associated with individual differences in EUB. Future studies should attempt to replicate the main EUB effects found here and, in addition, explore whether they can be accounted for by individual differences in more general cognitive variables.

There is an alternative explanation of the present results more specifically related to semantic memory. Recent findings suggest that differences in associative/semantic priming between people with and without diagnosis of schizophrenia may be due to structural differences in semantic memory [91]. That is, faster RTs to both related and unrelated prime-target pairs may be explained in dynamic terms (i.e., greater speed/strength and reaching of the activation propagation through semantic memory; [6,11]), but could also be explained in structural

terms (i.e., shorter and more ‘disorganized’ connections in semantic networks; [91]). Future studies could try to disentangle between these two non-exclusive explanatory mechanisms. In any case, given the exploratory nature of the present work together with the few preceding comparable studies, it would be very appropriate for future studies to evaluate whether the present results can be replicated in different participants, items and languages, thus also contributing to assess their generalizability. Going further, a test-retest study could be carried out to assess the temporal stability/reliability of our findings. In this sense, it should be kept in mind the considerations made in the Introduction: varying certain methodological aspects (e.g., short SOA vs. long SOA) may produce in itself different results between studies. Therefore, if the aim is direct replication, future studies should be methodologically as comparable as possible. However, a legitimate aim of future research could be to explore the generalizability of these results to other experimental paradigms and tasks. For instance, although in the present study we minimized the action of controlled and strategic processes by using a short SOA [15 Chapter nine, 26], this can be achieved also using a masked priming paradigm (e.g., [92]), in which the conscious exposure of the prime is substantially reduced.

A legitimate question to ask is why the pattern of results varies depending on the specific EUB dimension: we observed facilitatory main effects for some EUB scores but null for others. Although the EUB term is used to designate jointly beliefs that are not logically or empirically grounded [35], and that different EUB instances tend to be related (e.g., [34,36,93]), the multidimensional nature of this construct should not be overlooked (e.g., see [94]). In this regard, the mechanisms underlying different instances of EUB do not necessarily need to be the same (e.g., see [89 Discussions section, 93,94]). Therefore, it could be perfectly plausible that, for instance, high superstitious beliefs (PEUBI-S) but not high conspiracy beliefs (PEUBI-CT) were associated with an enhanced spreading of activation through semantic memory. Going further, unwarranted associations in conspiracy beliefs could be explained in terms of an attitudinal bias of suspiciousness against some individuals, groups and entities (e.g., see [93 Discussion section]), a fact that does not necessarily have to be reflected on semantic memory.

Despite the contributions and strengths of this study, some limitations must be also mentioned. First, the effects of all predictors were explored in a linear fashion, but non-linear relationships could also be possible. Exploring every possible statistical modelling alternative could be an endless process. However, the data are openly available, so that the interested reader can explore how the results would be with different analytical decisions. Second, the sample of participants (undergraduate university students) may not be representative of the general population. As mentioned, future studies could explore whether the present results can be replicated with a different sample of participants.

To conclude, this study suggests that there are individual differences in associative/semantic priming driven by participants’ individual differences in EUB. This finding adds to the literature regarding associative/semantic priming effects with respect to the psychosis continuum [10,12,17,40–42], and fits to the predictions made from the enhanced spreading of activation explanatory mechanism (e.g., [6,10–12]).

## Supporting information

**S1 File. Data analysis details (English).** More detailed account of our analytical and technical decisions (along with relevant code).  
(PDF)

**S2 File. Data analysis details (Spanish).** The same document as S1 but in Spanish.  
(PDF)

**S3 File. LMEMs complete reporting.** Complete report of Bayesian LMEMs. (PDF)

**S4 File. Endnotes.** Refer to this document for references from S4.1 to S4.10. (PDF)

## Author Contributions

**Conceptualization:** Daniel Huete-Pérez, Robert Davies, Javier Rodríguez-Ferreiro, Pilar Ferré.

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**Formal analysis:** Daniel Huete-Pérez, Robert Davies.

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