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Verbal segments and multiple-pair training in relational responding under a transposition paradigm in children

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ABSTRACT

Several studies have shown that the use of conventional or unconventional verbal segments (VS) can facilitate the presentation of transposition responses, even in *distance tests*. In those studies: A) the effect of limiting the use of VS during task resolution was not systematically evaluated; and B) only two stimuli were used during training, causing the VS to become redundant. Starting from the hypothesis that the consistency between the VS and the relational property of the stimuli could affect the functionality of the VS, the present study aimed to compare the functionality of three types of verbal segments: a) conventional-consistent (*CC*); b) unconventional-consistent (*UC*); and c) unconventional-inconsistent (*UI*), with 1 and 3 pairs of instances training, in a transposition task. Fifty-six children between 8 and 9 years of age participated. They were exposed to a computerized task with varying stimuli in the size dimension, as well as *near* and *far* tests. The findings of the present study suggest that: 1) *CC* verbal segments only became relevant, as facilitators, when more than one stimulus pair was presented in training; 2) the use of *UI* resulted in an interfering task that significantly limited relational responding under 3-instance-pair training; and 3) Regardless of the number of pairs of instances in training, participants trained with *CCs* obtained significantly higher percentages of correct answers in Test than those trained with *UCs*. The relevance of verbal segments and training variability to the establishment of transposition responses is discussed.

1. Introduction

1.1. The transposition phenomenon

Relational learning refers to the ability to respond to relational qualities (e.g., larger or darker object) rather than in their absolute qualities (e.g., specific size or color) (Andrade-González et al., 2020; Lazareva, 2012; Reese, 1968). In humans, this ability is assumed to be progressively influenced by language acquisition as the individual's development unfolds, preceding more complex behavior involved in concept learning, abstract learning, and social skills (Gentner et al., 2007). Although some evidence supports the assertion that verbal behavior facilitates learning of relational qualities (Marsh and Sherman, 1966; Wheeler, 1972), the role that verbal segments play in the development of relational learning is still unknown (Lazareva et al., 2018). Studying this issue was the aim of the present study.

As a methodological framework, the transposition task involves presenting pairs or triads of stimuli that vary along a relevant continuum, such that the qualities of one stimulus become relative to those of another (Andrade-González et al., 2020; Lazareva, 2012). In two-stimulus arrangements, two stimuli differing in at least one relevant dimension (e.g., A and B, where B is smaller) are presented simultaneously or successively. The selection of the stimulus that satisfies a relational criterion (e.g., "smaller than," in this case, stimulus B) is positively reinforced. If, during a test phase involving at least one novel stimulus (e.g., B and C, where C is now smaller), the participant selects the stimulus that satisfies the relational criterion (i.e., C) rather than the previously reinforced stimulus (i.e., B), the participant is said to have selected the relationally correct stimulus or demonstrated a transposition response. This indicates that the learned relation (e.g., "less than") remains intact despite changes in the perceptual qualities of the stimuli (Köhler, 1918/1938). Conversely, if the participant selects the previously reinforced stimulus (B), an absolute response is inferred, as the response is based on the absolute qualities of the stimuli rather than

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their relational properties.

One of the aspects for evaluating transposition responses in the test phase is the criterion known as *distance*, which refers to the proximity of the stimuli within the gradient. According to this criterion, the test situation can be *close* or *distant*. That is, considering a continuous series of stimuli that vary in a relevant dimension (e.g., size or brightness), *distance* refers to the progressive remoteness (usually described in *steps* of the gradient) between the stimuli used in training and those presented in the test. *Close tests* involve stimuli minimally different from those used in training (e.g., one gradient step apart), typically yielding higher transposition rates. In contrast, *Distant tests* involve stimuli that are substantially different from the training set, usually resulting in lower transposition rates (Reese, 1968).

The inverse relationship between the number of transposition responses and stimulus distance is known as the *distance effect* (Alberts and Ehrenfreund, 1951; Kuenne, 1946; Lazareva et al., 2005, 2008, 2014; Potts, 1968; Reese, 1962, 1968; Stevenson and Bitterman, 1955). In this regard, Kuenne argued that the children whose behavior is controlled by verbal segments (e.g., as "big", "small", "medium" or other equivalent) will tend to respond relationally, regardless of the distance between the stimuli used in the training and the test, because they will have abstracted the functional relationship. Nevertheless, the role of verbal segments in modulating transposition responses remains unclear.

One dimension of the analysis of this modulation is the categorization of the verbal segments, as conventional or unconventional. Conventional Verbal Segments (CVS), such as "big" or "small," are associated with greater ease in relational responding, as they facilitate the abstraction and generalization of relationships between stimuli (Kuenne, 1946). In comparison, Unconventional Verbal Segments (UVS) are arbitrary verbal segments that initially lack a relational function but may acquire one through consistent pairing with stimulus properties (Potts, 1968; Spiker and Terrel, 1955).

Even though studies suggest that the use of CVS facilitates the emergence of transposition responses, the truth is that the exact role of these segments remains debated, as many studies have inferred the use of CVS based on indirect measures rather than directly evaluating its effect during task resolution. Examples include: a) Chronological age as a proxy for verbal competence (Alberts and Ehrenfreund, 1951); b) Mental age as an indicator of cognitive ability (Kuenne, 1946); c) Pre-training verbalization tests, in which participants name the correct stimulus based on a relational property (e.g., "median figure," "largest figure") using either conventional or idiosyncratic terms (Caron, 1967; Spiker et al., 1956); d) Post-experiment verbal reports, in which participants describe the relational criterion they used (Reese, 1962; Robbins and Witte, 1978); and e) Spontaneous verbalizations during task resolution, interpreted as evidence of verbal mediation (Johnson and Zara, 1960).

