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EDITED BY
George Cremona,
University of Malta, Malta

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Nara University of Education, Japan
John A. Bateman,
University of Bremen, Germany

*CORRESPONDENCE
Renia Lopez-Ozieblo
✉ renia.lopez@polyu.edu.hk

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Effects of pedagogical gestures on learning abstract grammatical concepts in young adults

Renia Lopez-Ozieblo*

Department of English and Communication, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR, China

This study evaluates the benefits of gesture-enriched grammatical explanations to native speakers following an embodied cognitive approach. Spanish mother tongue speakers were taught the functions of a complex Spanish linguistic unit, “se.” For half the participants the explanations were enhanced with gestures and the other half received the same explanations without gestures. Their knowledge of the functions was tested before the treatment and then immediately after and a month after the treatment. Our results indicate that both groups benefitted from the explanations equally. However, in the long-term, participants in the gestures group consolidated their knowledge while those in the non-gestures group showed a steeper learning decay that those in the gestures group. This suggests that gestures might have a positive effect in learning which is only observable in the long-term after the knowledge has been consolidated.

KEYWORDS

pedagogical gestures, enhanced learning, young-adult learners, abstract concepts, linguistics

1 Introduction

In cognitive linguistics, embodied approaches view knowledge as the result of the integration of brain, body, and environment, thus motoric experiences, including gestures, are thought to be one of the keys to learning (Pulvermüller, 1999, 2003; Kuhl et al., 2003; Farina, 2021). Individuals learn from experiences processed through the senses and the motor system that help to understand new events. This mind–body connection is not new.

A number of studies suggest that when learners perform or pantomime actions or related gestures learning (recall, recognition, word accessibility, or comprehension) is improved (see Macedonia et al., 2011 for a review). However, learning is not only the result of our actions and direct physical experiences (Alibali and Nathan, 2018) but can also take place when observing the actions of others (Singer and Goldin-Meadow, 2005; Ping and Goldin-Meadow, 2008). It is believed that mirror neurons in observers might become activated when observing others performing an action (Rizzolatti and Craighero, 2004). Thus, even discrete actions performed by a teacher in the classroom, such as gestures, could have a positive effect on student learning, both in the conceptualization of new ideas and in memorizing content.

Overall, studies on pedagogical gestures indicate that there is a benefit to learners (Goldin-Meadow et al., 2001; Valenzeno et al., 2003; Sime, 2006; Kelly et al., 2010; Cook et al., 2013; Rueckert et al., 2017; Yeo et al., 2018). However, the most conclusive studies are those focusing on children (Goldin-Meadow et al., 2001; Ping and Goldin-Meadow, 2008; Cook et al., 2013; Yeo et al., 2018), while studies with adolescents/young adults report lesser or no effects (metastudy by Dargue et al., 2019), noting factors such as novelty and nature of the content—abstract vs. concrete—as potential variables (Macedonia and Knösche, 2011; Kaicher et al., 2022).

The field lacks conclusive evidence on the benefits of gestures to young adults in the classroom, as most studies with young adults are performed under lab conditions (Macedonia et al., 2019; Rohrer et al., 2020; Charles, 2021; Brown and Kamiya, 2022). This study contributes to the discussion by adding our results from an action-research study integrated within a naturalistic setting. Our study followed an experimental approach where two homogeneous groups of young adults were presented with abstract grammatical explanations, with and without gestures respectively, and their learning was tested at the end of the lesson and a month after.

1.1 Gestures in teaching

The field of gestures potentially includes all body movements involved in the communicative act: head, body, gaze, and hands. For the purposes of this study, we will only focus on arm and hand movements as speakers of all cultures move their hands when they speak (Goldin-Meadow, 2014). In addition, there is strong evidence that hand gestures co-occurring with speech form a single system with speech and thought (McNeill, 2005), thus they are considered an important element of any oral interaction. However, the study of pedagogical gestures, those performed by teachers with a pedagogical objective, is still under-researched (Wakefield and Goldin-Meadow, 2021; Tellier and Yerian, 2022).

Pedagogical naturalistic studies, based on classroom observations, point to the positive effects of gestures in creating cohesive interactions between students and teacher/students which can have the additional effect of lowering affective barriers (Sime, 2006; Zhang and Oetzel, 2006). Neurological evidence indicates that gestures (and other sensorimotor experiences) enhance the learning process (Pulvermüller, 2003; Engelkamp et al., 2004). Event-related potential (ERP) studies with mother tongue speakers confirm that the semantic meaning of gestures is integrated with co-occurring speech (Kelly et al., 2010; Chui et al., 2018), strengthening neurological information paths. Learning is improved if input is processed by more than one sensory-motor system, creating multiple neuronal activations (Matheson and Barsalou, 2018; Macedonia, 2019). Functional magnetic resonance imaging (fMRI) results indicate an association between movement and speech, as activation occurs in overlapping brain areas when reading an action word and moving parts of the body related to that action (Pulvermüller, 2003). Nevertheless, fMRI results have also produced conflicting evidence, with studies reporting both positive and no effects of gestures in language processing areas (for a review, Jouravlev et al., 2019).

Empirical studies correlating gestures with recall and transfer note that gestures have a positive medium-effect on learning in a range of subjects (Hostetter, 2011; Dargue et al., 2019). These results confirm teachers' overall perceptions that gestures aid learning (Nathan et al., 2019). Teachers' gestures have been found to help conceptualize new ideas in a range of topics including maths (Cook et al., 2012; Goldin-Meadow, 2014), chemistry (Ping et al., 2022), or geography (Beege et al., 2020), and to benefit vocabulary learning of both abstract and concrete nouns—although with a larger effect on concrete nouns (Macedonia and Knösche, 2011), and also in the processing and subsequent recall of narrations (Cutica and Bucciarelli, 2015; Dargue and Sweller, 2020); and scientific texts (Cutica and Bucciarelli, 2013; Cutica et al., 2014). These results suggest that gestures could also benefit the processing of abstract linguistic concepts.

