The Psychological Record (2022) 72:75–88
https://doi.org/10.1007/s40732-021-00461-2

ORIGINAL ARTICLE

Emergence of Third-Order Conditional Discriminations from Learning Discriminations with Unrelated Stimuli

Luis Antonio Pérez-González[1] · **Héctor Martínez**[2]

Accepted: 4 February 2021 / Published online: 17 November 2021

Abstract
This study explored learning and generalization of a third-order conditional discrimination. Two 8-year-old children learned two auditory–visual conditional discriminations in which they selected visual Japanese syllabic symbols in response to syllables spoken by the experimenter. Then, they learned a third-order conditional discrimination in which they selected between two visual symbols after being exposed to two spoken syllables and one visual symbol. Thereafter, we probed generalization with novel symbols and names by teaching two additional conditional discriminations with Nahuatl symbols and spoken words and probing without reinforcement a new third-order conditional discrimination in which they had to select between two visual Nahuatl symbols after being exposed to two spoken Nahuatl words and one visual Nahuatl symbol. The two children responded in a predicted way to the novel third-order conditional discrimination. The emergent performance was possible because the set of relations established among the stimuli of the third-order conditional discrimination with Japanese syllables was analogous to the set of relations established among the stimuli of the third-order conditional discriminations with Nahuatl words. These results demonstrated a novel type of emergent responding in third-order conditional discrimination with arbitrary relations.

Keywords Conditional discrimination · Emergent relations · Stimulus equivalence · Stimulus relations · Children

Learning with specific stimuli and relations often brings about transfer to learning with different stimuli. A significant type of learning transfer occurs when learning simple discriminations bring about learning simple discriminations with all novel stimuli: Harlow (1949) taught rhesus monkeys a simple discrimination until they reached a criterion. Then, he repeated the teaching with novel pairs of stimuli each time. Over several dozens of discriminations, he found that the monkeys reached the learning criterion of the discriminations within fewer and fewer trials. Such results indicate that even though the stimuli were different, and not specifically related to those of the first discrimination, learning a specific discrimination produced additional effects in further learning of discriminations. This process was dubbed a learning-set process. A related learning-set processes was described by Saunders and Spradlin (1990, 1993): they observed that people with learning difficulties found it hard and required complex procedures to learn an initial conditional discrimination, but fewer and fewer requirements were necessary for learning successive conditional discriminations. In a further step in the same direction, Pérez-González et al. (2000) observed learning-set effects when children learned a second-order conditional discrimination after learning a first-order conditional discrimination with related stimuli: For example, they taught matches of A1 to B1 (instead of B2) and of A2 to B2 (instead of B1), a first-order conditional discrimination. They then taught the same matches as before in the presence of a contextual stimulus X1 as well as matches of A1 to *B2* and matches of A2 to *B1* in the presence of another contextual stimulus X2; this was the second-order conditional discrimination. When novel successive first-order and second-order conditional discriminations, with stimulus sets completely different from the previous ones were taught, fewer and fewer errors were made before reaching criterion—alearning-set effect with second-order conditional discriminations.

A qualitative type of transfer arises when learning a few discriminative operants gives rise to the apparition of untaught operants—an emergence process. The most documented case

✉ Luis Antonio Pérez-González
laperez@uniovi.es

1 Departamento de Psicología, Universidad de Oviedo, Despacho 217, Plaza Feijoo s/n, 33003 Oviedo, Asturias, Spain

2 University of Guadalajara, Guadalajara, Mexico

is stimulus equivalence; for instance, when A is related to B and B is related to C, through conditional discriminations, humans typically relate B to A, C to B, A to C, and C to A in probes without specific instructions, prompts, or differential consequences (for reviews on equivalence, see Arntzen, 2012; Arntzen & Lian, 2010; Sidman, 1994). Stimulus equivalence accounts for cases of emergence in which simple relations among stimuli are involved. For example, relations between words and the corresponding objects, the written words, and synonyms are in essence instances of equivalence. Substituting a stimulus by an equivalent one produces the same response as the stimuli taught to respond with that response.