Given these limitations, some studies have attempted to clarify the role of verbal segments by investigating whether UVS can develop relational functionality during task resolution (Christie and Gentner, 2014; Gentner et al. 2011; Potts, 1968; Price, 1960; Spiker and Terrel, 1955). Initially, UVS do not serve as relational cues; however, they may acquire this function when consistently paired with stimuli possessing relational properties. By examining this process, researchers can identify the emergence of relational functionality of verbal segments in transposition responses, and evaluate, by contrast, the role played by the conventionality of the segment, in effect under CVS.

In this regard, discordant findings have been observed regarding the role of UVS in the emergence of transposition responses, due to methodological inconsistencies (Spiker and Terrel, 1955) or due to the morphological similarity of UVS with the relational morphology of CVS (Potts, 1968). All this also disagrees with the findings reported in recent studies developed under paradigms other than the transposition task, which have reported positive effects of the use of both conventional (Christie and Gentner, 2014; Loewenstein and Gentner, 2005) and unconventional (Christie and Gentner, 2014; Gentner et al., 2011) verbal segments on learning functional relations.

In all the above studies, both verbal segments and feedback were presented consistently, that is, the segments were presented contingently to the relational properties of the stimuli (e.g., "*big*" and "*dag*" segments always associated with the larger stimulus, trial after trial). It was assumed that responding also consistently would account for the emergence of the relational function of such verbal segments. In this context, it is plausible to suggest that the inconsistent presentation of UVSs (i. e., the random pairing of verbal segments with the relational properties of the stimuli) will interfere with transposition responses. An experimental design incorporating such considerations enables a systematic analysis of how consistency in verbal segment presentation affects its relational function. Additionally, such a design would provide insights into how verbal segments influence or constrain performance during transposition task resolution.

This is especially relevant when some studies suggest that verbal segments are not strictly necessary for successful transposition in *distant* tests, despite their facilitative role (Hunter, 1952; Johnson and Zara, 1960). This notion aligns with recent evidence from *implicit relational learning*, in which participants exhibit transposition responses even when unable to verbalize the relational criterion (Lazareva et al., 2018).

Furthermore, non-human animals—including rats (Ardila, 1974; Lazareva et al., 2005, 2008), pigeons (Kubo, 2023), horses (Hanggi, 2003), African penguins (Manabe et al., 2009), rufous hummingbirds (Henderson et al., 2006), and bumble bee foragers (Wiegmann et al., 2000)—demonstrate relational responding in transposition tasks, showing that verbal mediation is not a prerequisite for relational learning. These findings raise the question of to what extent verbal segments actively shape relational learning rather than merely accompanying a non-verbal relational response.

Beyond verbal mediation, another well-documented factor that facilitates relational responding is multiple-pair training (Beaty and Weir, 1966; Johnson and Zara, 1960; Lazareva et al., 2005, 2008, 2014; Sherman and Strunk, 1964; Rabinowitz, 1981). However, most studies analyzing the effect of verbal segments (conventional or not) have used only a single pair of instances during training (e.g., Alberts and Ehrenfreund, 1951; Caron, 1967; Kuenne, 1946; Potts, 1968; Spiker et al., 1956). This implies that the same instance is consistently designated as 'correct' and another as 'incorrect' on a trial-by-trial basis. In this context, the inclusion of a verbal segment (whether conventional or not) during training might become irrelevant, as these segments simply constitute additional qualities or components of the stimuli or instances, thereby becoming redundant in the process of differentiating between stimulus instances. However, training in which the relational value of a stimulus changes depending on another stimulus in the arrangement—such as in multiple-pair training—could promote the development of a relational functionality of the verbal segment, as it would no longer be associated with a particular instance but with a relational property.

In summary, despite extensive research in the field, several methodological gaps remain:

a) *Indirect Evaluation of Verbal Mediation*: Many studies assume CVS use based on factors such as age, intelligence measures, or post-task verbal reports, rather than directly evaluating their use during task resolution (Alberts and Ehrenfreund, 1951; Caron, 1967; Kuenne, 1946).

b) *Underexploration of Unconventional Verbal Segments*: There are inconsistent findings about the function of UVS, possibly due to methodological errors related to the experimental design (Spiker and Terrel, 1955); the morphological similarity of the UVS with the relational morphology of CVSs (Potts, 1968); or the lack of feedback (Price, 1960). Such discrepancies raise questions about the relevance of the conventionality of the verbal segment to the emergence of transposition responses.

c) *Absence of a control group on the restricted use of verbal segments:* There is a methodological limitation that skews the robustness of the findings by not contrasting the results of experimental conditions that explicitly require the use of CVS with a condition in which its use is constrained. This could be solved by the inconsistent presentation of UVS, which limits the functional use of the verbal segments during the task.

d) *Single-Pair Training as an artifact of the procedure*: Most studies using verbal segments employ single-pair training, which may limit the abstraction of relational properties. When the same pair of stimuli is consistently presented as "correct" or "incorrect," verbal segments may become redundant, as they are associated with specific instances rather than relational properties. This could lead to an underestimation of the effect of verbal mediation (Derenne and Garnett, 2016; Spiker et al., 1956). This limitation can be overcome by using multiple-pair training (Lazareva et al., 2005, 2008, 2014).

In this context, the present study aims to compare the functionality of four verbal segment conditions, in which the conventionality of the segments and the consistency of their presentation with the relational properties of the stimuli are varied. This allows us to assess, on the one hand, the role of verbal segment conventionality in the emergence of transposition responses, and at the same time, the relevance of the consistency of segment-relational properties for the emergence of such responses, using UVS. Additionally, it enables us to contrast a condition in which an explicit attempt is made to limit the use of verbal segments, given the inconsistent presentation of UVSs, with standard control conditions, in which verbal segments are simply not explicitly introduced during the task.

