Iconic gestures serve as primes for both auditory and visual word forms

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Previous studies using cross-modal semantic priming have found that iconic gestures prime target words that are related with the gestures. In the present study, two analogous experiments examined this priming effect presenting prime and targets in high synchrony. In Experiment 1, participants performed an auditory primed lexical decision task where target words (e.g., "push") and pseudowords had to be discriminated, primed by overlapping iconic gestures that could be semantically related (e.g., moving both hands forward) or not with the words. Experiment 2 was similar but with both gestures and words presented visually. The grammatical category of the words was also manipulated: they were nouns and verbs. It was found that words related to gestures were recognized faster and with fewer errors than the unrelated ones in both experiments and similarly for both types of words.

Keywords: iconic gesture, semantic priming, word processing, cross-modal priming

When talking or giving a discourse, people use not only words but also some nonverbal behavior to communicate. In addition to facial expressions, posture or gaze patterns, an aspect of nonverbal communication that has been investigated from a cognitive perspective are gestures, that is, those hand movements that often accompany speech (McNeill, 1992). There are different kinds of gestures (Alibali et al., 2001) and they can be perceived by listeners in different ways.

Some taxonomies about types of gestures have been proposed but these classifications have generated some debate, particularly about the differences between iconic gestures and pantomimes. In this study we will focus on iconic gestures (IGs, henceforth). There is some agreement about the definition of IGs: movements that accompany the speech and represent a spatial or a motor reference through a concrete action, the demonstration of a spatial property or an abstract idea. IGs can be distinguished from pantomimes, because the pantomimes can

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transmit meaning in silence or, at most, together with inarticulate onomatopoeia (McNeill, 1992). However, the definition of IGs is not always clear among authors. Many studies that have investigated the communicative effectiveness of gestures (e.g., Wu & Coulson, 2005, 2007a, 2007b; Bernardis et al., 2008; Yap et al., 2011; So et al., 2013) do not distinguish between IGs and pantomimes. Basically the only difference between IGs and pantomimes is that the latter are not accompanied by speech. For present purposes, we will follow McNeill (1985): the term IG refers to hand gestures that represent a meaning that is closely related to the semantic content of the accompanying speech.

The influence of gestures on language processing has been analyzed from different perspectives. Observational studies have suggested that gestures seem to provide key information about the meaning of the message (e.g., Kendon, 1980; Goodwin & Goodwin, 1986). McNeill (1992) proposed that IGs provide some additional semantic information about one's own speech, helping listeners to create better representations of the speaker's message. One of the first systematic reviews of the literature related to this question was conducted by Kendon (1994), who concluded that gestures benefit language comprehension, a point of view widely accepted today (but see Krauss et al., 1995).

Several theoretical proposals have emphasized an automatic integration of gestures with language. It is worth mentioning the Interface Hypothesis, which argues for a strong connection between gesture and speech, suggesting that IGs provide complementary meaning to language and that they are closely interconnected to language variations (Slobin, 1987, 1996; Kita & Özyürek, 2003). Similarly, Kelly et al. (2010) explored how different levels of semantic incongruence between gesture and language modulated their integration. The results supported their Integrated Systems Hypothesis by confirming that gesture and speech are integrated and interact mutually and obligatorily in a bidirectional way (see also Kelly et al., 2008; Kelly et al., 2010; Kelly et al., 2015).

In line with the present study, the possible facilitation of IGs for the comprehension of language has been investigated using different versions of the cross-modal semantic priming, where gesture were primes and single words acted as targets. The more concrete and underlying question to answer is: the encoding of an iconic gesture activates and (possibly) facilitates semantically related words?

Bernardis et al. (2008) carried out one of the first study using gestures produced without a linguistic context (not accompanying speech) and in the context of a semantic priming gesture-word. In their study, participants were presented with visual gestures (primes) followed by lexical objectives (target words). On the screen, a clip with an average duration of 3,672 ms was followed by the target word, presented for 500 ms. Bernardis et al. measured the time needed to name each lexical objective and compared it to a "neutral" reference latency, which was estimated using a group of participants who simply had to name the lexical targets aloud (no gestures: just the words). Participants took longer to name a word when it was unrelated to the gesture in comparison with the neutral baseline (i.e., inhibition). There was no significant difference between the related and neutral conditions, suggesting that IGs do not activate semantically related words. Thus, these results would seem to indicate that gesture and speech are somehow independent.

Nevertheless, and according to Yap et al. (2011) and So et al. (2013) these results should be interpreted with caution for two main reasons: the duration of the IGs (more than 3000 ms) and because they based their conclusion of a non-significant facilitation effect. In this regard, some problems associated to neutral baselines are argued (Jonides & Mack, 1984) and we will return to this topic later.

Based on the limitations described above, different priming experiments have been carried out in order to study whether the gestures facilitated the comprehension of language but using other tasks. In the study by Yap et al. (2011), participants were presented IG clips with semantic meaning followed by words or non-words, and they were asked to complete a typical lexical decision task (to decide whether the word visually presented was a word or a pseudoword). In the first experiment the clip lasted between 3000 and 4000 ms, followed by a blank screen for 200 ms. Then, the word was presented for 3000 ms or until the participants pressed a key. In their second experiment, the procedure was exactly the same as in the first one but with a duration of the clip of 1000 ms, in order to avoid the limitation of the experiment by Bernardis and his colleagues: reducing the time that participants supposedly might take to elaborate verbal labels related to gestures. The results of both experiments showed that participants responded more quickly and accurately to related words than to words not related to the gestures. These findings showed that IGs can facilitate the recognition of semantically related words (see also De Marco et al., 2015).

