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Implicit Semantic Priming in Spanish-Speaking Children and Adults: An Auditory Lexical Decision Task

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Although receptive priming has long been used as a way to examine lexical access in adults, few studies have applied this method to children and rarely in an auditory modality. We compared auditory associative priming in children and adults. A testing battery and a Lexical Decision (LD) task was administered to 42 adults and 27 children (8;1–10;11 years-old) from Spain. They listened to Spanish word pairs (semantically related/unrelated word pairs and word-pseudoword pairs), and tone pairs. Then participants pressed one key for word pairs, and another for pairs with a word and a pseudoword. They also had to press the two keys alternatively for tone pairs as a basic auditory control. Both groups of participants, children and adults, exhibited semantic priming, with significantly faster Reaction Times (RTs) to semantically related word pairs than to unrelated pairs and to the two word-pseudoword sets. The priming effect was twice as large in the adults compared to children, and the children (not the adults) were significantly slower in their response to word-pseudoword pairs than to the unrelated word pairs. Moreover, accuracy was somewhat higher in adults than children for each word pair type, but especially in the word-pseudoword pairs. As expected, children were significantly slower than adults in the RTs for all stimulus types, and their RTs decreased significantly from 8 to 10 years of age and they also decreased in relation to some of their language abilities development (e.g., relative clauses comprehension). In both age groups, the Reaction Time average for tone pairs was lower than for speech pairs, but only all adults obtained 100% accuracy (which was slightly lower in children). Auditory processing and semantic networks are still developing in 8-10 year old children.

Keywords: semantic priming, lexical access, auditory processing, lexical decision.
The nature of lexical access has been investigated through different paradigms and experimental tasks to better know the automatic access to semantic information. Research on development of lexical processing has mostly used visual lexical decision tasks, and those with auditory presentation are much less usual. This is a bit surprising considering that at least two studies found different neurophysiology indexes and Reaction Times (RTs) in adults for either auditory or visual modalities (Gomes et al., 1997; Holcomb & Neville, 1990). In auditory priming experiments, the verbal items (e.g., words) are presented auditorily usually through headphones, but in visual priming experiments the verbal items are only presented in written form on the screen. For example, a visual priming effect was found across different tasks with items preceded by related/unrelated items, in groups of children including 8-, 10-, and 12-year-olds (Simpson & Foster, 1986) and also of adults (Simpson & Lorsbach, 1983), who had to decide whether 2 letters were identical or who read a word aloud. More research is needed about auditory semantic priming without visual/orthographic lexical processing.

Only a few studies (in Japanese, English and French, respectively) have compared adults’ and children’s performance in a particular lexical decision semantic task (Nakamura, Ohta, Okita, Ozaki, & Matsushima, 2006; Plaut & Booth, 2000; Radeau, 1983). The first two studies used visual tasks, while the latter author seems to be the only one to use an auditory presentation for this type of developmental studies. Furthermore, different procedures have been used and some variables, like number of syllables in words, or grammatical categories (e.g., noun, adjective), have rarely been controlled for in previous studies (e.g., Radeau, 1983). More studies are also needed to better know how these cognitive processes develop from childhood to adulthood across languages including Spanish. For example, a better knowledge of the time course development of semantic networks (e.g., knowing the type of differences between children and adults) might contribute to design more adequate exercises for strengthening the word associations through their semantic network and developing their vocabulary in a particular language. The present research aims to broaden our knowledge about the development of auditory semantic priming across age groups (including older children) across languages, with a greater control of variables and a procedure excluding feedback after experimental trials.

**Semantic Priming and Lexical Decision Tasks**

One of the most typical paradigms used for this purpose has been the lexical decision semantic priming paradigm. In lexical decision tasks, participants are required to make a decision about a particular event (e.g., whether it is a word or pseudoword). This can be a word pair, a single word, etc. The modality of presentation has been traditionally visual (e.g., Nakamura et al., 2006; Plaut & Booth, 2000; Sánchez-Casas, Ferré, García-Albea, & Guasch, 2006). Few studies have used auditory stimuli in semantic priming (e.g., Rissman, Eliassen, & Blumstein, 2003). Their lexical decision task (only performed by adults) included auditory word pairs, word–non-word pairs and tone pairs. The first item of the word pairs (prime) and the second one (target), were either semantically unrelated or related (e.g., teacher-student); both sets had the same targets for comparison reasons. The authors found semantic priming in all adults (i.e., faster lexical decision latencies to semantically related word pairs than to those unrelated). They also found some neural activation differences between word pairs (semantically related vs. unrelated), word-non-word pairs and tone pairs. The words, which were nouns, verbs, adverbs and adjectives, had different syllable lengths varying from one to three, although they reported a similar average duration mean for each condition. The timing of events was jittered (i.e., the inter-trial interval was variable); null events were not included. We think that the use of an auditory lexical decision task would be particularly appropriate in older children who are still developing language and reading skills.

In general, research shows that typical adults display semantic priming in lexical decision tasks, mostly visually presented. This is interpreted within the semantic network theories according to which the presentation of a word activates the lexical–semantic network (i.e., related words).

A study in adults (20-32 years old), using Event-related Brain Potentials (ERPs), compared semantic priming in the visual and auditory modalities (Holcomb & Neville, 1990). Participants had to press a button if the second item in a pair was an English word and a different button if the target was not an English word. In both modalities, they showed semantic priming (a significant faster response to related words than to unrelated words). However, they found that auditory responses (reaction times) were significantly slower than visual responses for all target types (related/unrelated words, pseudowords, etc.), besides finding some neurophysiological differences. The authors concluded that there may be an overlap in the priming processes that occur in each modality but that these processes are not identical. This could also be the case when comparing two different age groups in a particular modality of a lexical decision task.