Thereby, four experimental groups were used: a) Conventional-Consistent (*CC*): Verbal segments consistently paired with relational properties (e.g., "big" always paired with the larger stimulus); b) Unconventional-Consistent (*UC*): Arbitrary verbal segments consistently paired with relational properties (e.g., "chaf" always paired with the larger stimulus); c) Unconventional-Inconsistent (*UI*): Arbitrary verbal segments inconsistently paired with relational properties (e.g., "chaf" randomly presented with the larger stimulus); and d) No Verbal Segments (*No*): A control condition without explicit verbal segments during training.

In turn, in order to evaluate the training variability and its effect on the functionality of the verbal segments (item *d*), these experimental groups were subdivided according to the type of training: a) Simple Pair Training (1-pair), where one instance was consistently reinforced; and b) Multiple Pair Training (3-pair), where three different stimulus pairs, with the reinforced instance permuted trial by trial, were presented.

As dependent variables, the number of trials required to achieve the training criterion (10 consecutive correct trials, with a maximum of 200 trials) and the response latency were measured during the Training phase. Whereas, in the Test phase, the accuracy and response latency were measured in *close* and *distance* tests. The latter made it possible to evaluate the *distance effect* (Alberts and Ehrenfreund, 1951; Kuenne, 1946; Lazareva et al., 2005, 2008, 2014; Potts, 1968; Reese, 1962, 1968).

It was expected that the effect of verbal segment conditions will depend on the training variability. Specifically, it was hypothesized that the consistent verbal segment groups (*CC, UC*) would enhance transposition responses, mainly in interaction with 3-Pairs Training. Additionally, the hypothesis was that the inconsistent verbal segment pairing (*UI*) would interfere with relational learning, reducing transposition responses; and finally, it was expected that training with multiple stimulus pairs would promote relational responding compared to single-pair training.

2. Method

2.1. Participants

The participants were recruited based on deliberate non-probabilistic sampling. The fifty-six children, aged 8–9 years (M=8.5, 24 males and 32 females), were experimentally naïve to the task, all from the same school, and all sessions were conducted by the same experimenter.

Although participants' age was not an independent variable in the present study, this information was methodologically relevant, every time the use of different types of verbal segments during the task was analyzed by reading them aloud before stimulus selection. Therefore, completing the task initially required reading skills. Considering that there is literature (Paris, 2005) suggesting a positive correlation between: a) fluency and comprehension in oral readers; and b) age and the development of reading skills; one of the criteria for determining the participants' age was that they had considerable mastery of reading aloud, which implied that they had already completed the first years of primary education (Paris, 2005). On the other hand, the second criterion was that participants were older than 5 years, given that it has been suggested that the relational processing involved in conditional discrimination tasks (such as *1-Pair Training* in the present study) may be more evident in children aged 5 years or older (Andrews et al., 2012).

2.2. Ethical Approval

The study was conducted in accordance with the Mexican Psychologist's Code of Ethics. It was approved by an ad hoc jury at Universidad Nacional Autónoma de México-Iztacala, with the research project code FT3–253/18.

2.3. Materials and experimental situation

The experimental sessions took place in the same school where the participants were recruited, in a classroom that they regularly attended. Each participant underwent a single experimental session (approx. 15–20 min) and the same experimenter conducted all sessions of the project. Each participant was provided with a chair, a personal desk and a 14" HP Pavilion Laptop where they were presented with the task, programmed with the Superlab 4.0 application. At the end of the session, the participants received a candy for their collaboration.

2.4. Design

A 2 × 4 factorial design was employed, with four dependent variables: number of trials required in training, response latency in training, percentage of correct responses in test and response latency in test.

Half of the participants were randomly assigned to the *1-Pair Training* condition and the remaining half to the *3-Pairs Training* condition (i.e., every pair of stimuli in Training was presented trial by trial, randomly). For each condition, participants were randomly assigned to one of four groups based on the type of segment included in training: 1) *CC*= conventional-consistent, 2) *UC*= unconventional-consistent, 3) *UI*= unconventional-inconsistent, and 4) *No*= no segment. Therefore, there were 7 participants in each experimental group.

2.5. Procedure

For every experimental condition (*1* and *3-Pairs Training*), a stimulus gradient composed of 10 squares of different sizes was used (see Fig. 1), whose dimensions were established based on the studies of Lazareva et al. (2005, 2008)

The participants went through the following phases and in the same order: (a) Familiarization, (b) Training, and (c) Testing, described below.

2.5.1. Training condition with 1 pair of stimuli

Familiarization. It consisted of six trials (with stimuli E5 and E6) without feedback and with the segment corresponding to the experimental condition (*CC, UC, UI* or *No*). Each trial consisted of a black screen with two white stimuli in the center and equidistant from each other. Depending on the experimental group, a conventional (i. e.,

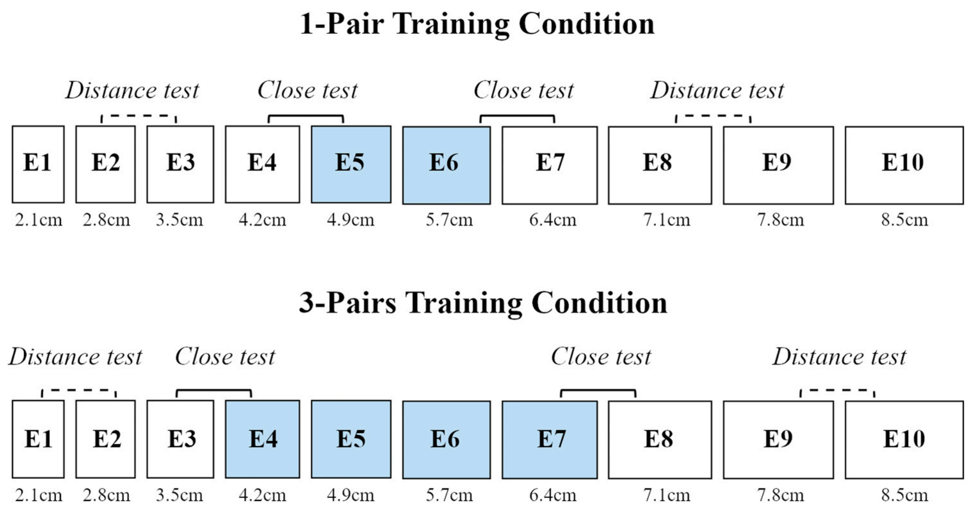

Fig. 1. Stimuli gradient composed by 10 squares. Blue-coloured squares indicate the stimuli used in training for *1-Pair Training* condition (upper panel) and for *3-Pairs Training* condition (bottom panel). *Close* and *Distant* tests were composed by pairs of stimuli one and three steps away from those used in training, respectively, for every experimental condition.