However, in these studies showing somehow contradictory results, gestures and then words were presented with certain asynchrony. But in everyday life, gestures and speech have temporal simultaneity (Morrel-Samuels & Krauss, 1992). With this limitation in mind, So et al. (2013) examined whether IGs accompanying speech would prime semantically related words and whether such priming was comparable in size to that produced by IGs presented alone in a lexical decision task (Yap et al., 2011). Participants were presented with one of three priming conditions (between participants): a gesture clip (gesture-only condition), an audio clip (speech-only condition), or a combination of both (gesture-accompanying-speech condition). The other manipulated factor was the relationship between primes and targets: they could be related or unrelated. The duration of the clips was 1000 ms. Primes in the three conditions were followed by a blank screen (for 200 ms) and then a word (or a pseudoword) was displayed for 3000 ms or until the participants made a lexical decision.

In general, response latencies were faster when the words were semantically related to the primes than when they were not. However, the priming effect in the Gestures-Accompanying-Speech condition was similar to the Speech-Only condition, but it was weaker than in the Gesture-Only condition. The results in the Gesture-only condition are the most relevant for the present research: IGs primed semantically related target words in a lexical decision, supporting the notion of a semantic link between gestures and lexical units and replicating the findings in Yap et al. (2011).

In line with the works reviewed above, our present study will make use of cross-modal priming paradigms to investigate the influence (i.e., possible facilitation) of IG on lexical access and word recognition processes. Our tasks will be lexical decisions to words preceded by IGs that may or may not be related to them (sharing meaning), Thus, a conscious task of deciding whether or not the gesture is congruent with the word is not required, as for instance in Wu & Coulson (2005) or Kelly et al. (2010, 2015).

In previous research using gesture-word priming, two types of design can be found. Some experiments have included some neutral condition or baseline, such as the word alone (Bernardis et al., 2008) while others have avoided baselines, based on the fact that this procedure carries several problems (Yap et al., 2011). First, the processing demands of naming or recognizing a word presented alone and preceded by (related or unrelated) gestures are different: necessarily, more time is needed to process both the gesture and the word (So et al., 2013; Yap et al., 2011). Second, it has been shown that the use of different neutral baselines can artifactually overestimates or underestimates facilitation and inhibition (Forster, 1981; Jonides & Mack, 1984; Yap et al., 2011). In order to explore facilitation or inhibition, it would be necessary that the neutral and the cuing conditions are identical in all variables except in the manipulation. For these reasons, it has been recommended that the neutral conditions should be excluded (Jonides & Mack, 1984; Yap et al., 2011). Consequently, our two priming conditions had gestures that could be related or unrelated with the target words.

It is obvious that gestures had an origin closely linked to spoken language, and that its use they are used more frequently and prominently when accompanying language. However, in real life, visual semantic information including IGs joins not only speech but also written language. Examples include cases in which we watch a movie with subtitles when we cannot hear the audio because the noise from outside is too loud to hear the audio of the movie or because you are deaf. But it is equally true that the semantic influence of IGs on word recognition does not necessarily have to be the same in both visual and auditory modalities. Some differences have repeatedly been found concluding that the semantic priming processes in each modality do not need to be identical (e.g., Holcomb & Neville, 1990) and these divergences could be even more pronounced in the context of non-verbal stimuli affecting words. To our knowledge, no previous study has compared the influence of IGs on the two sensory modalities (visual and auditory). Accordingly, investigating and comparing the influence of IGs over words presented either auditory (Experiment 1) and visually (Experiment 2) is not only novel but also theoretically relevant.

Research has shown that gesture and speech are closely synchronized (Morrel-Samuels & Krauss, 1992; McNeill, 2005). Thus, we consider that a critical issue remains unaddressed in the studies of Bernardis et al. (2008); Yap et al. (2011) and So et al. (2013): shorter durations of the IGs and shorter SOAs would be desirable and closer to the use of IGs in real life. In relation to this idea, some studies have tried to analyze, through ERP, how IG are integrated with linguistic and non-linguistic material by modifying the SOA in order to explore if the time frame leads to different integration between gesture and speech (Habets et al., 2011). They obtained a higher N400 when gesture and speech are inconsistent for a condition of SOA = 0 ms and for a SOA = 160 ms, but not for a SOA condition of 360 ms. They concluded that consistency between speech and gesture information affected the integration of speech and gesture only within a certain time window. It is possible that, when the gesture precedes the word by a relatively large margin, IG cannot influence speech in the same way. Our research will take into account this fact. In our two experiments: IGs and words will be presented with a great synchrony or overlapping.

Another of our aims is to study whether the possible facilitation of IGs can be generalized between grammatical modalities (nouns and verbs). Only in the study by Bernardis et al. (2008) the grammatical class was manipulated but with non-significant effects in the behavioral experiment although some differences were found in the ERPs experiment. We consider that the possible effect of the functional roles of gestures on the grammatical roles of nouns and verbs deserves more research (see for example Goldin-Meadow & Wagner, 2005; Bernardis et al., 2008). First, nouns tend to be conceptually more basic than verbs (Gentner, 1982). Second, IGs are functional mainly when their semantic meaning involve dynamic temporal and spatial information (Driskell & Radtke, 2003, and Hostetter, 2011) and this kind of information is clear in action verbs, the type we will use as stimuli, and more prominent than in nouns, even if nouns refer to real objects as in our next experiments. The third reason is related with the perspective of embodied cognition. Gestures involve movement and it is known that activate areas of the sensorimotor cortex (Martuzzi et al., 2014) and observing movements activates the same cortical areas as performing them (Wilson & Knoblich, 2005;

Wilson & Emmorey, 2006). Thus, the influence of IGs, gestures made by the body, on the processing of the same action verbs (i.e., a word involving movement) should be much greater and more straightforward than in the case of nouns.