Another ERP study found also some different neurophysiology indexes for either auditory or visual items but, conversely, faster Reaction Time (RT) for auditory items, when adults decided if a word was a repetition of two previous words (Gomes et al., 1997). More research is needed about auditory semantic priming across different tasks and ages without visual/orthographic lexical processing.
Development of Semantic Priming with Age

Few studies have compared adults’ with children’s performance in a lexical decision semantic priming task. A recent study in Japanese adults ($M = 30.9 \pm 5.8$ years) and 10-year-olds ($M = 10.7 \pm 2.8$ years) used a lexical decision task in which pseudowords, and repeated, semantically related and unrelated words were presented visually in a list (by the single-word presentation method), to analyze the development of implicit memory, (Nakamura et al., 2006). Participants were required to decide if the item was a word or pseudoword. The authors concluded that the strength of links between nodes (concepts) in the semantic network and the range of spreading activation expands developmentally. Their results suggested that activation spread faster in the semantic network in adults than in children (i.e., lexical access is faster), since in adults related nodes are stored close together and/or linked via strong links. No measure of language or intelligence skills was reported for any of the participants. However, the authors admitted that the age range for their children was large and involved gradual changes in semantic processing, so more developmental research in narrower age ranges was needed.

At younger age, children from 6;2 to 7 years old appear to have a similar lexical organization to adults in that both groups (native French speakers) exhibited significantly shorter reaction times for semantically related word pairs than for unrelated pairs (Radeau, 1983). However, two out of 24 children did not show this priming effect (all adults exhibited it), and children were slower than adults for all the pair type conditions of the auditory task; SDs (Standard Deviations) for RT or accuracy were not reported. No measures of language/intelligence skills or hearing were reported, although they could contribute to our understanding of the underlying variables in the development of lexical processing. The double decision task demanded a response to a pair of items. This procedure may be more helpful for children so that they attend to both items. The words had one or two phonological syllables (no measure of their duration in ms was reported) and the inter-trial interval lasted 6 seconds with a fix SOA (Stimulus Onset Asynchrony) of 500 ms. During this inter-trial interval, children and adults were informed about their accuracy response (moreover only children were verbally encouraged for their correct responses). Before these experimental trials, adults performed 32 practice trials (children practiced twice more). She used a lexical decision paradigm based on auditory presented items for analyzing development of semantic priming before reading acquisition (when items cannot be presented visually/written). The task included: 32 Related Word pairs (RW); 32 Unrelated Word pairs (half of them with the same target of RW, and half of them with the same prime of RW); 32 pseudoword-word pairs (with the same target of RW); 32 word-pseudoword pairs (with the same prime of RW).

Thus, it could be interesting to investigate how semantic priming develops after the age of seven as it approaches to adulthood, when children’s language is more developed, (e.g., its variability in children, increasing of processing speed and improving of accuracy across the item types).

Semantic priming across different ages has also been studied in English speakers. Plaut & Booth (2000) used a visual lexical-decision task with high- and low-frequency target words preceded by related, unrelated, and non-word primes. Adults, 3rd-graders ($M = 8.9$) and 6th-graders ($M = 11.8$) who received the PPVT-R test (Peabody Picture Vocabulary Test – Revised), were required to decide whether the second stimulus was a word or non-word. They found that only individuals with high visual perceptual ability across the groups exhibited a greater priming effect for low-frequency than for high-frequency targets. Children, unlike adults, showed no inhibition (i.e., they did not exhibit a slower recognition of a target following an unrelated prime compared with a non-word prime).

Another study found that English-speaking children (9-13 years), performed slower and less accurately than adults, in a homophone judgment task that included synonyms, (Wehner, Ahlfors, & Mody, 2007). In other types of speeded tasks, response time was found to decrease significantly with age in English speakers from childhood (7 years of age and older ages) to adolescence and adulthood (Kail, 1991). However, individual and group differences in RTs are influenced by overall speed and/or accuracy so that it makes difficult to compare groups across ages when children or the elderly are included (Chapman, Chapman, Curran, & Miller, 1994).

In summary, the studies that have compared adults’ and children’s performance in a particular lexical decision semantic task have found differences in speed and accuracy. Generally, the groups of children were slower and made more errors in several word/pseudoword conditions than adults (Nakamura et al., 2006; Plaut & Booth, 2000; Radeau, 1983). Only Radeau’s study was based on auditory items; nowadays a greater control of variables for the priming task and the participants (e.g., by including a testing battery) would be expected. It seems that despite the presence of semantic priming processes in all adults and most of children of the cited study, these processes are still developing and their specific features may vary depending on modalities/procedures of lexical decision tasks, languages skills, etc.

It would also be interesting to compare the magnitude of semantic priming effects in children and adults, since there are some contradictory findings in the literature. The previous study (Radeau, 1983) which compared adults and children in an auditory lexical decision semantic task found that, surprisingly, semantic priming effects (unrelated minus related latency) were larger for children (a difference of 181 ms) than for adults (123 ms). A previous meta-analysis study based on 15 studies with semantically related items, (and which included a lexical decision task or a task of
pronunciation of English words), concluded that semantic priming effects were larger for healthy older than for young adults (Laver & Burke, 1993). Their conclusions support aging models stating process-specific slowing (i.e., in tasks within a particular domain) rather than general cognitive slowing (i.e., in all cognitive tasks). In some children’s research, findings seem to support a general cognitive slowing in children when comparing them with adults, but we also need to find the process-specific patterns for each age group in investigating children’s semantic development. For example, it would be interesting to analyze how children’s reaction times for the different item types (within a lexical decision task) correlate with language skills and age in months.

There are no semantic priming studies comparing Spanish-speaking children and adults. Cross-linguistic research is important not only to know how semantic priming develops with age across languages, but also to get a language-specific baseline (e.g., in accuracy and RT) for comparison with individuals having language impairments. The studies about semantic priming in Spanish language are mostly based on adult populations and visual materials. For example, in a visual lexical decision task, adults exhibited semantic priming for both highly and moderately associated semantically related word pairs, although priming was higher for those highly associated word pairs (Sánchez-Casas et al., 2006). The words syllable length was not controlled for, and varied from one to four syllables. Having a more homogeneous length may aminorate the variability of reaction time (which would be especially important when comparing different age groups).

Purposes of the Research

The general aim of our investigation was to compare auditory implicit semantic priming in 8-10 year-olds to adults (who received a testing battery) by using a lexical decision task without giving any feedback (after experimental trials) to participants. We designed a lexical decision task by presenting auditory Spanish speech pairs of different types (semantically related/unrelated word pairs and word– pseudoword pairs), and tone pairs as an auditory control (for analyzing their basic response to auditory non-speech sounds). The task required the participants’ response to each pair of items (double decision task). Our study is part of a larger project including fMRI (functional Magnetic Resonance Imaging).