Cutica et al. (2014) suggest four interlinked explanations as to why gesture helps processing information: (1) gesture helps to ground the thought in an action. If the gesture is incongruent with the action described in the speech this interferes with the learning process (Goldin-Meadow and Beilock, 2010); (2) gestures bring additional information into the mental representation that is being created (Cutica and Bucciarelli, 2015); (3) gesture helps to lighten the load on working memory (Goldin-Meadow et al., 2001); and (4) gesture creates a spatial mental representation in working memory thus helping spatial thinking (Morsella and Krauss, 2004).

Studies on the benefits of gestures in language learning do not cover linguistic topics. They tend to focus on either children acquiring other concepts in their mother tongue/s (Valenzeno et al., 2003; Singer and Goldin-Meadow, 2005; Ping and Goldin-Meadow, 2008; Alibali et al., 2013; Cook et al., 2013) or on older individuals, adults, learning foreign languages (Huang et al., 2019; Macedonia et al., 2019; Rohrer et al., 2020; Charles, 2021; Brown and Kamiya, 2022; Kaicher et al., 2022; Lewis and Kirkhart, 2022). In neither case is the conceptualisation of linguistic abstract grammatical concepts the usual topic under study. When teaching children, grammatical explanations are often avoided when they are learning their mother tongue, as it is not until the onset of puberty that individuals develop their capacity to think in abstract terms (Fischer, 2003). From the age of 18 (young adulthood) to 22–25, these thoughts become more complex, and individuals are able to hold clusters of abstract thoughts (Simpson, 2008). Thus, the cognitive skills of children are not mature enough to process complex abstract explanations (Simpson, 2001) and by the time they are cognitively ready for them they have already acquired the concept and its language-based representation.

Compared to other subjects, such as maths or physics, there are not many studies into how older speakers develop a linguistic understanding of languages as opposed to how they acquire a language. However, in contexts with older learners of foreign languages, abstract linguistic concepts could be introduced—allowing educators and researchers to observe how conceptualization takes place. Currently this is also not very feasible, as many language curricula have moved away from explicit grammar teaching (Celce-Murcia, 2001) resulting in fluent speakers who are unaware of the rules or reasons behind specific functions of language items in the L2. In foreign language acquisition gesture studies tend to focus on specific language items (such as vocabulary or pronunciation). Anecdotal data and case studies from classrooms, with participants from various L1, e.g., Korean, Ukrainian, Japanese, Spanish, and English, learning various FL, e.g., English, Persian, Spanish, and German (Lazaraton, 2004; Belhiah, 2013; Matsumoto and Dobs, 2017; Smotrova, 2017), indicate that teachers' gestures are noticed by students, irrespective of cultural background, and integrated with the teachers' speech to create meaning. Students copy and repeat the gestures, unpack meaning and display alignment, indicating understanding of foreign language concepts (Belhiah, 2013). We expect the same to be true with speakers learning new linguistic concepts in their mother tongue.

Lab-based empirical studies with FL learners are increasingly finding mixed benefits to gesture enriched learning. In adult foreign language learning, there is evidence that iconic gestures facilitate word learning (Kelly et al., 2010, 2014; Huang et al., 2019; Macedonia et al., 2019), in particular concrete nouns (Macedonia and Knösche, 2011). However, contradictory results have also been reported by Nicoladis et al. (2022) who noted negative effects of gestures on noun learning, with no effects on verb learning, suggesting gestures might be interpreted incorrectly by interlocutors, who confuse gestures representing actions with those representing salient parts of the object (this could be a proficiency issue). Furthermore, a study by Macedonia et al. (2019) found no long-term benefits of gestures in learning words in Vimmi, a made-up language, although fMRI results indicated a possible stronger link between sensorimotor encoding and memory vs. audio-visual encoding. Two recent empirical studies addressing more complex and abstract concepts did not find positive gesture effects: Rohrer et al. (2020), studying beats to enhance story comprehension, and Nakatsukasa's (2021) testing the effect of feedback pointing gestures to represent the past; perhaps because these gestures were not aligned with the abstract content they represent. Overall, classroom observations suggest a more positive role for gestures in learning than the results obtained from lab-based experimental studies.

Studies with young adults and adults learning languages often note inconclusive results, showing mixed effects depending on variables such as type of gesture, congruency with content or novelty of the topic (Huang et al., 2019; Rohrer et al., 2020; Charles, 2021; Brown and Kamiya, 2022; Kaicher et al., 2022; Lewis and Kirkhart, 2022). Some of these are related to individual cognitive differences which have also been noted to be key factors in how gestures are processed, such as working, visual and spatial memory (for a review see Özer and Göksun, 2020). No effects were noted in other non-pedagogical gestures studies with young adults that tested their processing or recall of information delivered with and without gestures (Ouwehand et al., 2015; Sekine and Kita, 2017; Austin et al., 2018). Not all of the above studies specify the age-range of the participants, but as they are conducted in university settings, they are likely to have recruited participants below 25 years old. These results contrast with those obtained with children where the positive effects of gestures in learning are usually reported (Dargue et al., 2019).

2 The study

There is a gap in the literature relating to the benefit of representational gestures when teaching abstract but not completely novel concepts to young adults. Our study taught Spanish speakers an abstract linguistic explanation about the functions of one of the most frequent lexical units in Spanish, the marker "se" (Davies, 2002). When learners have some knowledge of the topic, gestures have been found not to be as beneficial (Beilock and Goldin-Meadow, 2010), therefore we sought a topic that would be novel to learners and to identify whether representational gestures illustrating congruently that topic (matching the speech), in this case the functions of "se," would enhance the learning of abstract ideas by young adults. We expected to see enhanced learning in the gestures group vs. the no-gestures group in both the short- and the long-term.