As far as we know, no behavioral studies have controlled for the fact that the participants were really looking at the gestures acting as primes when the task was focused on language materials. This could be an explanation for why the Gesture-Accompanying-Speech condition was similar to that of Speech-Only in So et al. (2013). The participants could paid more attention to speech than to gestures, and therefore it would not be entirely clear that gesture and speech will be combined in an integrated system as suggested by Kelly et al. (2010). In the two experiments we present here, we will add explicit questions about the relationship between IG and word in one fourth of the trials.

In addition, most of this type of research has been conducted with English-speaking participants (e.g., Wu & Coulson, 2005, 2007a, 2007b; Yap et al., 2011; So et al., 2013), Italian-speaking participants (e.g. Bernardis et al., 2008), and Chinese-speaking participants (e.g., Ng, Goh, Yap, Tse & So, 2017) but none with Spanish speakers: our participants. This fact will hopefully shed more light on the understanding of the links between gestures and words (i.e., the influence and possible facilitation of IGs on language comprehension) across different languages.

Experiment 1

Method

Participants

Twenty-nine undergraduate students of Psychology and Speech Therapy (3 men and 26 women) from the University La Laguna, with Spanish as their first language, and with no history of neurological problems participated in the experiment to fulfill a course credit requirement. They were between 18 and 39 years old (mean: 20.2 years).

Materials and design

Due to the fact that there was no previous normative study in Spanish, previously to the experiment a normative study was carried out with 80 IGs recorded as single video clips. Each clip displayed the half body of an adult male actor performing a significant gesture of an action (verb) or an object (noun) with both hands and arms, and with a controlled duration (between 800 and 1200 ms). For example, moving both hands forward as a representative gesture of "pushing"; or moving both hands from the center of the head to the ears as a gesture of "headphones".

All the gestures were presented to a system of judges (10 students who did not participate in the experiment) and they were asked to write a word (verb or noun) to describe the meaning of each of the gestures (the gestures were presented without audio). Since speech was not available, the participants interpreted the meaning of the gestures according to their physical forms and movements (characteristic of the IGs). Only those pairs of gesture-word with an agreement above 90% of the judges were chosen (see Goh et al., 2009). After this procedure, 24 action verbs in infinitive ("push", "eat" or "drink" type) and the 24 singular nouns ("zipper", "ring", "gorilla", etc.) and their corresponding IGs selected from the previous normative study, were used (see Appendix 1. Video clips can be seen in: https://riull.ull.es/xmlui/handle/915/23607).

This procedure was essentially the same than in Bernardis et al. (2008) who carried out a normative study to select the most representative IGs, where participants had to look at the clips and name the gestures. These clips were only video without auditory information. Since the selected gestures were understood without language, according to the definition of McNeill (1992) they would not be IGs but pantomimes in a strict sense (see Introduction) since they were easily recognized without the support of language. However, we consider that they meet the properties of IGs. Bernardis and colleagues also claim that both are representative gestures (IGs and pantomimes) and he used them indistinctly. In this study, we will proceed in the same way. First, they do not have a completely clear transparency. And second: although in the normative study the gestures were presented without speech, the gestures of the experiment will be presented with verbal and written language, being by definition IGs.

The words (nouns and verbs) and pseudowords were recorded by a male voice (same gender as the person in the videos). The duration of the sound files was between 500 and 1000 ms. and they were presented 500 milliseconds after the beginning of the clip (during the video), ensuring temporal simultaneity.

In order to perform the experimental task, 48 pseudowords (without meaning) were generated, changing one letter of the words. This letter was never the last one, so that the pseudowords could not be discriminated from words by superficial spelling processing, thus reducing the superficial access to conceptual meaning according to the LASS theory (Barsalou et al., 2008) (see Appendix 2. Audio can be heard in: https://riull.ull.es/xmlui/handle/915/4762).

The two types of word (verbs and nouns) were preceded by a congruent video (the action or gesture of pushing followed by the verb "push") or incongruent (the gesture of pushing followed by the word "drink"). Two counterbalancing sublists were generated (according to a Latin square), so that half of the verbs were preceded by congruent videos and the other half by incongruent videos, and the same for nouns, so that all the words were preceded by congruent and incongruent videos in different lists and no word or video was repeated in the same list. Each participant received only one list. The presentation of the different video-word (or pseudoword) pairs was random within each list.

Thus, the design was a factorial 2 × 2 within-subject design, with the factors being for Type of Gesture-Word Relationship (with two levels: related or congruent versus unrelated or incongruent) and Type of Word or Grammatical Category (also with two levels: verb and noun). The response latency or reaction time (RT) to the words (only for correct responses) as well as the error rates were the dependent variables.