Our general hypothesis was that both groups would exhibit semantic priming, but that adults would exhibit a larger priming effect. However, as we saw, there are some previous contradictory findings in the literature. We expected to find the auditory semantic priming in all adults, but not in all children (who could show more individual variability). We were interested in analyzing this possible variability in children. We were also interested in comparing their performance for word pairs of unrelated words to pairs consisting of a word and a non-word. Furthermore, we wanted to analyze consistency across items within each age group. We also expected children to be significantly slower and less accurate than adults for all pair types and a certain increase of processing speed with age in children (from 8 to 10 years old). Finally, we were interested in the possible relations between children’s lexical decision processes (speed processing across the different item types), age, IQ and standardized / non-standardized language tests scores. This may help us to better understand the underlying variables in the development of lexical processing.

Method

Participants

Adults. Forty-two university students (32 women and 10 men) with a mean age of 20 years (Range = 17;10 to 28;8, SD = 2;5) participated in the study after signing a consent form. All passed a hearing screening at 20 dB for five frequencies (500, 1000, 2000, 3000, and 4000 Hz). All participants were individually interviewed by the experimenter to determine language background, use, and environment; socioeconomic status; developmental and relevant medical history; etc. All, reportedly, had normal neurological function and language development. They all were native Spanish-speaking university students. All were born in Spain, and both of their parents were born in Spain (except for 1 mother from south of France). They had a very strong preference for mass media in Spanish, and were bilingual with Spanish as a first language and Catalan as a second language. They were also administered the Edinburgh Handedness Inventory (Oldfield, 1971). The scores in this questionnaire range from 100 (totally right handed) to -100 (totally left handed); a score of 0 means that the participant is ambidextrous. According to the testing results, 38 adults were strongly right-handed, M = 96.71 and SD = 5.23 (Range = 75 to 100), and 4 were left-handed, M = 87.50 and SD = 15.00 (Range = -70 to -100). Each participant performed the semantic priming task with the dominant hand, except for one who chose the other hand, (i.e., 39 performed it with the right hand and 3 with the left one).

Children. Most of the children were recruited from two public/semi-public schools in Castelló (Valencia region, Spain). The main teaching language at schools was Spanish, but the children also understood Catalan (it was taught at the schools as a subject), which are two closely related Romance languages. In the Valencia region, there is a diglossic bilingualism with Spanish as the formal language and Catalan as a non-formal language (although it is taught at the schools at least as a subject). A few children were recruited through psychologists/speech-language pathologists and by postings at the university. Twenty-
seven children (8;1 to 10;11 years, $M = 9;4$ years, $SD = 9.69$ months) participated; they were 13 boys and 14 girls. All of the children passed the hearing screening. After signing a consent form, parents were individually interviewed by the experimenter to complete a parent questionnaire, and a Social-Economic Status Scale (Hollingshead, 1975) to determine the extent to which Spanish was the primary language, their Social-Economic Status (SES), a possible history of language or other behavioral or learning deficits or neurological disorders as well as relevant developmental and medical history. All had normal neurological function and none of them had language disorders. Most came from Spanish-speaking homes with middle socioeconomic status ($M = 35.48, SD = 13.24$); a SES score between 30 and 39 is considered as middle SES. They were all born and grown up in the area of Castelló, and both of their parents were born in Spain (except for two children who each had one parent from France). They had a very clear preference for mass media in Spanish. Spanish was the L1 and Catalan was the L2 for 22 children and Catalan was the L1 for five balanced bilingual children with L2 = Spanish. They all were proficient in Spanish according to our language testing. All children received a battery of cognitive and language testing in Spanish including: Test of Nonverbal Intelligence (TONI-2; Brown, Sherbenou, & Johnsen, 2000); Peabody Picture Vocabulary Test (PPVT-III; Dunn & Dunn, 2006); four subtests from the Illinois Test of Psycholinguistic Abilities (ITPA; Kirk, McCarthy, & Kirk, 2001); the Vocabulary subtest from the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2007); the Token Test for Children (TTFC-2; McGhee, Ehrler, & DiSimoni, 2007); the test de Comprensión de Estructuras Gramaticales test (CEG; Mendoza, Carballo, Muñoz, & Fresneda, 2005); and the Evaluación de los Procesos Lectoros Revisada test (PROLEC-R; Cueto, Rodríguez, Ruano, & Arribas, 2007). They all had norms from Spain, except for the TTFC-2 test which has been translated into Spanish, but the norms are from USA (including a percentage of Hispanics). We also administered the Edinburgh Handedness Inventory (Oldfield, 1971), and two non-standardized language tasks in Spanish (which help to identify language status): a Non-word Repetition Task (Girbau & Schwartz, 2007a), and a Relative Clause Comprehension Task (Girbau & Schwartz, 2007b) that was translated from Friedmann & Novogrodsky (2002).

None of the children performed below normal limits on the TONI-2 test ($M = 109.78, SD = 13.07$, Range $= 89$ to 137). All of the children scored above -1 SD from the mean or above the 16th percentile on all of the language tests and subtests (Table 1). They did not have any Reading Disabilities or Language Impairment. On Edinburgh Handedness Inventory, 24 children were strongly right-handed ($M = 99.17, SD = 2.82$, Range $= 90$ to 100) and 3 were left-handed ($M = 93.33, SD = 11.55$, Range $= -80$ to -100). Participants performed the experimental task with the dominant hand (24 children with their right hand and 3 with the left one).

The Non-word Repetition Task (Girbau & Schwartz, 2007a) provided a measure of phonological working memory. The mean accuracy percentage for the subset of 3-4-5 syllable non-words was 61.42 % ($SD = 14.83$). In the Relative Clause Comprehension Task (Girbau & Schwartz, 2007b), they answered orally a comprehension question about each relative clause that they listened previously. The mean accuracy percentage out of 90 sentences was $M = 74.44$ % with $SD = 11.16$ %.