"mayor" or *"menor"* in Spanish, which is analogous to *"large"* and *"small"* in English, respectively) or unconventional (i. e., *"chif"* or *"chaf")* segment was presented below each stimulus, paired either consistently with the relational property of the presented stimuli (i. e., the *"mayor/chaf"* segment always with the large stimulus and *"menor/chif"* with the small stimulus) or inconsistently (with the randomly presented verbal segments). Fig. 2 exemplifies a pair of trials according to the type of segment added. On each trial, participants were required to read aloud the verbal segments of both stimuli before selecting one of them.

The instructions were given by the experimenter verbally. For the case of the *CC, UC* and *UI* conditions, the instructions were as follows:

In the following screens two figures will appear with their respective labels. The game consists of reading aloud the labels of both figures and then selecting one of them. To record your answer, place the mouse pointer over the figure you chose and click the left mouse button. If you have any doubts about the game instructions, you can ask us, otherwise, press the "Continue" button.

Whereas the instructions for the *No* condition were as follows:

In the following screens two figures will appear, the game consists of selecting the one you consider correct. To record your answer, place the mouse pointer over the figure you chose and click the left button. If you have doubts with the instructions of the game you can ask us; otherwise, press the "Continue" button.

Once the participants had solved the familiarization trials by reading the verbal segments of both stimuli before selecting one of them, the experimenters again gave the instructions described above to initiate the Training phase, adding that, on this occasion, they would be notified whether their response was correct or incorrect.

Training. During training, a pair of gradient stimuli (E5 and E6) was used, randomizing their position (right-left) trial by trial, and adding the verbal segment according to the experimental group: 1) *CC*: *"mayor"* y *"menor"* presented in a consistent manner; 2) *UC: "chaf"* y *"chif"* presented in a consistent way; 3) *UI: "chaf"* y *"chif"* presented in an inconsistent mode, and 4) *No*: without verbal segment. As in the previous phase, each trial consisted of a black screen, with two white stimuli in the center, equidistant from each other; additionally, feedback was provided immediately after each response by the text "Correct" or "Incorrect" in the center of the screen. The matching criterion was always "greater than"; thus, the participant had to select the larger stimulus to receive feedback of a correct response. Trials continued to be presented until the participant solved 10 trials correctly consecutively and with a maximum of 200 trials.

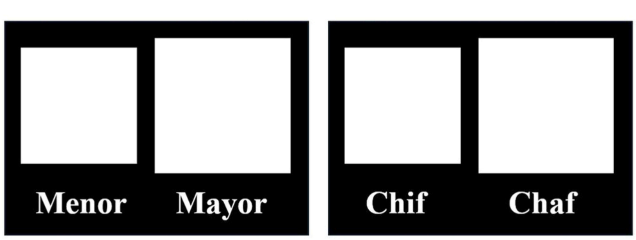

Fig. 2. Example of trials with added segment. From left to right, the following are shown: conventional-consistent segments -in Spanish- (*CC*) and unconventional-consistent segments (*UC*).

Test. Those participants who met the criterion of 10 consecutive correct trials during training moved on to the Test phase, which was composed of 24 trials, divided into two blocks; 12 trials comprised the *close test* block and 12 trials comprised the *distant test* block, presented in that order. In the *close test*, one of two pairs of stimuli (E4 and E5, E6 and E7), consisting of stimuli that were 1 *step* away from the trained stimuli (E5 and E6), were randomly presented in each trial. Whereas in the *distant test*, one of two pairs of stimuli (E2 and E3, E8 and E9) with stimuli 3 *steps* away from those used in the previous phase were randomly presented in each trial. For all experimental groups, the matching criterion was *greater than*, there was no feedback and no verbal segments were added.

2.5.2. Training condition with 3 pairs of stimuli

Familiarization. The parameters, characteristics and instructions for this phase were the same as in the previous condition, and Training was initiated once participants learned to read both verbal segments before selecting a stimulus, trial by trial.

Training. The characteristics of this phase were the same as in the previous experimental condition, with the exception that the trials were composed of three pairs of stimuli, specifically: E4 and E5, E5 and E6, E6 and E7, presented randomly. The instructions were given verbally by the experimenters and were the same as in the previous phase, adding that, on this occasion, the participants would be told whether their response was correct or incorrect.

Test. This phase had the same characteristics as the Test phase in the previous condition (i.e., *1-Pair Training*), however, the 12 trials of the *close test* were composed of stimuli E3 and E4; E7 and E8, whereas the 12 trials of the *distant test* were made up of stimuli E1 and E2; E9 and E10.

2.6. Data analysis

2.6.1. Transformation of dependent variables

To address heteroscedasticity, a logarithmic transformation was applied to the following dependent variables: the number of trials required to achieve the training criterion (Log Trials to Criterion) and the mean latency during both the training and test phases (Log Mean Latency). The transformation was performed using the logarithmic function in MATLAB (refer to the code and dataset provided in the Online Supplementary Material, OSM). For the test phase, the percentage of correct responses (Accuracy) was used without transformation, as it satisfied the assumption of homoscedasticity.

2.6.2. Statistical analysis

Training Phase. A factorial ANOVA was conducted with Verbal Segment and Pairs as fixed factors. The dependent variables were Log Trials to Criterion and Log Mean Latency (see OSM).