Procedure

The experiment was run on a computer using E-Prime 2.0 software (Schneider et al., 2002). Each test session was conducted in a quiet room, free of noise. It began with precise instructions: Participants were informed that they would watch videos with gestures of familiar, everyday words followed by auditory presented words (or pseudowords) that might or might not be related to the gesture, played binaurally through the headphones connected to the computer. The videos would always show IGs, that is, all gestures had meaning regardless of whether the auditory stimulus was a word or a pseudoword. For the 48 pseudowords, 48 different videos were generated for those of the verbs and nouns. The task they had to perform was to decide, as quickly as possible and without making mistakes, by pressing one of two keys (one labeled "YES" and the other labeled "NO"), whether the auditory stimulus was a word or not, leaving their fingers always on top of the response keys.

Each trial began with a fixation point (a cross) for 500 ms, presented in the center of a 17-inch color monitor, with a black background. Then, a blank screen for 200 ms was followed by the clip in the center of the screen (640 × 480 pixels). 500 ms after the onset of the clip the word sound file was presented (to ensure gesture-audio synchronization). The clip remained until the participant responded or until a total of 5000 ms (stopped and static at the end of the video, in the last image). There was an interval of 1 second before the start of the new trial. 6 practice trials were presented at the beginning.

In order to ensure that participants did not miss the videos, since their main task was about words or pseudowords, and in order to ensure that the videos were processed, in 25% of congruent trials and in 25% of incongruent trials, after the lexical decision task, the following question appeared on the screen: "IS THE VIDEO RELATED TO THE WORD?", to which participants had to answer "yes" or "no" using the two answer keys. The question was posed for a maximum of 5000 ms and the participants were also informed about this issue during the instructions.

Results and discussion

The answers to the question about the video-word relationship showed that the participants processed the videos: the rate of correct answers was above 95%.

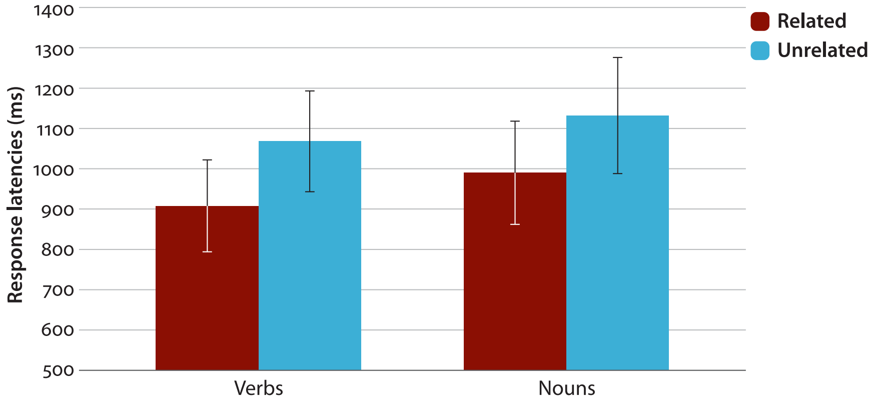
Errors and response latencies faster than 200 ms were excluded from the RTs analyses. Response latencies more than 2.5 SDs above or below each participant were also excluded from the analyses (2.29% of the data in total).

Both RTs for correct responses and error rates (see Figure 1) were analyzed using Linear Mixed Models, which simultaneously take into account the variability for participants and for items (Baayen et al., 2008; Bates, 2005). R-based statistical software was used for this purpose with the lme4 package (Bates & Maechler, 2009). More specifically, the ULLRToolbox was used (Hernández-Cabrera, 2011). After checking that the factor sublist was not significant (required by the Latin Square and theoretically meaningless), the factors Relatedness (related vs. unrelated) and Grammatical Category (nouns vs. verbs) were entered as within-participant factors. We used a fitted mixed-design ANOVA with Satterthwaite approximation for degrees of freedom. The model was estimated following Barr et al. (2013) with all repeated measures factors as fixed and random slopes across participant.

There was an effect of relatedness, $F(1,27) = 118.8$, $p < 0.001$: words in the related condition were answered faster than words in the unrelated condition ($M = 949.14$ ms, $SD = 122.55$ ms vs. $M = 1099.96$ ms, $SD = 228.57$ ms). The effect of grammatical class was also significant $F(1,48) = 5.8$, $p < 0.05$: the verbs were answered faster than the nouns ($M = 983.67$ ms $SD = 228.39$ ms vs. $M = 1056.65$ ms, $SD = 231.35$ ms). The interaction was not significant, $F(1,1057) < 1$.

Accuracy (error rates) was analyzed through a Logistic Linear Mixed Model that showed that related condition produced less errors (1%) than the unrelated one (10%), X^2 (1) = 7.8, $p < 0.01$. Both the effects of category and the interaction were not significant, X^2 (1) = 0.01, $p > 1$ and X^2 (1) = 0.3 $p > 1$, respectively.

Overall, we found that the IGs facilitated the recognition of a semantically related word (noun and verb) in the auditory mode. Words presented while semantically related gestures are being processed were answered faster and more accurately than words that were not related.



Note. Mean response latencies for an auditory lexical decision task for nouns and verbs, with related vs. unrelated gesture primes (Experiment 1). Standard error bars are included.

Figure 1.

Since the temporal and spatial information is clearer in action verbs than in nouns, we expected an interaction of the two factors, namely a greater advantage of the related IGs over non-related IGs is expected for verbs than for nouns. Although verbs were responded faster than nouns, there was no difference in the facilitation of the IGs between nouns (objects) and verbs (actions). Therefore, it seems that there is an integration independently of the grammatical modality. As mentioned, we expected an interaction, with related and non-related IGs presented to the same nouns or verbs (i.e., within-items). The main effect of grammatical category is hardly interpretable and does not make sense theoretically since psycholinguistic variables in nouns and verbs were not matched as it was not our goal.