### Table 1

<table>
<thead>
<tr>
<th>Language tests</th>
<th>$M$</th>
<th>$SD$</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^a$PPVT-III test</td>
<td>64.41</td>
<td>19.36</td>
<td>[27–91]</td>
</tr>
<tr>
<td>$^b$WISC-IV: Vocabulary subtest</td>
<td>.70</td>
<td>.62</td>
<td>[+.33 – +2.33]</td>
</tr>
<tr>
<td>$^b$ITPA Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auditory Comprehension</td>
<td>.24</td>
<td>.30</td>
<td>[+-.39 – +.74]</td>
</tr>
<tr>
<td>Auditory Association</td>
<td>.28</td>
<td>.60</td>
<td>[+-.85 – +1.41]</td>
</tr>
<tr>
<td>Verbal Expression</td>
<td>.67</td>
<td>.69</td>
<td>[+-.7 – +1.63]</td>
</tr>
<tr>
<td>Grammatical Integration</td>
<td>.84</td>
<td>.41</td>
<td>[+-.37 – +1.49]</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>.55</td>
<td>.35</td>
<td>[+-.07 – +1.32]</td>
</tr>
<tr>
<td>$^a$TTFC-2 test</td>
<td>66.11</td>
<td>23.79</td>
<td>[30–97]</td>
</tr>
<tr>
<td>$^a$CEG test</td>
<td>65.85</td>
<td>23.46</td>
<td>[30–99]</td>
</tr>
</tbody>
</table>

Note. $^a$ The scores for PPVT-III, TTFC-2 and CEG tests are given in Percentiles. $^b$ The Vocabulary subtest from WISC-IV and the ITPA subtests scores are given in z-scores or SDs (in relation to mean scores from the norms).
**Semantic Priming Task**

The task included: (a) four lexical decision blocks (LD); and (b) two tone control blocks (TC), which were used to examine auditory non-verbal performance. Thus, each participant had six runs of experimental blocks, the order of which was held constant across participants: TC, LD, LD, TC, LD, LD.

**Stimuli.** The tone trials were a pair of pure tones of 1,000 Hz. The trials for each LD block were pairs of either two real words (56 pairs), or a word and a pseudoword (56 pairs). In this way, the number of items was the same for both speech pairs (word-word / word-pseudoword). The whole task had 112 speech pairs (see Appendix). Each word and pseudoword had two syllables and ranged from 4 to 6 sounds. All words were common nouns. They were digitally recorded by a native Spanish-speaking female, at a sampling rate of 44,100 Hz to produce 16-bit digital stereo sound files, using Cool Edit Pro (Syntrilium Software Corporation, 2002).

Table 2

<table>
<thead>
<tr>
<th>Speech Pairs</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantically Related Word Pairs</td>
<td>1011</td>
<td>21</td>
<td>[966 – 1044]</td>
</tr>
<tr>
<td>Unrelated Word Pairs</td>
<td>1016</td>
<td>15</td>
<td>[990 – 1042]</td>
</tr>
<tr>
<td>Word-Pseudoword Pairs</td>
<td>1020</td>
<td>14</td>
<td>[982 – 1043]</td>
</tr>
<tr>
<td>Word-Pseudoword Pairs Set 1</td>
<td>1021</td>
<td>19</td>
<td>[958 – 1043]</td>
</tr>
<tr>
<td>Word-Pseudoword Pairs Set 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Each of the four sets had 28 speech pairs. The overall mean of the 4 averages was $M = 1017$ ms ($SD = 5$).
null events were presented randomly across each block, after the response window for an auditory stimulus pair. This response window was 3047 ms, the sum of 2000 ms plus the maximum duration for a speech pair (1044 ms). The null events were distributed across each block so that each event type had the same probability of occurrence (that is, 1/5 for events in LD blocks and 1/2 for events in TC blocks). There were 44 null events in the task, which were equally distributed across the four lexical decision blocks (7 null events within each LD block) and the two tone control blocks (8 null events within each TC block).

We programmed four possible jittering durations (0, 500, 1000 and 1500 ms) so that the mean was 750 ms. The jittering times were randomized with the constraint that a particular duration was never repeated consecutively. There were never two or more consecutive null events, or two or more adjacent jittering events.

The presentation of speech event types was also randomized in a way that there were never more than two consecutive events of the same condition (i.e., related, unrelated, or pseudoword. Moreover, there never were more than three consecutive speech prime-target pairs with a word as a target. Obviously, these two requirements were independent of the presence/absence of null or jittering events between the speech events. Finally, there were never 2 speech prime-target events with exactly the same target within a LD block; e.g., sello-carta (stamp-letter) and hueso-carta (bone-letter) were presented in different LD blocks.

In summary, each participant performed 6 runs of experimental blocks with the next event distribution: (a) 28 speech trials (i.e., 7 speech events for each of the four 28-speech prime-target pair sets) and 7 null events per run in every LD block; (b) and 8 tone trials (8 tone prime-target pairs) and 8 null events per run in each TC block. In this way, we had the same probability of presentation for each event type within a block.

Procedure

Presentation. The stimuli were presented over stereo headphones plugged into a computer with a keyboard and E-Prime software (Psychological Software Tools, 2002) installed. The sound level was adjusted as needed for each participant. The experimenter explained the task individually.

Instructions. The program began with some general audio-recorded instructions, which were followed by two blocks of practice with feedback (a smiling/frowning face): (1) eight LD trials of the 3 condition types (different from the experimental trials), and (2) eight TC trials. The general instructions were:


[Welcome! You are going to listen to two tasks: one on words and another on tones. In one task, you’ll listen to some made-up words and to other words that do exist. You will listen to the words in pairs. Press 1 if you hear two real words. Press 2 if you hear at least one made-up word. Listen attentively to the words. Remember to press always as soon as you’ll know the answer. In the other task, you’ll listen to tones in pairs. As soon as you hear the second tone, press a key. Press 1 for the first pair, 2 for the second pair, 1 for the following one, 2 for the following one, etc. Listen to the tones. Remember to press as soon as you hear the second tone. Before beginning you will practice. Press as fast as possible. The computer will not wait for your answer. Ready? Press a key to begin.]