Stimulus equivalence is one among many possible stimulus relations. For example, relations between words and objects are equivalent only in a given setting: One can point to an apple, to the word "apple," and to a picture of an apple; thus, by means of the pointing response, these stimuli are rendered equivalent. However, when other responses are considered, these would not be equivalent: We can eat the actual apple but we cannot eat the word "apple" (for similar examples, see Horne & Lowe, 1996; Sidman, 1994; and Tonneau, 2001). This fact has challenged the scope of stimulus equivalence conceptualizations that deal with complex verbal phenomena of this sort. A solution that has been proposed to the problem exemplified by the apple is that stimuli can belong to different classes according to the context. In another similar example, Kennedy and de Gaulle are members of the same class in the context of occupations, because both of them were politicians (i.e., as separated from other stimuli, such as painters like Constable and Monet—notice that the occupation is what establishes the partition between the class of politicians and the class of painters). However, these are not members of the same class in the context of nationalities, as each had different nationalities (Sidman, 1986). This example suggests that equivalence is determined by the context or that class membership can be contextually controlled. Sidman and colleagues presented an analogous example of contextual control with arbitrary relations (Bush et al., 1989; Lynch & Green, 1991). The concept of contextual control led to studying conditional discriminations in which the response is controlled by the sample and an additional stimulus. Pérez-González and Serna (1993, 2003) taught AB conditional discriminations (i.e., select B1 in the presence of A1 and select B2 in the presence of A2). Then, they taught to match stimuli that have been matched before (e.g., match A1 to B1) in the presence of a stimulus X1 and to select the alternative comparison (e.g., match A1 to B2) in the presence of another stimulus X2. Therefore, correct selections depended on the presence of two stimuli. A novel type of emergence was demonstrated when a new conditional discrimination CD was taught and participants demonstrated selections of the D stimulus in the presence of both the X and the C stimuli. This outcome was possible because the functions of X1, equivalent to telling the participant "select the same as before," and X2, equivalent to telling him/her, "select the alternative comparison," transferred to the stimuli C and D, which had the same relation among them than stimuli A and B. By definition, the X–AB and the X–CD are denominated second-order conditional discriminations, because both the contextual stimulus (either X1 or X2) and the sample (e.g., either C1 or C2) control comparison responding. This emergence process has been replicated (e.g., Alonso-Álvarez & Pérez-González, 2017, 2018; Meehan & Fields, 1995; Pérez-González & Martínez, 2007; Serna & Pérez-González, 2003). Other types of contextual control were subsequently demonstrated (Pérez-González, Álvarez, et al., 2015). Moreover, stimuli that function as contextual stimuli, but are different and have been taught with different stimuli, become functionally identical (Pérez-González, Díaz, et al., 2015). Additional emergence processes were demonstrated with the X1 and X2 functioning as comparisons, similar to responding "yes" (X1) when the two stimuli in the sample are related to one another (e.g., C1 and D1), and "no" (X2) when these stimuli are not related (e.g., Carpentier et al., 2000, 2002a, 2002b; Junior et al., 2001; Junior & Costa, 2003; Pérez-González, 1994).