According to previous research (e.g., Holcomb & Neville, 1990; Holcomb & Anderson, 1993; Anderson & Holcomb, 1995) semantic processing is shared by the two sensory modalities (visual and auditory) but in different ways, that is, they use the same semantic processing but in different ways. Our objective was to analyze whether these similar processes between modalities can be extrapolated to the influence of non-verbal communication, specifically gestures. As seen above, most of the cross-modal experiments using IGs as primes have used target words visually presented. In this study, priming effects have been found also when words are presented in the auditory modality. It is also important to highlight that, in contrast with previous research, words were presented overlapped with the IG: words sounded while the IG clips were being released, basically in the middle of them.

Experiment 2

Nowadays, gestures do not just accompany the language we hear. In many situations, gestures (or visual dynamic information) appear in synchrony with the written language. This is the case of many videos that we see on the computer, conferences or films with subtitles, talks accompanied by visual material where noise prevents us from hearing clearly, etc. On the other hand, seeing images or speakers accompanied by a visual transcription of the message (subtitles) is relatively frequent in the case of deaf or persons with hearing loss.

Therefore, the next goal was to analyze whether the influence or facilitation of gestures on the coding of language is something specific to spoken language or, on the contrary, it also occurs when we process (read) written words. In line with other cross-modal studies (Holcomb & Neville, 1990; Holcomb & Anderson, 1993), we expect similar results to Experiment 1. For example, the study by Holcomb & Neville (1990) compared semantic priming in visual and auditory modalities using event related potentials (ERPs) and behavioral measures. Participants made slower responses and made more errors to unrelated words than to related words in both modalities. However, the ERP priming effect began earlier, was greater, and lasted longer in the auditory modality than in the visual modality. These results suggest that the priming processes of each mode are connected but not identical. In addition, this possible sensory mode independence is a relevant theoretical objective in itself. Thus, this second experiment will attempt to analyze this issue. Basically, it will be a reproduction of Experiment 1 but with words presented visually.

Method

Participants

Thirty undergraduate students of Psychology and/or Speech Therapy (3 men and 27 women), from the University La Laguna, with Spanish as their first language and with no history of neurological problems, took part in the experiment for course credit. The age range was between 18 and 25 years, with a mean of 19.1 years. None of them participated in Experiment 1.

Materials and design

Both the primes and the targets were the same as in Experiment 1.

Thus, the design was again a 2 × 2 factorial within-participant design, with the Type of Gesture-Word Relationship (with two levels: related or congruent versus unrelated or incongruent) and Type of Word or Grammatical Class (also with two levels: verb and noun) factors. RTs to the correctly-responded words and error rates were also the dependent variables.

Procedure

The whole procedure was identical to that in the previous experiment. In this case, the words and pseudowords were presented visually 500 ms after the start of the gesture clip (to ensure gesture-word synchronization like in the first experiment). They appeared just above the clip in lowercase and in white letters, with a font type of Arial, size 40. They were on the screen until the participant pressed one of the two response keys.

As in the previous experiment, in order to ensure that the videos were processed, in approximately 25% of congruent tests and in 25% of incongruent tests, after the lexical decision task, the following question appeared on the screen, "IS THE VIDEO RELATED TO THE WORD?", to which the participants had to answer "yes" or "no" using the two answer keys. The question was exposed for a maximum of 5000 ms.

Results and discussion

The same type of analysis and the same type of data cleaning was used for the two measures or dependent variables (RT and error rates) as in the previous experiment. The answers to the question about the video-word relationship showed that the participants did the task quite well: there were above 93% correct answers.

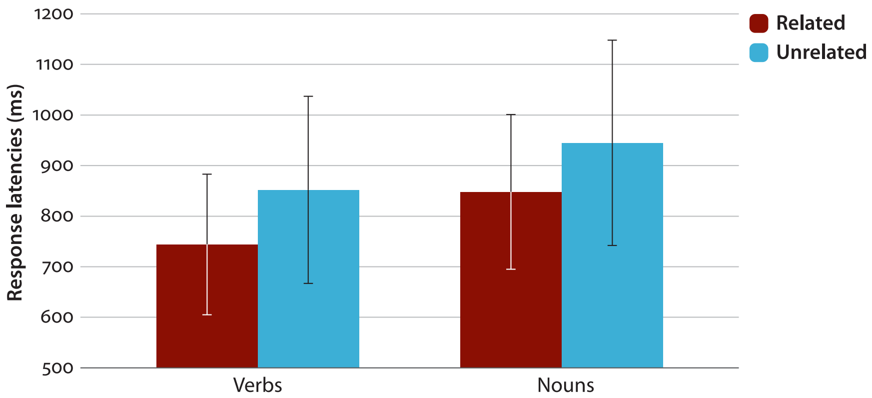
Errors and response latencies faster than 200 ms were excluded from the RTs analyses. Response latencies more than 2.5 SDs above or below each participant were also excluded from the analyses (in total, 2.49% of the data).

As with Experiment 1, both types of data were analyzed using Logistic Linear Mixed Models using R statistical software with the lme4 package (Bates & Maechler, 2009). More specifically, the ULLRToolbox was used (Hernández-Cabrera, 2011).