Mother tongue speakers are expert users of their language, however, they might not be familiar with the functions of specific linguistic units (such as modal verbs in English, Tyler, 2012; or the Spanish linguistic unit "se," Lopez-Ozieblo, 2020) and most of these speakers, unless linguistically trained, are not able to articulate the reasons why one linguistic unit is chosen over another and their specific functions. These tend to be highly abstract concepts, although usually grounded in concrete ones. Spanish L1 speakers are likely to have an implicit understanding of the marker "se," how to use it as well as some of the meanings it adds to the utterance. However, most speakers do not have a full understanding of the nuances of the functions of "se." Thus, "se" is an optimal topic for a study such as this, exploring the benefits of pedagogical gestures to mother tongue young adults.

2.1 Topic to be taught

"Se" is a lexical unit with more than 12 possible functions, most highly abstract (Montes Giraldo, 2003), which is seldom explicitly taught. Many non-linguist Spanish L1 speakers refer to "se" as a reflexive pronoun indicating that the subject is doing the action to itself when not in an impersonal sentence (see Lopez-Ozieblo, 2020 for a detailed explanation of the various functions).

Four different "se" functions were selected for this study, with explanations following Maldonado's (2019) cognitive linguistics framework. These are: reciprocal and middle voices for self-benefit consumption, mental changes, changes in location, and changes of posture. These cases provide a range of grammatical functions, which can be easily illustrated with widely recognized representational gestures (e.g., bringing an object toward oneself and indicating its totality; turning the wrist to indicate a change and pointing to the head and the heart; moving an arm from the vertical to a horizontal axis; indicating the beginning and end of a trajectory as well as tracing a path between two points, see Figure 1 and refer to the Appendix for a full explanation). These have been selected based on observations of gestures used by native speakers when using "se" (Lopez-Ozieblo et al., 2022) and previously tested with other Spanish speakers not involved in this study.

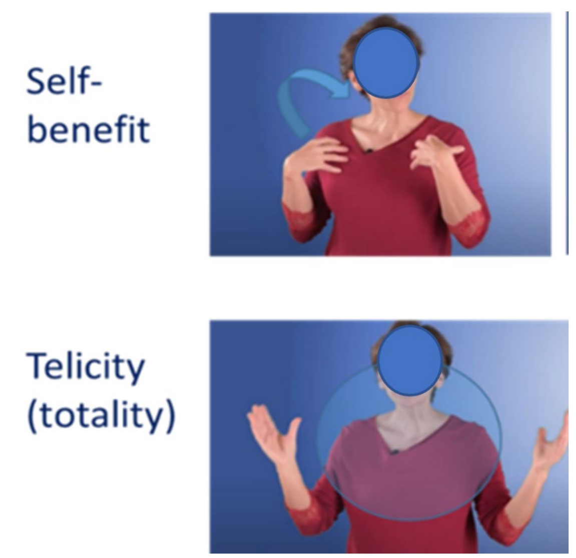

FIGURE 1
Examples of gestures.

2.2 Procedure

The treatment task took place during a linguistics lecture on embodied cognitive linguistics. Students at the lecture and the lecturer (the researcher, not their usual teacher) were all L1 speakers of Spanish. Students were not familiar with the concept of embodied cognition. The lecture introduced the historical development of linguistic studies and the relationship between one's body and how the world is experienced differently by people with different bodies before introducing the task. The task was introduced as an example of an explanation of how a grammar point could be presented from an embodied cognitive linguistics perspective. Students were not aware the explanations were part of the experiment until later.

Students were asked to stand up and move to an empty space within the room and form a semicircle to be able to hear and see the lecturer well. They were not allowed to take notes. They were told to pay attention to the explanation as well as to the pedagogical steps taken to deliver it as both issues were to be discussed later. Before the grammar explanation students filled in a pretest (on paper), to evaluate their existing knowledge. The grammar explanations focused on the four different functions of the Spanish marker "se" mentioned above. Explanations were delivered without gestures, for Group 1, and with gestures for Group 2, and took about 5 min. Each explanation was repeated twice. After the grammar explanations the steps were discussed with the students to identify the embodied cognitive elements employed (as a distractor). The lecture then introduced the use of gestures in the classroom, pointing out their potential benefits when delivering explanations. At this point, students were told about the research and were invited to participate by repeating the test to see how much they had learnt about "se" at the end of the lesson and again after a month. They were told their results would be compared with those of the other group. At the end of the lecture, more or less an hour after the explanations, students were asked to complete the test again (posttest). Students' consent to use the data for research purposes was collected at this point when they were fully aware of the objectives of the research.

The second group was taught the same lesson immediately after Group 1 (Group 1 students had been asked not to disclose information about the task). They were given the same grammar explanations, also repeated twice, but with gestures. The explanations with and without gestures had been rehearsed previously and were the same as those used in a previous study of "se" (Lopez-Ozieblo et al., 2022). The lecturer (the researcher) controlled intonation, speed of delivery, and facial gestures.

A month later, a colleague of the researcher asked the two groups of students to complete a delayed posttest. The questions in the three tests were the same, although the pretest contained additional questions to introduce the students to the topic and check that their use of "se" was correct, and a sample question/answer that was explained before the pretest.