Test Phase. A repeated measures ANOVA was conducted with Distance (Close Test vs. Distant Test) as a within-subjects factor, while Verbal Segment and Pairs were included as between-subjects factors. The dependent variables were Accuracy and Log Mean Latency (see OSM).

Training vs Test Comparison. A paired-samples t-test was performed to compare Log Mean Latency between the training and test phases (see OSM).

Assumption Checks. For all ANOVA analyses, the assumption of homogeneity of variances was tested using Levene's test and was satisfied. Normality was also satisfied for the *t*-test analysis (see OSM).

3. Results

3.1. Training phase

A factorial ANOVA was conducted to evaluate the effects of *Verbal Segment* (*CC*, *UC*, *UI*, *No*) and *Pairs* (1, 3) on Log Trials to Criterion (Table 1, OSM) and Log Mean Latency (Table 4, OSM). The analysis revealed a significant main effect of *Verbal Segment* on Log Trials to Criterion, $F(3, 48) = 3.58$, $p = .02$, $\eta p^2 = .183$, as well as a significant main effect of *Pairs*, $F(1, 48) = 7.80$, $p = .007$, $\eta p^2 = .140$. Participants in the *Single Pair* condition reached the criterion in fewer trials than those in the *Multiple Pair* condition.

Post hoc comparisons (Table 2, OSM) indicated that participants in the *UI* condition required significantly more trials to reach the criterion than those in the *CC* condition ($p = .012$). Additionally, the *Verbal Segment* × *Pairs* interaction was significant, $F(3, 48) = 3.96$, $p = .013$, $\eta p^2 = .198$, suggesting that the effect of *Verbal Segment* varied depending on the number of training pairs (*1-Pair Training* vs. *3-Pairs Training*). Post hoc comparisons for this interaction (Table 3, OSM) revealed an interesting effect: consistent verbal segments facilitated reaching the criterion compared to the *UI* condition, but only under the *3-Pairs Training* condition. This was evidenced by significant differences between *CC-3Pairs* and *UI-3Pairs* ($p = .022$) and between *UC-3Pairs* and *UI-3Pairs* ($p = .044$). A similar trend was observed between the consistent segment conditions (*CC* and *UC*) and *No-3Pairs*, but this difference was not statistically significant (see Fig. 3).

For Log Mean Latency (Table 4, OSM), a significant main effect of *Verbal Segment* was found, $F(3, 48) = 3.23$, $p = .031$, $\eta p^2 = .149$, while *Pairs* did not significantly affect latency. Interestingly, post hoc comparisons (Table 5, OSM) indicated that participants in the *CC* condition had significantly longer latencies compared to those in the *No* condition ($p = .029$) (see Fig. 4). The *Verbal Segment* × *Pairs* interaction was not significant.

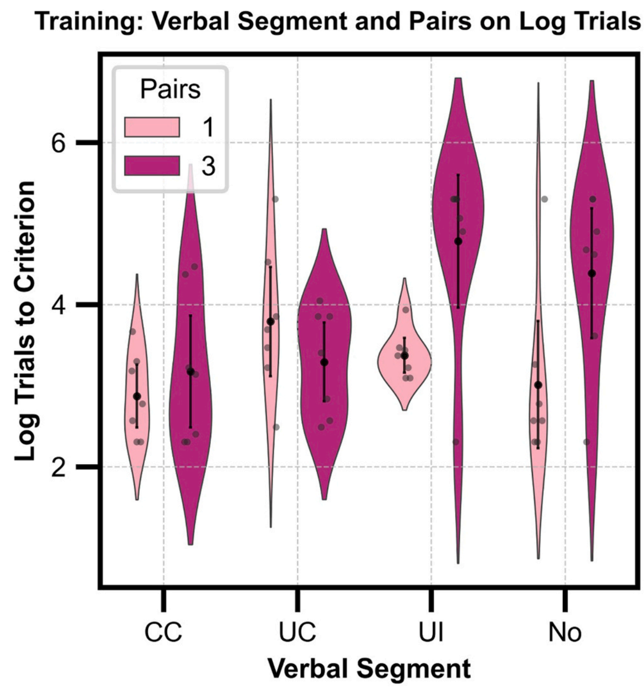

Fig. 3. Effect of Verbal Segment and Number of Pairs on Log Trials to Criterion during Training. Violin plot showing the distribution of log-transformed trials to criterion across different Verbal Segment conditions (*CC, UC, UI, No*) and Pairs Training conditions (1 vs. 3). Darker colors represent the *3-Pairs Training* condition, whereas lighter colors represent the *1-Pair Training* condition. Black dots indicate individual data points, and error bars represent the mean with 95 % confidence intervals (CI).

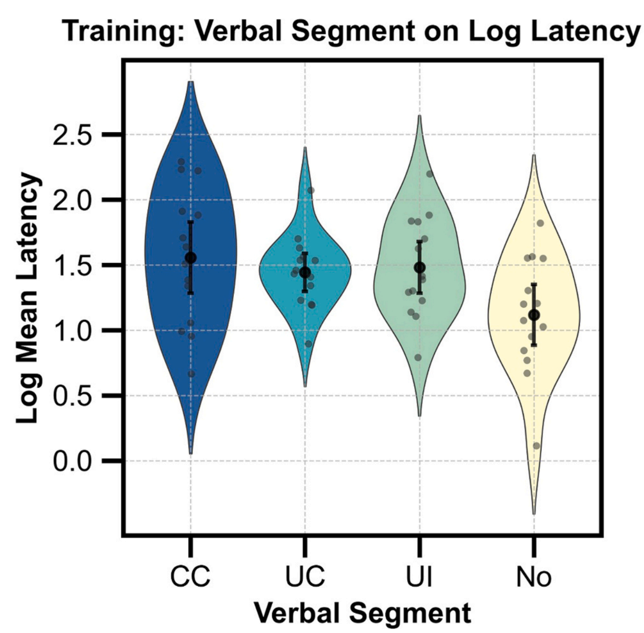

Fig. 4. Effect of Verbal Segment on Log Mean Latency during Training. Violin plot showing the distribution of log-transformed mean response latency across different Verbal Segment conditions (*CC, UC, UI, No*) during the training phase. Black dots represent individual data points, and error bars indicate the mean with 95 % confidence intervals (CI).