For each lexical decision block they were given these instructions: “Vas a oír palabras y palabras inventadas. Pulsa 1 si oyes dos palabras. Pulsa 2 si oyes al menos una palabra inventada.” [You are going to listen to words and made-up words. Press 1 if you hear two words. Press 2 if you hear at least one made-up word.]

Similarly, each TC block was preceded by the following instructions: “Vas a oír pares de tonos. Pulsa 1 para el primer par, 2 para el segundo par, 1 para el siguiente, 2 para el siguiente, etcétera.” [You are going to hear pairs of tones. Press 1 if you hear two pairs. Press 2 if you hear at least one made-up word.]

Participants were required to give their response as quickly and accurately as possible, by pressing either 1 or 2 on the computer keyboard with their index and middle fingers respectively. Their responses were registered by E-Prime (Psychological Software Tools, 2002) for both accuracy and Reaction Time (RT). No feedback on accuracy was provided to any participant after practice (i.e., for any of the experimental trials). The RT latencies were measured from the onset of the auditory prime-target pair. The entire task lasted 15-20 minutes.

Results

We analyzed data from the lexical decision task (reaction time and accuracy) within and between age groups. First, we analyzed data separately for adults and children with one-way repeated-measures ANOVAs (analysis of variance). Afterwards, we compared the reaction times between adults
The analyses focused on Reaction Time (RT) and accuracy (percentage of correct responses). Each of the 42 adults showed semantic priming, that is, their response time averages were faster in the semantically related condition than in the unrelated one. Only correct responses were included in the next analyses on response latency; omissions (which include out of time response times that were above 3047 ms) and errors were excluded. Accuracy will be analyzed afterwards.

A one-way repeated-measures ANOVA (analysis of variance) with the only factor being speech pair type with 4 levels (related, unrelated, and pseudoword sets 1 and 2) was done for RT. Results revealed a significant effect of the speech pair group on the Reaction Time, $F(3,41) = 122.32$, $p < .0001$. Post hoc pair-wise comparisons (Student’s t-Tests) are reported in Table 3. The reaction time average for semantically related word pairs was significantly lower than for the unrelated condition and than for each of the two pseudoword sets (Table 4). As Figure 1 illustrates, the adults’ average RT for each of the 28 word pairs in the related condition is always faster than for each of the 28 word pairs with the same target in the unrelated condition. Figure 2 shows the overlapping RT averages in the pseudoword condition, which included two sets of 28 word primes with the same pseudoword targets. These two lines for the pseudoword condition also overlapped with the unrelated condition for adults in Figure 1.

The average percent of correct answers as well as the individual scores for adults were consistently at or near ceiling (see Table 4). Thus, because of the ceiling effects, we did not conduct statistical analyses for accuracy. The best performance was on the semantically related word pairs; only five adults got the minimum score of 93% (29 participants scored 100%). On the other side, we could see the unrelated condition with one adult scoring as low as 79% correct (and only 10 participants reaching 100%). For the word-pseudoword pairs, the lowest score was 89% for set 1 and 86% for set 2.

Finally, we analyzed the accuracy and speed for adults’ performance on the two tone control blocks. The percent of correct answers (out of 16 tones) was always 100% for each of the 42 adults, that is, the accuracy average was $M = 100\%$. The reaction time average was $M = 704$ ms, $SD = 131$ ms.

The analyses focused on reaction time (milliseconds) and accuracy (percentage of correct responses). Again, only correct responses were included in the next analyses on response latency; omissions (which include out of time response times that were above 3047 ms) and errors were excluded.

For the children, we first analyzed data from the lexical decision task as we did for adults. Then we studied the relationship of these data with age, IQ and other language skills.

**Implicit Semantic Priming.** The analyses focused on reaction time (milliseconds) and accuracy (percentage of correct responses). Again, only correct responses were included in the next analyses on response latency; omissions (which include out of time response times that were above 3047 ms) and errors were excluded.

Children’s fastest RT for speech pairs was 704 ms, except for an anticipated response at 60 ms that was excluded from all the analyses (since it was clearly an impulsive response before listening to the word pair). Nineteen of the 27 children showed semantic priming, that is, their response
Table 4
Mean and Standard Deviation Reaction Times and Accuracies in the Three Conditions (Four Groups of Speech Pairs) of the Semantic Priming Task: Adults and Children

<table>
<thead>
<tr>
<th>Condition</th>
<th>Reaction Time (ms)</th>
<th>Accuracy (% correct)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Adults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td>1114</td>
<td>66</td>
</tr>
<tr>
<td>Unrelated</td>
<td>1208</td>
<td>68</td>
</tr>
<tr>
<td>Pseudoword Set 1</td>
<td>1210</td>
<td>78</td>
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<td>Pseudoword Set 2</td>
<td>1203</td>
<td>76</td>
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<tr>
<td>Children</td>
<td></td>
<td></td>
</tr>
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<td>Related</td>
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<td>205.34</td>
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<tr>
<td>Unrelated</td>
<td>1533</td>
<td>186.91</td>
</tr>
<tr>
<td>Pseudoword Set 1</td>
<td>1623</td>
<td>238.02</td>
</tr>
<tr>
<td>Pseudoword Set 2</td>
<td>1609</td>
<td>223.24</td>
</tr>
</tbody>
</table>

Note. For adults, n = 42 and for children n = 27.

Figure 1. Mean reaction times (in milliseconds) for each of the 28 speech pairs in the two word pair conditions (semantically related vs. unrelated): Adults and Children.

Note. The mean reaction times are based on 42 adults or 27 children (in the corresponding age group). The numbers for each speech pair (from 1 to 28) correspond with the numbers in Appendix.
time averages to the target were faster in the semantically related condition than in the unrelated one. We calculated the Mean reaction time (and Standard Deviation) for each of the four 28-pairs sets in each child. Then we eliminated the outliers across all the trials in the task, that is, all reaction time values equal or above 3 SD from the own individual mean; a total of 28 responses to speech trials were eliminated. Finally, we recalculated the individual mean RTs (and SDs) without the outliers, and the group means (and SDs) for each of the 4 pair groups (Table 4).