2.3 Participants

The students attending the lectures were year 1 primary-school teacher training university students in a public higher education institution in Spain. Group 1 had 24 students and Group 2, 25. However, some students decided not to participate in the research or did not complete the delayed posttest, which left Group 1 with 20 participants and Group 2 with 17. The participants in the two groups had an average age of 18.6 (Group 1) and 18.5 (Group 2). All participants were Spanish mother tongue speakers from Spain (from the same region). Group 1 had 35% male participants and Group 2, 30%. Their answers to the pretest confirmed their correct use of "se."

A power analysis calculation to estimate the sample size needed for this study, using an effect size *f* of 0.25, alpha error probability 0.05 and power of 0.8 indicated that a sample of 64 at a critical power *F* of 3.17. As this was an in-class study, based on an existing cohort of students, the higher error was chosen as a compromise to give us an indication of the optimum sample size. Significant results would still suggest the effects to be robust. However, as mentioned above, the final number of participants was below 64, weakening our results.

2.4 Analysis

The answers to the four questions were transcribed and evaluated following a simple rubric that compared participants' responses with the original information provided during the explanations. Key ideas, either paraphrased or given with the same words as the original explanation were given one point. Three of the functions were given a total of three possible points and the fourth one 2. If an answer provided explanations referring to two different functions a point was deducted (seven instances in the no-gestures group, and just one in the gestures group). The researcher repeated the evaluation within a month to confirm the first results (no changes were required). The first evaluation was carried out without the researcher knowing which data belonged to which group.

For each question, the scores were normalized as a percentage and then added up (maximum score 400, 100 per question). A Shapiro–Wilk test indicated the distributions were normal and a Levene's test confirmed the equality of the variances for the results of the post immediate and post delayed tests for the gestures and no-gestures groups. The scores of the pretest were all zero except for one case and thus were not normally distributed. Although the distributions of the pretest results (for both the gestures and no-gestures group) were not normally distributed, as the values of the pretest were mostly zero, we proceeded to test the differences between the various sets of results via a Repeated Measures ANOVA with the treatment (gestures/no-gestures) as the between-subjects factor. A Repeated Measures ANOVA was considered the best choice for comparing the results of the two independent groups as each group had been tested multiple times. It also yields more accurate results than t-tests because it considers both within-group and between-group variation. *Post hoc* comparison tests were carried out to compare these and confidence intervals were corrected using the Bonferroni method. Cohen's *d* effects were calculated using pooled standard deviations, a small effect was noted when $d = 0.2$, $d = 0.5$ was recorded as a medium one and $d = 0.8$ as a large effect (Cohen, 1992). Eta-squared (η^2) was used to indicate the effect size when reporting for the Repeated Measures ANOVAs, $\eta^2 = 0.01$ indicates a small effect, $\eta^2 = 0.06$ a medium effect and $\eta^2 = 0.14$ a large effect.

3 Results

Both treatment groups performed equally poorly in the pretests, indicating no knowledge of the various functions of "se" that were the topic of the treatment and confirming the content taught was novel to them. It was expected that participants, all university students, would be able to articulate their implicit knowledge of the various functions of "se," if they had an understanding of those. In the majority of instances, this was not the case and participants described most functions as "reflexive." After the explanations, participants in both treatment groups improved their knowledge of "se" functions equally. After a month, participants in both groups forgot some of this knowledge but less so in the gestures group than in the non-gestures one, see Figure 2. The descriptive data for the results of the pre- and posttests are provided in Table 1.

A Repeated Measures ANOVA with least significant differences pairwise comparison identified significant differences in test scores within the three tests (as expected, as the results of the pretest were mostly zero and most participants were able to provide quite detailed explanations during the immediate posttest). The assumption of sphericity was violated, as Mauchly's test indicated that $\chi^2(2) = 6.021$, $p = 0.049$. Greenhouse–Geisser $\varepsilon = 0.86$ estimated this was a modest violation. Therefore, we report the Huyn-Feldt corrections: $F(1.801, 63.046) = 144.911$, $p < 0.001$, $\eta^2 = 0.692$, a large effect. A significant difference was found in the interaction between the time of the test (pre, immediate and delayed posttests) and the group $F(1.801, 63.046) = 4.43$, $p = 0.019$, $\eta^2 = 0.021$, although the effect was small. The residual *Sum of squares* = 239,893.29 and $Mean^2 = 3{,}805.02$, representing the variance not accounted by the model, was noted to be high. No significant difference was identified in test scores within the two groups $F(1, 35) = 0.367$, $p = 0.549$, $\eta^2 = 0.001$. *Post hoc* tests, with Bonferroni corrections, comparing the scores of each of the tests by group found no differences in neither the two pretests, the two immediate posttests nor the two delayed posttests ($p > 0.05$).

A series of *post hoc* comparison tests was carried out to confirm significant differences between the scores of the pretest and the immediate posttest $t(36) = -16.588$, $p < 0.001$, $CI = [-260.019, -193.028]$ $d = 4.87$, an expected large effect (d is reported as an absolute number), the pretest and the delayed posttest $t(36) = -11.608$, $p < 0.001$, $CI = [-192.013, -125.023]$ $d = 0.92$, also a large effect; and between the immediate posttest and the delayed posttest $t(36) = 4.98$, $p < 0.001$, $CI = [34.511, 101.501]$ $d = 0.92$, also a large effect.

A further *post hoc* comparison of the scores obtained in each test pair (pre and immediate posttest/immediate and delayed posttests) within each group identified significant differences in the results of the no-gestures group between the pretest and the immediate posttest $t(16) = -12.878$, $p < 0.001$, $CI = [-294.664, -182.136]$, $d = 6.48$ and between the immediate posttest and the delayed posttest $t(16) = 5.812$, $p < 0.001$, $CI = [51.336, 163.864]$, $d = 1.53$, in both cases, the effects were large. In the gestures group, there was also a significant difference between the scores of the pretest and the immediate posttest $t(19) = -10.69$, $p < 0.001$, $CI = [-275.674, -153.62]$, $d = 3.82$, a large effect. However, the score difference between the immediate posttest and the delayed posttest in the gesture group was not significant and the effect was small ($p = 1$, $d = 0.34$).