All the mentioned types of learning-set and emergence have been demonstrated with second-order conditional discriminations. Wulfert et al. (1994) conducted the only study we know that demonstrated comparison selections by three stimuli in arbitrary relations—third-order conditional discriminations—and emergence. They first taught three conditional discriminations AB, AC, and AD and probed the emergence of symmetry and equivalence (e.g., Sidman & Tailby, 1982). Then, they added a second-order, or contextual stimulus. In the presence of a blue background, the relations remained the same as before; in the presence of a red background, samples A were presented with three stimuli B, C, D; now the correct comparison was the same with the same numeric notation as the sample (e.g., in the presence of sample A1, comparisons B1, C1, and D1 were presented and B1 was correct), and probed the emergence of symmetry and equivalence. Therefore, a partition among stimuli was made in the presence of red (with class A1, B1, C1, and D1, class A2, B2, C2, and D2, etc.) and another partition was made in the presence of blue (with class A1, B1, B2, and B3, class A2, C1, C2, and C3, etc.) Finally, they introduced a tone as a third-order stimulus. In the presence of Tone 1, the relations remained as in the previous phase; in the presence of Tone 2, the relations reversed (thus, for example, Tone 2 and red controlled the same relations as the absence of tones and background colors). They also probed symmetry and transitivity. Altogether, nine participants in two experiments learned the third-order conditional discrimination and demonstrated emergence of the contextually controlled and changing stimulus relations.

In the present study we introduced for the first time an experimental procedure involving a complex discrimination that can produce a novel type of emergence with arbitrary relations. The procedure is illustrated in Fig. 1. Conditional discriminations AB and CD were intended to teach basic (equivalence)sound–symbol relations. Here, the A and C stimuli were spoken syllables in Japanese. The B and D stimuli were the corresponding written characters in Japanese. Conditional-discrimination CA–D–B (see Fig. 2) was a third-order conditional discrimination (or a conditional discrimination with three stimuli in the sample—C, A, and D). The C and A spoken syllables indicated which comparison to select given a D sample. Here, two possibilities arise: First, the sample D of the trial was the one indicated by C (e.g., D1 was related to C1, as established in conditional discrimination CD); then, the correct comparison was the one indicated by A (e.g., C1 and A1 were the auditory samples and D1 the visual sample in that trial, then the correct comparison is B1, because D1 was related to C1 in CD and B1 was related to A1 in AB). In other words, if the D stimulus was the correct comparison in CD, then the correct comparison in CA–D–B was the correct comparison in the presence of A in AB. Second, the sample D of the trial *was not* the one indicated by C (e.g., D2 was not related to C1 in conditional discrimination CD); then, the correct comparison was the stimulus unrelated to A (e.g., C1 and A1 were the auditory samples and D2 the visual sample in that trial, then the correct comparison is B2, because D2 was not the stimulus related to C1 in CD). In other words, if the D stimulus was the incorrect comparison in conditional discrimination CD (e.g., in the presence of C1, D2 was the *incorrect* comparison), then the correct comparison in CA–D–B was the *incorrect* comparison in the presence of A in AB (e.g., in the presence of A1, the incorrect comparison was B2 and because of that, it was the correct comparison in CA–D–B). For simplicity, we will use the terms *related* and *unrelated*.