A one-way repeated-measures ANOVA (analysis of variance) with the only factor being speech pair group with 4 levels (related, unrelated, and pseudoword sets 1 and 2) was done for the Reaction Time. There was a significant effect of the speech pair group on the Reaction Time, \( F(3, 26) = 25.25, p < .0001 \). Post hoc pair-wise comparisons (Student’s t-Tests) are reported in Table 3. The reaction time average for the semantically related word pairs was significantly lower than for the unrelated condition and than for each of the two pseudoword sets (Table 4). Even the reaction time average for the semantically unrelated word pairs was significantly lower than for each of the two pseudoword sets in children; this was not found in adults. However, as expected, children’s reaction time means for the 4 sets correlated highly in all the 6 bilateral correlations, which ranged from \( r = .94, p < .0001 \) for the two pseudoword sets to \( r = .88, p < .0001 \) (Unrelated / Pseudoword Set 1 conditions). Here the significant \( p \)-value starts at \( p = .00833 \) (that is, \( p = .05/6 \)) using the Bonferroni correction. Thus, the reaction times (i.e., processing speed), despite the differences across the conditions, were consistent within children.

Despite the significant priming effect within the children’s group, 8 out of the 27 children showed semantic inhibition (instead of semantic priming), since their average differences between the two conditions [related – unrelated]
ranged from 22 ms to 42 ms (except for one child with 134 ms). Their ages ranged from 8;3 to 10;8, and they were 3 girls and 5 boys.

Consistency across lexical items was also analyzed. A multivariate analysis for the items across the conditions and age groups could not be undertaken due to the number of empty cells (i.e., errors, omissions, and anticipatory responses). As Figure 1 illustrates, the children’s reaction time response average for each of the 28 word pairs in the related condition was typically faster than for each of the 28 word pairs with the same target in the unrelated condition, (although not as fully consistently as for adults). Figure 2 shows the overlapping children’s RT averages for the speech pairs with the same target in the pseudoword condition. These two lines did not overlap with the unrelated condition that is shown in Figure 1 (as it occurred in adults). In addition, generally, children’s RTs were more variable than in adults.

The average percent of correct answers as well as the individual scores for children were mostly at or near ceiling, although somewhat less than for adults, (see Table 4). Thus, again because of these ceiling effects, we do not report any statistical comparisons but only at a descriptive level. The best performance was on the semantically related word pairs; the minimum score was 82% by one child (seven children scored 100%). In the unrelated condition, only one child had the same minimum score of 82% (six children scored 100%). The poorest performance was on the word-pseudoword pairs: the lowest scores were 68% correct in one child for set 1 and 75% in two children for set 2; only 7 values of 100% were obtained out of the 54 scores in both sets.

The children’s average percent of correct answers out of 16 tones (on the two tone control blocks) was $M = 93.75\%$ (SD = 12.74). The reaction time average was $M = 1130$ ms (SD = 283ms).

**Relation of Semantic Priming to Children’s Age, IQ and Other Language Skills.** We were interested in the relations between lexical decision processes, children’s age/IQ and standardized / non-standardized language tests scores. For that purpose, we calculated Pearson Product Moment Correlations. We found significant correlations between children’s age (months) and reaction times (ms) in the next 4 speech pair sets (lexical decision): related ($r = -.47$, $p = .014$), unrelated ($r = .-47, p = .012$), pseudoword Set 1 ($r = -.50, p = .008$), and pseudoword Set 2 ($r = -.43, p = .025$). Using the Bonferroni correction, the significant $p$-value starts at $p = .0125$, these correlations did not reach any significance (despite a trend for RT to decrease as IQ increased). Finally, we found significant correlations between the percentage of accuracy in Relative Clauses Comprehension Task (Friedmann & Novogrodsky, 2002; Girbau & Schwartz, 2007b) and reaction times in the next sets: related ($r = -.53, p = .005$), unrelated ($r = -.45, p = .019$), pseudoword Set 1 ($r = -.43, p = .027$), and pseudoword Set 2 ($r = -.48, p = .011$). Thus, reaction time in the LD task decreased significantly as performance on relative clause task improved, especially for the semantically related word pairs (the significant $p$-value starts at $p = .0125$ using Bonferroni). The correlations did not reach significance (using Bonferroni) between percentiles in TONI-2 (McGhee et al., 2007) and reaction times in the next sets: related ($r = -.46, p = .015$), unrelated ($r = -.43, p = .024$), pseudoword Set 1 ($r = -.40, p = .037$), and pseudoword Set 2 ($r = -.47, p = .013$).

No significant correlations were found for the remaining test and subtest scores. For the percentage of accuracy in the 3-4-5 syllable subset of the Non-word Repetition Task (Girbau & Schwartz, 2007a) the correlations were: related ($r = -.31, p = .12$), unrelated ($r = -.35, p = .07$), pseudoword Set 1 ($r = -.19, p = .34$), and pseudoword Set 2 ($r = -.33, p = .09$).

For the PPVT-III percentiles (Dunn & Dunn, 2006), they ranged from $r = -.32, p = .11$ (pseudoword Set 1) to $r = -.24, p = .23$ (pseudoword Set 2). For the CEG percentiles (Mendoza et al., 2005), they ranged from $r = -.28, p = .15$ (related) to $r = -.15, p = .45$ (pseudoword Set 1). For the SD (z-score) in the Vocabulary subtest from the WISC-IV (Wechsler, 2007), they ranged from $r = .07, p = .75$ (pseudoword Set 2) to $r = .03, p = .87$ (related). For the overall mean of the SD (z-score) in the four subtests of ITPA (Kirk et al., 2001), they ranged from $r = -.22, p = .26$ (unrelated) to $r = -.14, p = .49$ (pseudoword Set 2). For the SD (z-score) in each of the four subtests of ITPA, they ranged from $r = -.21, p = .29$ (Auditory Comprehension/ pseudoword Set 2) to $r = -.03, p = .89$ (Auditory Association/ pseudoword Set 1).

**Adults versus Children: Implicit Semantic Priming**

The analyses to compare both age groups focused on reaction time (milliseconds), accuracy (percentage of correct responses) and items. Again, only correct responses were included in the next analyses on response latency; omissions, errors and outliers, as defined before, were excluded.