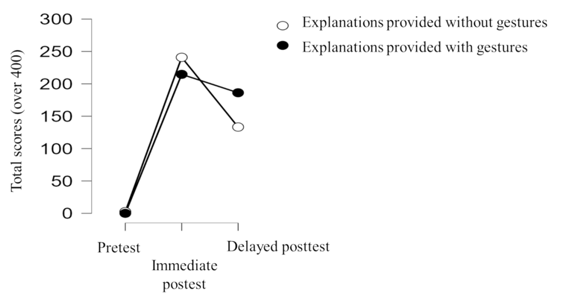

FIGURE 2
Pre and posttests results.

4 Discussion

Our results suggest that gestures did not have an effect on short-term learning, however they seem to have had a positive long-term effect in learning for this group of young adults. Although no significant differences were found in the test results between the gestures and no-gestures group when comparing the results of the three tests (the pretest, the immediate posttest and the delayed posttest), it would seem that memory decay was slower in the gestures group. To confirm these results, the data was manipulated to find the increase or decrease in knowledge between each pair of tests. For this we calculated the difference in scores for each individual between the pretest and the immediate posttest and between the immediate and delayed posttests (i.e., Difference = score of pretest − score of immediate posttest, note that an increase in knowledge between tests results in a negative number). A violin dataplot was created to visualize differences between the results of the pre and post immediate tests (Figure 3A), also showing the confidence intervals of the mean (Figure 3B) and between the post immediate and post delayed tests (Figures 4A,B).

The difference in scores between the pretest and the immediate posttest are quite similar for the gestures and the no-gestures groups, aside from one extreme outlier in the gestures group (we chose not to delete this datapoint as we had insufficient grounds to believe these results were not reliable, although we suspect they might not be as the answers to the immediate posttest scored mostly zero). These results confirm that overall, immediate learning was quite similar in both groups.

However, the difference in the scores between the immediate and delayed posttests is quite striking, shown in Figures 4A,B (the relevant data from the outlier identified in Figure 3A does not impact the overall dataplot pattern). Figure 4B shows how there is very little overlap between the Confidence Intervals of the two means, suggesting the effect is large. Figure 4A helps illustrate the difference further as it

TABLE 1 Descriptive statistics: mean (M) and standard deviation (SD).

	Pretest M (SD)	Immediate posttest M (SD)	Delayed posttest M (SD)
Gestures group ($n = 17$)	0 (0)	214.647 (79.464)	186.235 (86.764)
No-gestures group ($n = 20$)	2.5 (0.236)	240.9 (52.058)	133.3 (84.452)

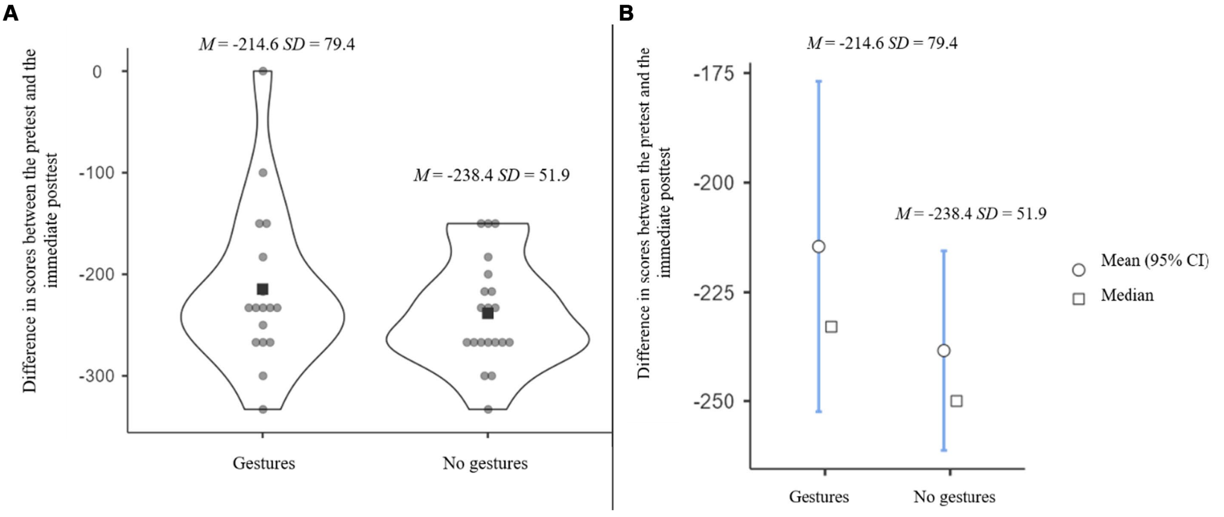

FIGURE 3
(A) Difference between pre and post immediate test results. **(B)** Mean 95% confidence intervals.