3.2. Test phase

As was described in the Procedure section, only those participants who met the criterion of 10 consecutive correct trials during training moved on to the Test phase. Therefore, the number of participants analyzed for each experimental group was as follows: 1) *CC*= 7 out of 7 both for the *1-Pair Training* condition and for the *3-Pairs Training* condition; 2) *UC*= 7 out of 7 both for the *1-Pair Training* condition and for the *3-Pairs Training* condition; 3) *UI*= 7 out of 7 for the *1-Pair Training* condition, and 3 out of 7 for the *3-Pairs Training* condition; 4) *No*= 6 out 7 for the *1-Pair Training* condition and 5 out for 7 for the *3-Pairs Training* condition.

A repeated-measures ANOVA was conducted on *Accuracy*, with *Distance* (Close vs. Distant) as a within-subjects factor and *Verbal Segment* and *Pairs* as between-subjects factors (Table 6, OSM). No significant effects of *Distance* were found. However, in the *Between-Subjects Effects* analysis, a significant main effect of *Verbal Segment* was observed, $F(3, 41) = 4.16$, $p = .012$, $\eta p^2 = .084$ (Table 7, OSM), with participants in the *UC* condition exhibiting significantly lower *Accuracy* compared to *CC* ($p = .012$) and *No* ($p = .049$) (see Table 8, OSM, and Fig. 5). This finding contrasts with the higher effectiveness (fewer trials required to achieve the criterion) observed during training. The *Verbal Segment* × *Pairs* interaction was not significant.

A repeated-measures ANOVA was conducted to examine the effects of *Test Distance* (Close vs. Distant), *Verbal Segment*, and *Pairs* on Log Mean Latency (Table 9, OSM). The analysis revealed a significant main effect of *Test Distance*, $F(1, 41) = 13.615$, $p < .001$, $\eta^2 = .073$. Unexpectedly, response latency in the *Close Test* was higher than in the *Distant Test* (see Fig. 6). However, the interaction effects between *Test Distance* and *Verbal Segment*, *Test Distance* and *Pairs*, and the three-way interaction were all non-significant.

To further explore the effects of *Verbal Segment* and *Pairs* on Log Mean Latency, a factorial ANOVA was performed (Table 10, OSM). The analysis did not reveal significant main effects of *Verbal Segment*, and similarly, the *Verbal Segment* × *Pairs* interaction was not significant.

3.3. Training vs test comparison

Finally, for Log Mean Latency, a paired-samples *t*-test comparing *Training* and *Test* phases revealed a significant increase in latency during the test phase, $t(48) = -34.0$, $p < .001$, $d = -4.86$ (see Fig. 7), suggesting a robust delay in responding when the feedback was removed.

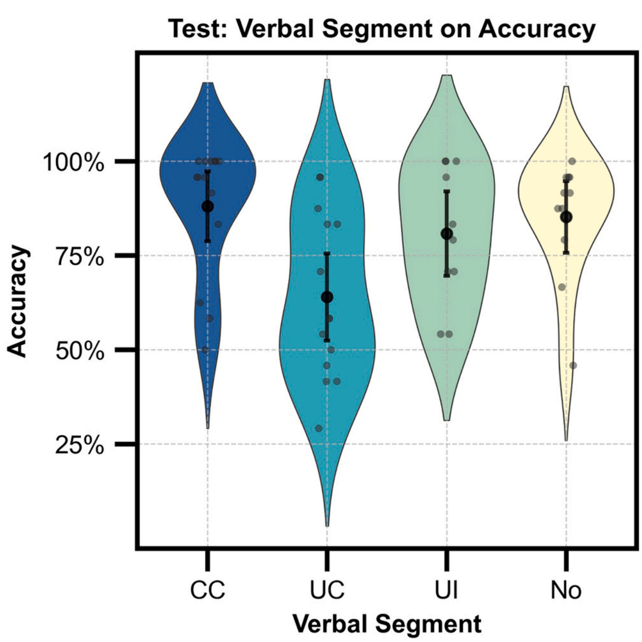

Fig. 5. Effect of Verbal Segment on Accuracy during the Test Phase. Violin plot depicting the distribution of accuracy across different Verbal Segment conditions (*CC, UC, UI, No*) during the test phase. Black dots represent individual data points, and error bars indicate the mean with 95 % confidence intervals (CI).

Fig. 6. Effect of Test Distance on Log Mean Latency during the Test Phase. Violin plot illustrating the distribution of log-transformed response latency for *Close* and *Distant* test conditions. Black dots represent individual data points, and error bars indicate the mean with 95 % confidence intervals (CI).

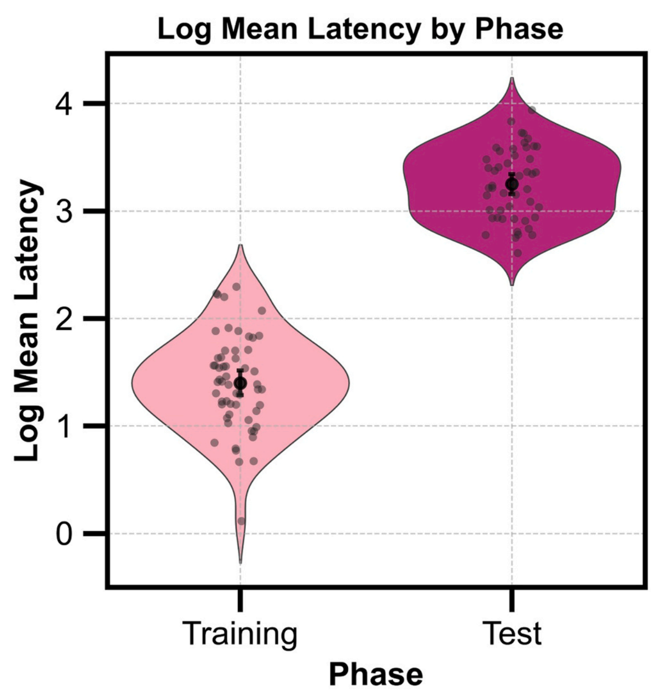

Fig. 7. Comparison of Log Mean Latency between Training and Test Phases. Violin plot showing the distribution of log-transformed mean response latency across the Training and Test phases. Black dots represent individual data points, and error bars indicate the mean with 95 % confidence intervals (CI).