First, we compared the reaction times between adults ($n = 42$) and children ($n = 27$) for the four conditions of speech pairs. Since it was an unequal $n$ design, a GLM repeated-measures analysis with sums of squares Type III was calculated for Reaction Time. There was one within-subjects factor (speech pair group) with 4 levels (related, unrelated, and pseudoword sets 1 and 2) and one between-subjects factor (adults/children). Results
revealed a significant between-subjects factor (age) effect on Reaction Time, $F(67,1) = 121.95, p < .0001$. There was also a significant within-subjects factor (speech pair) effect on Reaction Time, $F(67,3) = 83.11, p < .0001$. Finally, a significant interaction of Speech Pair X Age was obtained, $F(67,3) = 12.27, p < .0001$. As Table 4 shows, adults’ response time averages were significantly faster in any of the four conditions than children’s responses. Moreover, the size of semantic priming effect was twice larger for adults than for children. Particularly, the difference between the unrelated and related mean latencies was 94 ms in the adults’ group and 46 ms for children’s group. Accuracy was high for adults and children in any of the four conditions, but because of ceiling effects no statistical comparison was done.

Adults’ reaction time response average for each of the 28 word pairs in the related condition was always lower with respect to each of the 28 word pairs with the same target in the unrelated condition (Figure 1). The graph was similar for children with somewhat more variability and except for items 4 and 8 with inhibition (instead of priming; see Figure 1).

Discussion

Our findings for the auditory lexical decision task will be discussed here for each age group separately. Then we will also discuss our results comparatively for this developmental research.

Semantic Priming in Adults

Our general results in adults are similar to some previous research that found a semantic priming effect, mostly done with a visual presentation and single decisions, in adults across languages (e.g., Rissman et al., 2003; Sánchez-Casas et al., 2006). In the present experiment, Spanish-speaking adults exhibited auditory semantic priming in a double lexical decision task, an effect that was clearly consistent across all items. Furthermore, all adults had significantly faster reaction times to targets that were semantically related with the previously presented primes than to unrelated word pairs. The adults were also significantly faster deciding in the semantically related condition than in each of the two pseudoword sets as other authors found in a Spanish visual task (e.g., Sánchez-Casas et al., 2006).

All these results were also found in a similar study by Rissman et al. (2003), including semantically related word pairs (with fMRI) in 15 English-speaking adults on the basis of the same number of conditions for auditory prime-target pairs. However, unlike the referred work (which also used a double decision task), we did not find any significant difference for the reaction times between the unrelated condition and each of the pseudoword sets (that these authors analyzed as one joined set to get more statistical power in their fMRI task). The authors also found lower accuracies, than in our present behavioral study, for all conditions (97% for related, 89% for unrelated and 81% for pseudoword). This might be related to the fMRI context and/or some different task features. For example, despite they also used some jittering and controlled for not having the same targets in adjacent runs, they did not report any control for not having several consecutive events of the same condition (e.g., related vs. unrelated) or type of target (word vs. pseudoword). Their words were nouns, verbs, adverbs and adjectives with different syllable lengths (varying from one to three); we used two-syllable nouns. More research is needed to better know the effects of the different experimental variables that are involved in semantic priming processing.

As expected, reaction time average for tone pairs was lower than for speech pairs. The simplicity of the type of decision explains their faster speed with respect to the lexical decision. Their accuracy in the control tone blocks, with no mistakes at all, was also better than in the lexical decision blocks. The previous study (Rissman et al., 2003) did not report any data about this. Our data are reported as a description of auditory non-language reaction time and accuracy, which will be compared with the children’s study.

Semantic Priming in Children

Our main results support partly some previous research about lexical processing in younger children (6;2 to 7 year olds) and adults performing a similar auditory double lexical decision task in French (Radeau, 1983), although our children’s group showed more variability. In the present experiment, 70.4% of Spanish-speaking children (8;1-10;11 year-olds) showed auditory semantic priming in a double lexical decision task; 91.7% in the French younger children who always received immediate feedback, which was not given in our study). Thus, the children from the French study could have become more conscious of their response accuracy and therefore more able to better self-regulate their performance, thanks to the immediate feedback. Furthermore, our remaining 29.6% showed semantic inhibition so that all children had some kind of special response in any direction for the semantically related words (when compared with the unrelated words). Our children’s group had significantly faster reaction times to semantically related word pairs than to unrelated word pairs, and also than in each of the two word-pseudoword sets to which children responded with similar speed (i.e., both sets of pseudowords had similar difficulty). Reaction times for these two sets were significantly slower than those for the semantically unrelated word pairs in children (not in adults); more research is needed on this issue (their semantic networks and vocabulary are still developing). Thus, children’s reaction times increased significantly and
consistently with the increasing difficulty of the conditions, that is, their RTs were faster for semantically related word pairs compared to unrelated and to word-pseudoword pairs (the slowest one). Accuracy showed a similar trend, although it was rather close to ceiling.

On the other hand, processing speed was consistent within each child across conditions. This can lead us to see processing speed as an individual trait in children that is progressively developing. Interestingly, results showed that reaction time decreased as age increased from 8 to 10 years of age. There was also a trend for reaction time to decrease as IQ increased. Finally, reaction time in the LD task decreased significantly as accuracy in Relative Clauses Comprehension Task (Girbau & Schwartz, 2007b) improved, especially for the semantically related word pairs. Both tasks involve semantic processing and high demanding comprehension.

As expected, the reaction time average for tone pairs was lower than for speech pairs. As in Experiment 1, the simplicity of the type of decision to tones explains their faster speed with respect to the lexical decision. Their accuracy in the control tone blocks was somewhat better than in the two word-pseudoword sets, but similar to semantically related/unrelated word pairs. Thus, it seems that the auditory processing is not yet fully developed at this age.