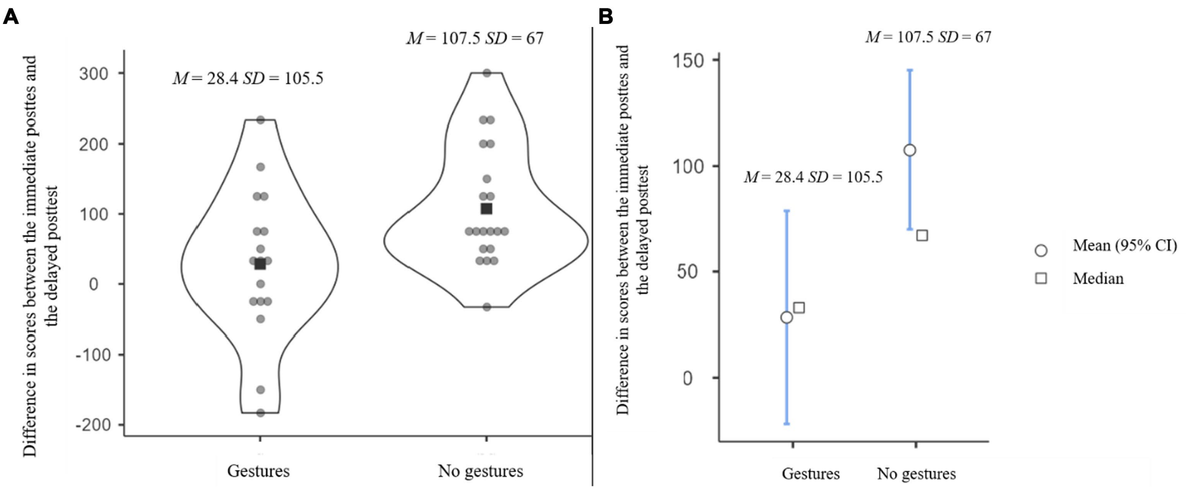

FIGURE 4
(A) Difference between post immediate and post delayed test results. **(B)** Mean 95% confidence intervals.

shows how only one participant from the no-gestures group consolidated their knowledge (obtaining a higher score in the delayed posttest, shown in the graph as a negative value) while six individuals improved their scores in the delayed posttest. The graph shows that there was knowledge consolidation by six participants (35% of n_{gestures}) in the gestures group, compared to only one participant (0.05% of $n_{\text{no-gestures}}$), these results are quite striking, we consider this simple effect to be strong, confirming the standardized effects reported in the results. However, these results should be treated with caution as our study had a small sample size and underpowered studies have been noted to have inflated effect sizes.

After visualizing the data, we proceeded to test the differences between the scores of the pretest and immediate posttest and immediate and delayed posttest with two independent-pairs Student's *t*-tests (this had not been included in the original methodology). The tests confirmed that the differences in score between the pre and immediate posttest in the gestures and no-gestures groups were similar ($p > 0.05$, $d = 0.36$) and that there was a significant difference in the difference between the scores of the immediate and delayed posttests: $t(35) = -2.52$, $p = 0.017$, $CI = [-143, -15.3]$ $d = 0.83$, a strong effect. The content taught and tested was limited, but the results suggest that even for small amounts of information delivered during a short window, gestures do benefit some learners in the long-term, once the information has been consolidated.

Results from previous studies with participants who have to process content with and without gestures suggest that the relationship content-gesture might be an important factor. Previous studies have found that participants perform better when recalling concrete, rather than abstract, concepts (Macedonia and Knösche, 2011). Gestures tend to be metonymical or metaphorical representations of concepts which are grounded in concrete concepts but can vary from culture to culture. Using gestures to explain novel abstract concepts runs the risk of the learner finding the gestures incongruent with the speech perhaps because they do not have a common cultural understanding, or it is too complex. Running this study with Spanish native speakers eliminated potential cultural misunderstandings. The gestures used had been observed in Spanish speakers (collected from previous studies) and tested with other Spanish speakers.

Gestures have also been noted not to be beneficial unless they provide additional information to that in the speech (Ouwehand et al., 2015; Sekine and Kita, 2017; Austin et al., 2018). However, studies with second language learners have found that congruent (matching) iconicity enhances vocabulary learning (Hupp and Gingras, 2016), linking speech to meaning, at least in foreign language learners. Lewis and Kirkhart (2022) observed a negative effect on vocabulary recall with incongruent gestures and Ng et al. (2017) also noted negative effects in processing time-related metaphors (abstract concepts) when the gesture was not congruent with the cultural axis for time. Native speakers could be considered to be "experts" in the processing of content in their mother tongue and so their focus is on new information—unlike learners of the language who need to pay attention not only to the content but also to the linguistic units that deliver it, thus, any additional resources aid the processing of new input. In this study the input was abstract and the gestures were congruent with speech, providing the same information. This congruency might have limited the benefit of the gestures to our participants.

The novelty of the content has been identified as one of the potential variables affecting the impact of pedagogical gestures, with gestures enhancing recall only for new words in foreign language learners (Kaicher et al., 2022). In this study, we sought to eliminate the possible effects associated by novelty. The two groups of learners were very homogeneous and their initial knowledge of the content to be learned was similar. Participants had no understanding of the functions of the linguistic unit being taught although they were all familiar with its use, as proven by the preliminary questions they answered. Thus, the novel explanations should have enhanced pre-existing neurological circuits relating to the pragmatic use of "se," strengthening them with the additional functional information provided during the teaching.

Bearing in mind the potential effects of novelty, gesture congruency and abstractness, the study designed a topic that would be novel, but scaffolded on existing knowledge, and the gestures were congruent with the abstract explanations provided. The explanations had been designed to be easily understood, no metalinguistic terms were included, and the accompanying gestures were designed to be recognizable (see Figure 1). After the explanations, participants' answers to the immediate posttest were similar in both groups, indicating a good understanding and recall of the taught contents, suggesting that, at least in the short-term, gestures did not enhance learning. All participants seemed to have understood the various functions, identifying the most salient elements of the explanations, often paraphrasing them. The high scores obtained in the immediate posttest confirmed that participants had been paying attention and were engaged during the explanations. In the classroom, this is one of the variables that might affect the results of a naturalistic study. Lab-based studies employ volunteers, often rewarded, somewhat skewing results as participants' attention and engagement are more likely to be guaranteed than in a classroom setting.