Analysis showed a main effect of relatedness, $F(1,29)=31.03$, $p<0.001$: words in the related condition were answered faster than words in the unrelated condition ($M=796.13$ ms, $SD=265.13$ ms vs. $M=898.58$ ms, $SD=345.65$ ms). The effect of grammatical class was also significant $F(1,37)=24.57$, $p<0.001$, verbs were answered faster than nouns ($M=796.21$ ms, $SD=287.19$ ms vs. $M=895.37$ ms,

$SD = 325.69$ ms). In this case, the interaction was not significant either, $F(1,11) > 0.28$.

Accuracy (error rate) was analyzed using a Logistic Lineal Mixed Model, which showed that less errors were observed for related words (1%) than for unrelated words (6%), X^2 (1) = 5.75, $p < 0.01$. Neither the effect of grammatical class or the interaction yielded significance, respectively X^2 (1) = 0.08, $p > 1$, and X^2 (1) = 0.06, $p > 1$. See Figure 2.



Note. Mean response latencies for a visual lexical decision task for nouns and verbs, with related vs. unrelated gesture primes (Experiment 2). Standard error bars are included.

Figure 2.

In general, the results were as expected and close to those in Experiment 1. We found that the IGs facilitated the recognition of a semantically related word (noun or verb), this time in the visual modality. Thus, words preceded by semantically related gestures were responded faster and more accurately than unrelated ones. On the other hand, the grammatical class did not show any difference in terms of facilitation, similarly to Experiment 1 and to the behavioral data found in a previous ERPs experiment (e.g., Bernardis et al., 2008). However, they found that verbs generated a greater effect with respect to the N400 than nouns and even showed that the increase in the N400 revealed by verbs was more emphasized in the left hemisphere than in the right hemisphere.

In both experiments we decided to compare only the two condition of relatedness without any baseline or control condition, mainly following Yap et al. (2011) and because the problems of choosing and using neutral baselines that have been previously argued and earlier discussed. However and in order to get a more comprehensive overview of the data, we decided to carried out a post hoc ANOVA by items, collapsing grammatical class (since the interaction between the two factor was not significant) and comparing the lexical decision times of our two relatedness conditions with the RTs to our word stimuli in the Spanish lexical decision database SPALEX (Aguasvivas et al., 2018), a megastudy from a massive online data collection with adults. The RTs in SPALEX to the words alone were entered as a kind of control condition to be compared with the mean for each item in our related and unrelated conditions, with the exception of four words that were not in the database and were excluded from the analysis. The One-Way ANOVA showed that the priming condition was significant, $F(2, 82) = 8{,}25$, $p < 0.001$. Post hoc comparisons showed that the control condition (RTs to the words alone in SPALEX: 861 ms) was significantly shorter than our unrelated condition (940 ms: an inhibition of 79 ms), t (84) = 4,21, $p < .05$. The difference between the control and the related condition was close to significance (808 ms, a tendency to facilitation of 53 ms), t (84) = 1,71, $p = 0.08$. The implications of this analysis will be discussed next.

General discussion

Our study intended to examine whether related or congruent IGs influence (i.e., facilitate) word recognition compared to unrelated or incongruent gestures, taking into account grammatical modality (verbs and nouns) and sensory modality (auditory and visual) of the words. For this purpose, we opted for an overlapped prime-target presentation, including also a control procedure to ensure that the participants were actually attending to the gesture and could not ignore it. The task was a classical lexical decision task to words (and pseudowords) auditorily (Experiment 1) and visually (Experiment 2) presented. The results from our two priming experiments have confirmed our predictions: When gesture and speech transmitted the same semantic information or are congruent, participants responded faster and with fewer errors, independently of grammatical class and sensory modality. In other words, IGs influence and facilitate auditory and visual word recognition. Faster RTs for verbs than for nouns were observed but as previously mentioned, this effect is hardly interpretable because it was not our objective to compare both per se and that is why psycholinguistic properties were not matched. The interaction we expected (but non-significant) showing a bigger influence of the IGs for verbs than for nouns would have been meaningful and more interesting theoretically.

Previous research has pointed out that the amount of benefit from the gesture over the comprehension of verbal language depends on the type of gesture. Most of the studies that have investigated the communicative capacity of gestures have used representative gestures (e.g., Krahmer & Swerts, 2007; Hubbard et al., 2009), and more specifically IGs, representing a spatial or motor reference through a specific action (McNeill, 1992).

In some of the studies exploring the possible influence of the IGs on word processing, participants were instructed the judge if the IG prime and the target (word) are congruent with each other (e.g., Wu & Coulson, 2005; 2007a), which made the participants highly aware of the congruency. However, other studies have opted for a lexical decision task (deciding whether a visually presented stimulus was a word or a pseudoword) coupled with priming gesture-word, as it was the choice for the present research. With this task, it is possible to check the influence (possible facilitation) of IGs in the automatic processes of lexical access and word recognition, since a conscious task of deciding if the target (word) was congruent with the prime (IG) was not required. In general, the experiments that have been carried out using lexical decision as the main task exploring the influence of IGs on lexical units have found priming effects (Yap et al., 2011; So et al., 2013; De Marco et al., 2015). However, in these works the target (i.e., word) was always presented visually but none of them presented the target auditory.