4. Discussion

4.1. Training phase and learning efficiency

The present study aimed to compare the functionality of four verbal segment conditions (*CC, UC, UI, No*) and the effects of training variability (*1-Pair Training, 3-Pairs Training*) on responding under a transposition paradigm. Our first hypothesis was that the effect of verbal segment conditions would depend on training variability. Although factorial ANOVA indicated main effects for both verbal segment condition and training variability, the most notable finding was that consistent verbal conditions under *3-Pairs Training* (*CC* and *UC*) required fewer trials to achieve the training criterion compared to *UI-3Pairs*. These training findings are consistent with those of Kitao (1974) and Potts (1968), who observed a greater number of transposition responses in participants who verbalized conventional and non-conventional segments, respectively, during task resolution. Likewise, the results align with recent studies conducted under other paradigms, which have found a positive effect of using both conventional and non-conventional verbal segments in learning functional relationships (Christie and Gentner, 2014; Gentner et al., 2011).

Notably, under *1-Pair Training*, there was no difference in the number of trials required to achieve the training criterion across verbal segment conditions. This could be due to the redundancy of the segment in the consistent groups (*CC, UC*). Specifically, in this experimental arrangement, the same paired instance was presented with the same segment trial after trial (*e.g., large square – "Mayor"/"Chaf" segment, small square – "Menor"/"Chif" segment*).

A particularly interesting finding was the higher response latency under the *CC* condition during training compared to the *No* condition. This is especially relevant because it represents an inverse relationship with the number of trials required to reach the criterion, where the lowest values corresponded to the *CC* condition. This may have been because participants in the *CC* condition, unlike those in the *No* condition, were forced to use verbal segments to identify the relatedness criterion based on the consistent pairing of the added segments and the relevant qualities of stimuli, which could have required more time to respond. This suggests that, when verbal segments are introduced into the experimental arrangement, participants tend to use them during task resolution, while their omission seems to facilitate perceptual contact not mediated linguistically (León et al., 2017; Lazareva et al., 2018), implying a shorter response time.

The fact that only in the *CC* and *UC* conditions all participants satisfied the training criterion (with both 1 and 3 pairs) supports the previous hypothesis, given that the use of verbal segments has been observed to increase training accuracy in both transposition tasks (Kitao, 1974; Potts, 1968) and other paradigms (Christie and Gentner, 2014; Gentner et al., 2011). This finding is relevant given that standard procedures in this field usually assume the use of verbal segments during task resolution without having explicitly introduced them into the experimental arrangement.

4.2. Test phase and transposition responses

A second hypothesis was that both consistent verbal segment conditions (*CC, UC*) would enhance transposition responses in the test phase, especially in *distant* tests. Nevertheless, the findings showed that, even though *UC* exhibited similar performance to *CC* during training, a significant difference emerged in the test phase: *UC* had significantly lower accuracy than *CC*.

Other comparisons should be interpreted with caution due to a procedural limitation: only participants who achieved the training criterion were exposed to the test phase (*3 out of 7 for the UI condition and 5 out of 7 for the No condition*). However, the comparison between *CC* and *UC* remains robust, as all participants in these conditions met the training criterion and were tested.

This suggests that the verbal segments under *UC* did not extend their functionality to the test phase and were useful only in an intraepisodic manner, serving as indicators of the current relationship while present during training (Delgado et al., 2011; León et al., 2017). However, they were not carried over to the test phase. This finding aligns with Price (1960), who found that the use of conventional verbal segments (CVS), rather than unconventional verbal segments (UVS), favors the emergence of transpositional responses in an intermediate-size task.

These results suggest that, although *UC* segments developed a function as indicators of the current relationship during training, they failed to facilitate stimulus generalization in the test phase, unlike *CC* segments. Some possibilities could explain it. First, this difference may stem from the fact that *CC* segments, due to their conventional use, already function as indicators of relational properties. In this sense, participants exposed to *CC* segments had to identify the relevant dimension that satisfied the relationship already indicated by the segment itself. Thus, *CC* segments play an instructional function (Goldiamond, 1966), developed through extensive and varied exposure over the participants' lifetimes. It is plausible to hypothesize that with extended training, *UC* segments could eventually acquire an instructional function similar to that of *CC* segments. However, the present findings indicate that this process did not occur within the study's time frame.

Second, there is a possibility that the unconventional segments (i.e., "chif" and "chaf") were not sufficiently discriminable due to their morphological similarity. As a result, participants may have been unable to consistently associate a differential function for each of these segments. Third, it is possible that the participants did not consider the *UC* segments relevant, either because they sounded funny or because they lacked semantic value in Spanish. In the latter case, it is possible that the participants simply ignored them. Finally, there is the possibility that the *UI* condition has produced a blocking effect, whereby other Spanish words (as in the *CC* condition) gained relational control, making it difficult for new verbal segments to do the same.

Despite differences in accuracy between *CC* and *UC*, no significant differences were found between groups in the *Close* and *Distant* tests. This was an unexpected result, likely due to the study's limited statistical power, particularly in the test phase, due to an insufficient sample size (N). Future studies should address this issue by increasing the number of participants and extending the training duration to further examine the potential instructional role of *UC* segments.