It is possible that in some cases pure memorization had taken place (not all students paraphrased). Participants' parroting skills might be high and this distorted the effect of the gestures. Spanish learners have been found to perform better in audio-based tasks than learners from other educational systems (Lopez-Ozieblo, 2018), probably because they have been educated in a system which gives priority to the aural modality. It is more likely that the information provided by the speech might be given processing priority, while the gesture information takes longer to process but has a slower decay rate. This hypothesis is supported by the delayed posttest results. Although there is no significant difference in the results of the two groups, and in both cases, there is memory decay, it seems that this is considerably less in the gestures group, with a number of individuals (as described above) improving their scores in the delayed posttest. These results confirm those of studies where the gestures group was found to have improved learning with time, from 24 h (Cook et al., 2013) to a few months (Andrä et al., 2020). Cook and colleagues proposed that the processing of the gestures is slower and their effects do not become evident until all the information has been consolidated, thus the benefits of teaching gestures are not obvious until the following day, after sleep. Sleep has been found to aid memory consolidation in adults (Wilhelm et al., 2008) and young adults (Semsarian et al., 2021), specifically in declarative tasks (Gais et al., 2006). As only a handful of gesture studies are longitudinal, this consolidating effect might be going unreported. We strongly recommend that gesture studies include delayed testing of the effects of the gestures.

The data from the residuals indicates that there are a number of additional factors, not considered by this study, which might be affecting the effect of gestures. A key factor is likely to be individual cognitive differences. Some of these might be related to age, at 18 the brain might not have reached its full maturity. Due to differences in cognitive skills, adolescents/young adults and children/adults might benefit differently from pedagogical gestures. In adolescents and young adults, our participants, cognitive abilities are still developing (Simpson, 2008), this might include working memory, visual and spatial skills and verbal ability. Studies with young adults note that individuals with lower cognitive abilities have been found to benefit from gestures more than those with higher abilities (Özer and Göksun, 2020; McKern et al., 2021), a factor that might explain no-effect results in studies with this age group (Macedonia et al., 2019). Studies with children tend to be more consistent in finding positive effects of gestures in learning (Dargue et al., 2019), with additional benefits after consolidation (Valenzeno et al., 2003; Cook et al., 2013). Children have not had sufficient exposure to gestures and so, seeing or enacting them is novel to them and helps builds up information resulting in longer-term benefits (Calvo-Merino et al., 2006). On the other hand, older adults also benefit from gestures. These individuals are able to integrate information from different modalities, they are likely to have an extensive library of past experiences and the concepts being taught can be related to existing mental networks, perhaps in another language. A gesture-enhanced teaching approach might be beneficial to older adults as the gestures reactivate those existing networks, strengthening them (Andrä et al., 2020). Among our participants we are likely to have had considerable differences in brain maturity which might have affected the results. For some participants, those who consolidated their knowledge in the long-term, seeing gestures might have had a positive effect, building up information. The link between age and brain-maturity is a well-recognized one in secondary education, where individual cognitive differences are very noticeable, but it seems to be less relevant in higher level institutions. We would like to call attention to this, as many of our higher-level students have not yet reached brain maturity, resulting in a high degree of heterogeneity in terms of cognitive development which impacts how input is processed. As suggested by our reviewers, future studies should consider this variable and test it before the treatment. Another valuable addition to the study would be to incorporate qualitative methods, such as stimulated recall interviews, to provide a deeper insight into how pedagogical gestures affect the recall or comprehension of grammatical concepts in L1.

5 Conclusion

Our study tested the benefits of gesture in learning novel information regarding the functions of a frequently used linguistic unit in native speakers of Spanish. We expected the gesture group, taught with iconic gestures illustrating the speech, to show enhanced learning, in terms of recall and understanding of the concepts taught, compared to the no-gestures group. The pretests carried out confirmed that all participants had little knowledge of the content to be taught. Our predictions were only partially correct, as the effects of gestures was only noted in the long-term.

The results of the immediate posttest showed that participants in both groups had performed equally well, confirming learning in the short-term. Therefore, neither the abstract nature of the explanations nor the congruency nature of the gestures had an effect, positive or negative, on understanding the new concepts. It would seem that in the short-term gestures had, at worst, a neutral effect on learning the abstract concepts.

Although there was no significant difference in the immediate or delayed posttests results between the two groups of participants, we did note a significant difference between the delayed and immediate posttest results in the no-gesture group, indicating a larger memory decay than in the gesture group, where test results seemed to be similar (not significantly different).

Further analysis of the data indicated that participants in the gesture group had performed significantly better in the delayed posttest than in the immediate posttest, consolidating the taught content and slowing down the memory decay. In the long-term, gestures might have a learning-enhancing effect, helping consolidate new input, especially if learners are provided with some scaffolding, existing knowledge, on which to "attach" this new input. Previous studies had indicated that congruent gestures, matching the speech, might not be very valuable to natives, but in our study, this was not the case. Perhaps the effect of congruent gestures is also dependent on the content itself, the abstract nature of the input might also be a related significant factor. From a cognitive linguistics perspective this would not be surprising, as abstract words—and concepts—are embodied representations, developed from concrete experiences (Lakoff and Johnson, 1999; Barsalou, 2008), and the gestures might make the mapping abstract-concrete more effective that the speech.