**General Discussion: Adults vs. Children**

One of our main findings in Spanish speakers agrees with previous research comparing adults’ with children’s performance in a lexical decision semantic task. Thus, we also extend the findings to bilinguals; their lexical access in the primary language seems no different than behavioral results reported for monolinguals. Spanish-speaking children (8;1-10;11 year-olds) and adults showed significantly faster reaction times to semantically related word pairs than to unrelated pairs, but children were significantly slower than adults for all the pair type conditions of the auditory task. This last result agree with previous findings in other types of speeded tasks in which response time was found to decrease significantly with age from childhood to adolescence and adulthood (Kail, 1991). Our findings are also similar to Radeau (1983), who found semantic priming in native French-speaking adults and younger children (mean age of 6;8) using a similar auditory double lexical decision task in French with some differences (e.g., giving immediate feedback to all participants and an intensive practice, which was not given in our study). The semantic priming effect was robust for adults in both studies, but children exhibited some variability (which was greater in our study): it was shown by all adults in the two studies, and by at least 70% of the children’s groups (22 out of the 24 French kids and 19 of the 27 Spanish children). Therefore, semantic effects may be developmentally variable in children. In fact, the remaining 8 children showed semantic inhibition. Thus, all our children had a particular response (priming/inhibition) for the semantically related words (when compared with the unrelated words). Furthermore, Reaction Time sometimes appears to be a limited measure of cognitive processes and internal activation. For example, individual and group differences in reaction times are influenced by overall speed so that the comparisons of RTs across age groups including children may not be so reliable (Chapman et al., 1994). On the other hand, in a phonological category decision task, adults exhibited no RT differences, but clearly different brain responses (Rodriguez-Fornells, Rotte, Heinze, Nosselt, & Munte, 2002). Thus, neurophysiological measures could help us to clarify the underlying processes in semantic priming tasks for children and adults and could contribute to explain this variability in children across different ages, tasks and procedures (e.g., with/without feedback). According to both studies, auditory semantic priming is shown in preliterate children and in children who are becoming literate (with speed decreasing as age increased from 8 to 10 years of age). In our study, the groups of children and adults were also significantly faster deciding in the related condition than in each of the two word-pseudoword sets, which required more time in the participant’s decision.

However, activation appears to spread faster in adults’ semantic network than in children, probably because in adults related nodes are stored close together and/or linked via stronger links than in children as old as 10 years of age (Nakamura et al., 2006). This development of semantic networks might also partly help to explain why only children (but not adults) were significantly slower for the word-pseudowords than in the unrelated word pairs. It appears that our children are slower searching for a particular pseudoword within their brain’s lexical database, which is still under development. Thus, only children’s processing speed decreased significantly with the increasing difficulty across all conditions, from semantically related word pairs through those unrelated to the pseudoword condition. Parts of these results were also found in adults, but not significantly from unrelated word pairs to the pseudoword condition. More research is needed about this particular result in adults. A previous similar work in English adults did find significant differences between the three conditions, which are related, unrelated and pseudoword conditions (with the two joined pseudoword sets), (Rissman et al., 2003).

Our results also showed that the semantic priming effect is more consistent in adults, across the items and participants, than in children. However, although latencies exhibited more variability in children than in adults, intraindividuals’ processing speed was consistent across all conditions in children. Accuracy was quite good in both groups, although adults gave more right responses than children in the pseudoword sets.
The size of the semantic priming effect was twice larger for adults than for children. Our results disagree with the previous work using also an auditory double lexical decision semantic task in adults and younger children (Radeau, 1983). This French study found that semantic priming effects were larger for children than for adults. A possible explanation could be that their children may have benefited more from the long practice (children practiced twice more than adults) and the immediate feedback after each experimental trial (only children were verbally encouraged for their correct responses, although all participants received immediate feedback). A previous meta-analysis found that the semantic priming effect was larger for older than for young adults (Laver & Burke, 1993). They supported process-specific slowing aging models (rather than general cognitive slowing). Our studies showed that children’s semantic priming processes are very similar to adults’ processing, though semantic networks and vocabulary are still developing and, thus, they showed some different patterns (e.g., some slight item differences in semantic priming, some differences depending on item types, magnitude of semantic priming effect). Some processing speed differences from 8 to 10 years of age were also found. Therefore, the general aging cognitive slowing in children (compared to adults) goes together with some process-specific patterns.

As expected, the reaction time average for tone pairs was lower than for speech pairs in both age groups (with perfect accuracy in all adults, but somewhat lower in children). The simplicity of the type of decision explains their faster speed with respect to the lexical decision. It seems that the auditory processing is still developing at this age as it is the semantic network.

In the future, the present auditory double lexical decision task could be used to study semantic priming in other populations, including those with language pathologies as Specific Language Impairment, who have been reported to show a general slower processing speed. More research is also needed to better understand how older children’s lexical decision speed/accuracy approaches to that in adults, through the development of semantic networks and the particular patterns related with age. This lexical processing information would be useful as a baseline for comparison to other age-matched groups with possible language deficits. These patterns could be better known by using neurophysiology measures for analyzing the age course development of auditory semantic priming.

References


Hollingshead, A. B. (1975). Four factor index of social status. Unpublished manuscript. Department of Sociology, Yale University, New Haven, CT, US.


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### APPENDIX

**SEMANTIC PRIMING TASK: SPEECH PAIRS IN THE FOUR LEXICAL DECISION BLOCKS FOR RELATED, UNRELATED AND PSEUDOWORD CONDITIONS.**

<table>
<thead>
<tr>
<th>Nº</th>
<th>Related condition</th>
<th>Unrelated condition</th>
<th>Pseudoword condition&lt;sup&gt;Set 1&lt;/sup&gt;</th>
<th>Pseudoword condition&lt;sup&gt;Set 2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>sitio-lugar</td>
<td>botón-lugar</td>
<td>atún-cópris</td>
<td>muela-cópris</td>
</tr>
<tr>
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<td>hueso-cartas</td>
<td>curva-istpo</td>
<td>ángel-istpo</td>
</tr>
<tr>
<td>3</td>
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<td>lata-bebé</td>
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<tr>
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<tr>
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<tr>
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<td>pincho-marte</td>
<td>muelle-óprac</td>
<td>mueble-óprac</td>
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</tbody>
</table>

*Note. Each of the four conditions had 28 prime-target pairs, which numbers (from 1 to 28) matched with the numbers in Figures 1 to 2.*