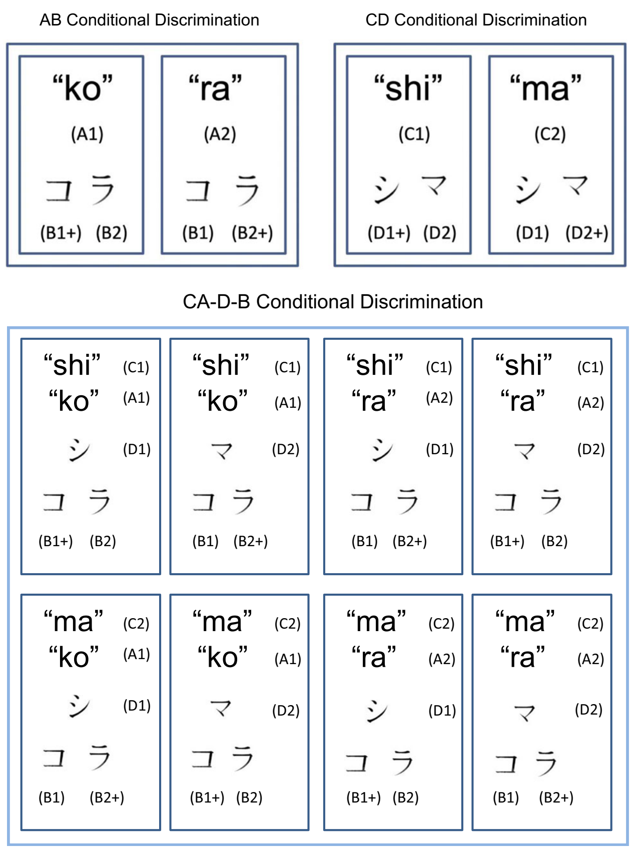


Fig. 1 Conditional discriminations taught with Set 1

An initial goal of the present study was to teach the third-order conditional discrimination outlined above to children, as a demonstration that the discriminative processes necessary for learning this conditional discrimination may be sufficient for achieving such a complex level of discriminative control.

The second and main goal of the present study was to explore the emergence of a novel third-order conditional discrimination. To that goal, we used novel stimulus sets with new spoken sounds and visual symbols and taught the corresponding single-sample conditional discriminations necessary for teaching the sound–visual symbol relations; thereafter, we probed the emergence of the third-order conditional discrimination with the new symbols (see Fig. 2). Even though the third-order conditional discriminations with the new symbols did not share any stimulus with the taught third-order conditional discrimination, we hypothesized that the novel conditional discrimination could emerge based on the collection of relations necessary for responding to the third-order conditional discriminations. In other words, it is possible that learning the first third-order conditional discrimination implies not only responding to particular stimuli relations, but also learning a *set of relations* that encompasses the simple stimulus relations established among the eight elements of the conditional discrimination—as shown by the five stimuli implied in each instance of the conditional discrimination. In this case, learning to select comparison B1 given the C1–A1–D1 stimuli in the sample (and other instances of that conditional discrimination) can also imply learning a generalized skill consisting of the following: given stimuli X and Y, if a stimulus related to X is also present (the visual sample), then select the comparison related to Y. This is true for any stimulus set with the only condition that stimulus X and the visual sample are related to one another and stimulus Y and the selected comparison are as well related to one another. A second generalized skill is also necessary for the cases in which the stimulus related to X is not present as the visual sample, as explained above.

As a result, we taught the first third-order conditional discrimination and the two related first-order conditional discriminations with the Japanese syllables and we probed generalization with stimulus sets with a completely different