The participants were L1 speakers of Spanish, and thus were expected to have an implicit understanding of the use of "se." This was confirmed by their performance on the pretest, which demonstrated that all participants could correctly use the marker. However, when asked to explicitly explain the various functions of "se" during the pretest, only a few participants provided detailed nuances. As they were all beginning tertiary education, it is expected that they would have been fluent enough to try to explain their implicit knowledge of the various functions, should they have had it. The lack of detailed knowledge is not surprising, some the functional explanations we were covering in this study have only begun to be developed with the advent of cognitive linguistics. It is unlikely that the treatment would have just clarified implicit knowledge about "se." We believe it added to participants' understanding of this abstract concept and the gestures helped consolidate it. Nevertheless, as language acquisition is such a complex process, we call for more studies of this nature to confirm our conclusions. The biggest limitation of this study is its small sample size. At the same time, we were limited by the actual size of the classroom. In classroom-based gesture studies it is not feasible to present gesture content to large audiences and remain confident that all participants can view the gestures and are paying attention. It is also not possible to re-arrange the number of students without breaking down the existing classroom dynamics and thus invalidating the context in which the teaching is taking place. Another limitation, as mentioned above, is the quantity of input being tested. The usual amount of new content delivered during a normal classroom session is much larger than the quantity we tested. We did not test the learning of the input delivered during the rest of session (on embodied cognitive linguistics); this would have given us valuable control data. In addition, the one individual whose participation might be questioned (the outlier mentioned above) could have been eliminated had we asked attention check questions. These points will be considered in future studies.

The duration of the training, the number of repetitions, might have been a significant factor (Macedonia et al., 2019). We suspect that additional training time in a classroom context will have an overall positive effect for teaching with gestures, although with certain limitations, as the attention span of classroom participants might not be that of lab participants. Future studies could explore whether gestures have a stronger and long-term effect (after 1 month and longer) with more training.

The main difficulty experienced by studies integrated with the teaching of an existing subject is that ethical issues drive the content to be taught to the control group. It would not be possible to knowingly put one group at a disadvantage in relation to another, by using incongruent gestures or not providing explanations in full, for example, when the topic taught is part of a syllabus. For this specific study, finding young-adults interested in linguistics but without a full command of a commonly used linguistic unit was not easy; future studies could look for similar knowledge gaps in speakers of other languages. We encourage more practitioners to take advantage of classroom situations where it might be possible to test the effects of pedagogical gestures, especially when a control group might be feasible, to continue contributing to this discussion.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Hong Kong Polytechnic University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RL-O: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

Appendix I—"Se" functions included in the study

The descriptions below were simplified explanations taken from Maldonado (2019) and Lopez-Ozieblo (2018). The original speech was in Spanish (the English translation is provided) and the gestures that enhance the key idea are described in brackets. The word/s co-occurring with the gesture have been marked in bold.

The reciprocal function was described as follows:

- "Se" can indicate a reciprocal action. These are actions where one individual (represented by the right arm bent at the elbow, forearm vertical and the palm open facing left, the arm swinging at the elbow away from the body and back);
- does the action (represented by the arm swinging at the elbow toward the left and back, fingers bending slightly up and down toward the left);
- to a second individual (represented by the left arm bent at the elbow, forearm vertical and the palm open facing right, the arm swinging at the elbow away from the body and back);
- and the second individual (represented by the left arm bent at the elbow, forearm vertical and the palm open facing right, the arm swinging at the elbow away from the body and back);
- does the action (represented by the arm swinging at the elbow toward the right and back, fingers bending up and down toward the right);
- to the first individual (represented by the right arm bent at the elbow, forearm vertical and the palm open facing left, the arm swinging at the elbow away from the body and back); and
- They do the action to each other, simultaneously (represented by the palms facing each other, the arms swinging at the elbow toward each other and bending the fingers simultaneously toward each other).

The self-benefit consumption function was described as follows:

- for this function, "se" indicates that the subject takes (represented by both hands facing each other as if grabbing an object in front of the body);
- into their area of influence (represented by the hands coming toward the body, as if bringing something toward it – see Figure 1 – Self-benefit);
- an object or idea for their own benefit and consume (repetition of the previous gesture); and
- all of it (represented by the hands facing each other turning at the wrists to form a circle – see Figure 1 – Telicity).

The mental changes function was described as follows:

- "Se" is used when we want to indicate that there is a change (represented by right arm extended forward, palm facing down and turns at the wrist upwards, gesture to indicate change; Calbris, 2011);
- to the mental state (represented by pointing to the head with the right hand);
- or the mood (represented by pointing to the heart with the right hand);
- of the subject. Originally the subject is in one state/mood (represented by a small horizontal movement of the hand palm facing down left to right – gesture to indicate no change; Harrison, 2018);
- and then there is a change (represented by repeating the first gesture); and
- "Se" marks that change (represented by repeating the first gesture).

The changes in location function was described as follows:

- "Se" can be used with verbs that indicate displacement (represented by the hands facing each other and moving from the right of the body, point A, to the left, point B, in a straight line);
- moving from point A (represented by the hands facing each other and moving up and down the point to the right of the body, point A, to the left, point B, in a straight line);
- to point B (represented by the hands facing each other and moving up and down the point to the left of the body, point B);
- to highlight the origin, point A (represented by both hands moving up and down at the previously marked point A);
- or the final destination, point B (represented by both hands moving up and down at the previously marked point B);
- without "se" these verbs mark the movement (represented by a repetition of the first gesture);
- with "se," these verbs emphasize the origin (represented by both hands moving up and down at the previously marked point A); and
- or the destination (represented by both hands moving up and down at the previously marked point B).

The changes of posture function was described as follows:

- "Se" is used with verbs that indicate a change (represented by right arm extended forward, palm facing down and turns at the wrist upwards, gesture to indicate change; Calbris, 2011);
- in the physical position (represented by a gesture of the forearm moving from the vertical axis to the horizontal axis and back);
- of the body (represented by hands moving from neck to waist fingers toward the body); and
- or a change in its physiological internal state (represented by both hands at chest level pointing toward the body and producing an arc outwards and back toward the body, similar to the gesture in see Figure 1 – Self-benefit).