Lexical decision (LDT) is one of the most used tasks to investigate lexical access and those variables involved in word recognition. The task has been proven to be sensitive to effects that take place at different levels of processing, both lexical and sublexical. To perform the lexical decision task, some processes are mandatory: The analysis of the input (auditory or visual) at a very basic or perceptual level, the activation and/or competition among sublexical units (phonemes, letters, syllables, morphemes, etc.) and the activation and/or competition among lexical units or word nodes (Vitevitch, & Luce, 1998; Sidhu et al., 2020). The processes that link orthography and phonology both at lexical and sublexical levels with semantics continue to be discussed. But importantly, semantic priming effects in lexical decision tasks has been widely reported, even with very short SOAs, although some controversy about the automaticity of the semantic priming effects remains (see, for instance, Perea & Rosa, 2002). What seems clear is that making lexical decision can be mainly based on the processing of linguistic forms without a deep conceptual processing that would take place probably later (So et al., 2013). That is why So and collaborators have argued that the facilitating semantic effects of gestures could be weakened in LDT. In our two experiments, IGs were presented for a very short duration and virtually overlapped with the words, as it will be discussed next. This fact suggests that a non-linguistic but semantically-related stimulus can activate a related word nodes relatively early and this activation can be observed in the LDT, as suggested by De Marco et al. (2015). Thus, our observed priming effects of gestures in this task argue for an unavoidable and fast influence of the IGs over the word, even when the task can be done without an important role of semantics.

In previous experiments using lexical decision, the IGs were always presented with some asynchrony (SOA) with the target words: first the gesture and then the words, usually with some blank screen in the middle: more than 3000 ms in Bernardis et al. (2008) and Yap et al. (2011, Experiment 1), 1200 in Yap et al. (2011, Experiment 2) and in So et al. (2013), etc. However, this is somewhat artificial since in normal life IGs are usually produced together with linguistic utterances, as previously mentioned. According to McNeill (1992, 2005) a gesture is comprised of three stages: preparation, stroke and retraction. For example, when the gesture for "push" is produced, the person lifts both arms to chest height (preparation phase), then moves both hands forward (stroke phase) and finally relaxes both hands until they return to their initial position (retraction phase). These phases are time-consuming, and obviously there are limitations in order to reduce the duration of an IG without losing its meaning. In addition, and even using very short SOAs but without any overlapping, some preparation effects can be playing some role, for example, participants may try to come up with a lexical label for the prime gesture, as stated by Yap et al. (2011) in their comments to Bernardis et al. (2008). With this in mind, So et al. (2013) added some synchronization in their study: in one of the priming conditions of their study, the gesture was presented at the same time as speech, and then, the target word. They wanted to examine whether IGs accompanying speech could generate semantically related words and compare it with gestures only and speech alone (see details in the Introduction). However, the SOA between prime and target was 1200 ms. On the other hand, some researchers have concluded that gestures can only be processed correctly when accompanied by verbal language (Krauss et al., 1991; Krauss et al., 2000).

In this regard we have provided two innovations: First, the duration of the IGs clips was kept as short as possible, less than 1000 ms, preserving the stroke phase, and second, the word was presented at the same time, virtually an overlap, while the IGs was being displayed and being processed. We consider that this greater synchrony assures us, to some extent, that the participant did not have too much time to label the gesture with a predetermined word in their memory or to recode the gesture primes to lexical primes. When the word was received, the gesture could not be fully processed. Our results confirm that, even when prime and target were presented at the same time, IGs facilitated word recognition.

This so-called facilitation effect, however, could be questioned. Due to the problems mentioned above, we decided not to use a baseline, control condition or neutral prime, only comparing congruent and incongruent gestures and following other authors (e.g., Yap et al., 2011). Thus, the facilitation we are referring to may not be taking place and perhaps the congruent gesture is not helping to recognize the word. Instead, it could be argue that incongruent IG is hindered lexical decision. In addition, it would be possible that IGs facilitate lexical decision through attention-related mechanisms rather than by a cross-modality priming effect. However, the exploratory analysis carried out in Experiment 2 suggested otherwise. RTs to words in our congruent and incongruent priming conditions were compared to RTs in LDT to the words alone in the SPALEX database, a sort of control condition. An inhibition of the incongruent primes and a tendency ($p = 0.08$) to facilitate of the congruent primes (both compared to the control condition) were found. Since the processing demands of recognizing a word alone and preceded by a gesture are different and probably bigger in the second case, the observed tendency to facilitate of the congruent gestures suggest that IGs are actually priming word recognition.

It could be conceivable that gestures could influence word processing to a greater or to a different extent when words have to be read instead of be heard. A written or spoken word can convey the same meaning, but that does not mean that its processing needs to be the same. After all, IGs are an effective tool that can improve communication, probably developed in close association with oral language through human history. However, reading is a cultural artifact that does not need the emitter to be presented, precisely one of the greatest advantages of literacy. But with the developing of new technologies (i.e., videos in the computer), it is also true that in order to understand them, subtitles and visual language are needed in many conditions. As mentioned, this is the case for deaf people or watching a movie in a foreign language. Anyhow, comparing directly the possible different effects of IGs on both reading and hearing words is a question that deserved being explored in our opinion.

No study using lexical decision tasks has compared different sensory modality using the same words and closely the same procedure to investigate the possible influence of IGs so far. From our two experiments, it is possible to conclude that the participants responded faster and with fewer errors in the related condition, independently if the word was presented in an auditory (Experiment 1) or visual (Experiment 2) forms. Our results suggest that there is an integration between gesture and language, whatever the sensory channel for lexical processing and point out that the semantic priming is similar in both modalities, even when gestures were developed in close connection with spoken language. Accompanying spoken words with gestures or other non-linguistic audiovisual material is a frequent and generalized pedagogical strategy in education. In this sense, our results could modestly suggest that analogous procedures would also be beneficial in the instruction of written material.