4.3. Latency in the test phase

Beyond accuracy, another critical aspect of the test phase was response latency, where a difference was found between the *Close* and *Distant* tests. However, unexpectedly, the *Close Test* showed higher *latency* than the *Distant Test*. This could be because the *Close Test* included previously trained stimuli, whereas the *Distant Test* featured novel stimuli.

We hypothesize that prior experience with the stimuli, combined with changes in their relational properties (Castaneda and Worell, 1961), may have required greater attention and response inhibition in the *Close Test* compared to the *Distant Test*. Future research should delve deeper into this finding. No other significant differences in latency were found based on training variability or verbal segment condition.

4.4. Interference effect of inconsistent verbal segments

A third hypothesis proposed that inconsistent verbal segment pairing (*UI*) would interfere with relational learning, reducing transposition responses. Our findings partially support this hypothesis. The *UI* condition interfered with training in the *3-Pairs* condition, as it required the highest number of trials to reach the criterion. Additionally, only 3 out of 7 participants met the training criterion. Nevertheless, those who met the criterion did not differ in the test phase from those in the *CC* condition.

The above may have been because, given the participants' age—that is, their extensive training history—they were sufficiently skilled at responding to a "greater than"/"less than" criterion in the size dimension, even under strictly perceptual contact, that is not linguistically mediated. Therefore, it is possible that the *UI* condition did not interfere sufficiently to prevent correct responding in the test phase. However, it is possible that the *UC* condition did interfere with the emergence of transposition responses, given that significantly lower accuracy was observed in this condition than in the *CC* and *No* conditions during the test. Future studies could explore the qualities of the *UC* segments and the conditions under which they systematically interfere with transposition responses.

In the context of the role of verbal segments in the emergence of transposition responses, it is important to note that the ability to engage in relational responding has been well documented in nonhuman animals (Ardila, 1974; Hanggi, 2003; Henderson et al., 2006; Kubo, 2023; Lazareva et al., 2005, 2008; Manabe et al., 2009; Wiegmann et al., 2000). However, these responses are limited by the *distance effect* (Lazareva et al., 2005, 2008, 2014), which could be similar to what was observed under *UI* verbal segments in the present study. On the other hand, relational responding under conventional and consistent segments (*CC* condition) shows quantitative and qualitative differences compared with relational responding in nonhuman animals, such as robustness to the *distance effect*. All of the above provides evidence of the relevance of the conventionality and consistency of the verbal segment as a facilitator of transposition responses with stimuli that are far removed from those used during training.

This finding represents a first step to clarify the function of verbal segments in the relational behavior field, and proposes an alternative to standard procedures (Caron, 1967; Spiker et al., 1956; Reese, 1962; Robbins and Witte, 1978) to examine how verbal inconsistency affects transposition responses.

4.5. Effects of training variability on relational responding

A fourth hypothesis proposed that training with multiple stimulus pairs would enhance relational responding compared to single-pair training. Whereas our data did not provide strong support for this assertion, this result should be interpreted with caution. Given the extensive evidence supporting this hypothesis (Lazareva et al., 2008), it is possible that the study's statistical power, particularly in the test phase, was insufficient to detect this effect. Future research with a more robust statistical design and larger sample sizes could further clarify this relationship and offer a clearer understanding of the effects of multiple-pair training.

4.6. Impact of feedback removal on response latency

In the comparison of latency between phases, a significant and robust increase was observed from the training to the test phase. The removal of verbal segments and feedback in the test phase appears to have introduced a substantial change, making the task more challenging for participants and leading to increased response latency.

Relatedly, previous studies on conditional discrimination in children have reported that greater reinforcement delays are associated with longer response latencies, although not with the number of correct responses (Etzel and Wright, 1964). These findings are relevant, every time that the latency response is a frequent reference associated with the accuracy level. To our knowledge, the present study is among the first to report such a strong effect on relational behavior under a transposition paradigm.

4.7. Limitations and future research directions

Two key limitations of this study warrant consideration. First, including a group with an inconsistent conventional verbal segment could have provided a more robust design to further explore the effects of conventional segment inconsistency. It would have been valuable to observe whether these segments would have had an interfering effect, similar to the *UI* segment. A second limitation was the lack of statistical power, as the uneven number of participants across conditions in the test phase restricted the scope of the analyses.

Regarding future research directions, given the differences between *CCs* and *UCs* in the test phase, it would be important to investigate whether extended and varied exposure to *UC* segments enhances their instructional function, and, on the other hand, explore their possible interference function with children younger than those used in the present study. Additionally, exploring the replication of this study under saturation conditions could be valuable, as it has been documented that transposition tasks become more challenging in this context (Andrade-González, 2021; Jackson, 1939), potentially amplifying the effects of verbal segments.

Following the same logic of increasing task difficulty, reducing the distance between stimuli could make differentiation more challenging, providing further insights into the role of verbal segments. Another alternative would be to introduce irrelevant or distracting dimensions to assess their impact on relational learning. Finally, incorporating gaze and cursor tracking analysis would help bridge the behavioral gaps left by latency measures by providing data on stimulus exploration and inspection (León et al., 2021; Santibáñez-Armenta et al., 2024).

CRediT authorship contribution statement

Guzmán Reyes Isiris: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization, Software. **Santibáñez Armenta Joao:** Writing – review & editing, Validation, Investigation, Formal analysis, Data curation. **Medina Arboleda Iván Felipe:** Writing – review & editing, Resources, Funding acquisition. **Alejandro León:** Writing – review & editing, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.beproc.2025.105275.

Data availability

The data associated with the present study are available at the following link:

Guzmán, R. I., Medina, A. I. F., Santibáñez, J. A., & León, A. (2024). Test&Train_Transp_verbseg_pairs_rawlog [Data set]. Mendeley Data, V2. https://data.mendeley.com/datasets/w3dt6jnf3v/2

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