It is worth reiterating that gestures improve communication when they include spatial or motor information rather than when they do not (Krauss, 1998; Beattie & Shovelton, 2002; Alibali, 2005). The majority of research has used action verbs, as they represent actions. However, few studies have used spatial and action information (verbs) and non-action information (nouns) to analyze the benefit of gestures over language. To our knowledge, the experiments by Bernardis et al. (2008) are the only ones where the grammatical class (verbs-nouns) was manipulated as a factor, concluding that there was no difference from a behavioral point of view (Experiment 1), but finding a difference in the ERPs (Experiment 2), verbs generating a greater negative amplitude (N400) than nouns in the unrelated condition compared to the related condition. However, nouns also generated a N400, although less ample than verbs. Our results are consistent only with those behavioral data from Bernardis et al., suggesting that there is no difference between verbs and nouns in the amount of facilitation of the related IGs, contrary to our expectations. Even when the dynamic, temporal and spatial information included in the gestures are also properties of the action verbs and much clearer than in nouns, IGs facilitated similarly the recognition of both type of words. Nevertheless, it could be the case that the iconicity and the conceptual, semantic (spatial and temporal features) or even motor information transmitted by the gestures were comparable for both our verbs and nouns. In fact, in our normative study, we selected only those IGs that clearly represented concrete nouns that would act later as targets. If this were the case, it would be conceivable that the influence of IGs could be weaker in more abstract nouns, an issue that could be studied in a near future.

None of the previous studies made sure that the participants were actually looking at and processing gestures in an explicit controlled way, specifically when the responses in the tasks were directed to words. It seems clear that this is not a problem for those studies that clearly found priming effects of IGs over words in within-subject design. However, this fact could explain some results such as those of So et al. (2013), as the authors themselves acknowledged. In some way, the Speech-Only condition was comparable to the Gestures-Accompanying-Speech condition. It is likely that the attention of the participants was directed to the auditory information, ignoring the gestures. In our study we decided to include, in approximately 25% of the trials, an explicit question about the relatedness between IGs and words, to which the participants had to answer "yes" or "no" using two answer keys. The high proportion of correct responses ensured us that the participants did not miss the videos even when their task was about words or pseudowords. It could be argued that this procedure is somewhat artificial and could increase the influence of the gesture on the word, overestimating the priming effect. However, the objective was that the participants could not ignore the gesture, something similar to what happens in normal life, where we automatically associate gestures and speech. In addition, the gestures acted as primes and no response to them was requested.

In summary, it seems evident that gestures, mainly iconic ones, share with language the property of having meaning, and this meaning is activated and can facilitate word recognition. Our cross-modal priming effects are in line with this idea, also suggesting that semantics activated by gestures interacts and influence a task (LDT) where the objective is just processing words and deciding about them and that can be driven mainly by linguistic forms, without a strong access to semantics.

The sum of our results, including the priming effect being independent of the sensory modality of the presented word (visual or auditory) highly synchronized with the gesture, cannot claim anything about the origin of the link between IGs and words. However, our outcomes appear to generally support those theoretical proposals that emphasize a close interaction and integration of gestures and linguistic information, like the Integrated Systems Hypothesis (Kelly et al., 2010) or the Interface Hypothesis (Slobin, 1987, 1996; Kita & Özyürek, 2003). Even when both are theories that come from the speech production, they are also relevant to the processes involved in language comprehension (e.g., Kelly et al., 2010). When building a mental representation is needed in the process of communication, human seems to be opportunistic and cannot prevents to link nonverbal information like gestures and language in an interconnected product.

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Appendix 1

List of words used in the two experiments.

Verbs	**Nouns**
Abrir (open)	Anillo (ring)
Afeitar (shave)	Baloncesto (basketball)
Agarrar (catch)	Cascos (headphone)
Aplaudir (clap)	Círculo (circle)
Barrer (sweep)	Corazón (heart)

Beber (drink)	Corbata (tie)
Caminar (walk)	Cremallera (zipper)
Comer (eat)	Cuadrado (square)
Conducir (drive)	Espiral (spiral)
Cortar (cut)	Flauta (flute)
Disparar (shoot)	Gallina (chicken)
Dormir (sleep)	Golf (golf)
Empujar (push)	Gorila (gorilla)
Escribir (write)	Guitarra (guitar)
Escuchar (listen)	Línea (line)
Fumar (smoke)	Moto (motorbike)
Leer (read)	Ola (wave)
Levantar (lifts)	Pintalabios (libstick)
Llamar (call)	Prismáticos (binoculars)
Mirar (look)	Rectángulo (rectangle)
Nadar (swin)	Rombo (rhombus)
Pensar (think)	Triángulo (triangle)
Sonarse (blow)	Violín (violin)
Volar (fly)	Voleibol (volleyball)

List of pseudowords used in the two experiments

Acorcar	Lorar
Arña	Marcollar
Aterquillar	Monjoña
Atiñar	Mul
Baen	Nunzar
Becobol	Ogrinoar
Berrer	Oqui
Bitir	Plito
Carrar	Poanar
Chanar	Pontar
Circular	Poño
Coper	Poscar
Cronelito	Poteño
Croz	Repuver
Cusa	Saltocar
Elaponte	Selarar
Enlujer	Semechar
Ento	Tamodrar
Escumuta	Tepluar
Estrocho	Tifar

Fonograniar	Titoron
Golmiar	Volir
Halor	Volmuar
Jufas	Vular

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