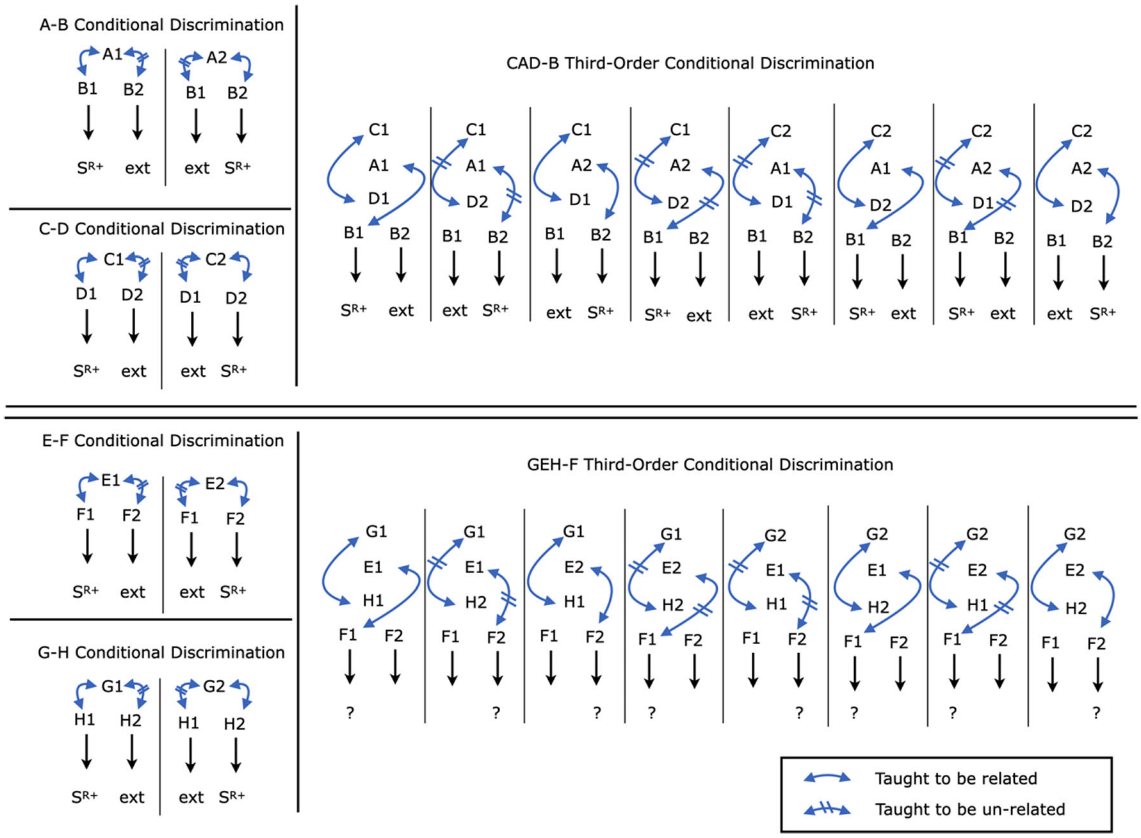


Fig. 2 Conditional discriminations taught (AB, CD, CAD-B, EF, and GH) and probed (GEH-F). In half of the discriminations of the CAD-B conditional discrimination, the sample D of the trial was the one indicated by C (e.g., D1, related to C1 as taught in conditional discrimination CD); then, the correct comparison was the one indicated by A (e.g., B1, related A1 as taught in conditional discrimination AB). In the remaining half of the discriminations, the sample D of the trial *was not* the one indicated by C (e.g., D1, was unrelated to C1 in conditional discrimination CD); then, the correct comparison was the one unrelated to A (e.g., B2, unrelated to A1). Analogous relations exist among the AB, CD, and CAD-B conditional discriminations and the EF, GH, and GEH-F conditional discriminations

topography: spoken Nahuatl[1] words and their corresponding written logograms. Moreover, with the purpose of emphasizing the discriminative processes involved in this complex skill and in order to diminish the influence of the participants' previous history in learning the third-order conditional discrimination and demonstrating the emergence of the other discriminations, we conducted the study with 8-year-old children and we minimized the use of instructions.

Method

Participants

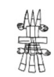
Two 8-year, 2-month, normal-developing girls participated: Elisa and Marta. They spoke Spanish and attended a public school in Oviedo, Spain. They were selected among the children with parental permission of a classroom who volunteered to participate and had learned conditional discriminations in pilot probes for other studies. They were not familiar with Japanese or Nahuatl languages, because they were not exposed to these languages prior to the start of the study.

Materials

Four stimulus sets were used (see Fig. 3). Set 1 was used for teaching. The stimuli consisted of spoken and written Japanese Katakana syllables corresponding to the sounds "ko," "ra," "shi," and "ma." Sets 2, 3, and 4 were used to probe transfer. They consisted of spoken names and their corresponding symbols in Nahuatl. Sets 2–4 were used for probing generalization. Set 2 consisted of the words "tepec" (hill), "ameyalla" (spring), "coatl" (snake), and "ollin" (movement). Set 3 consisted of the words "tecpatli" (a plant), "acatl" (feather), "mazatl" (dear), and "mayahuel" (jinx). Set 4 consisted of the words "miquiztli" (dead), "nezotli" (ritual), "omitl" (bone), and "omeyocan" (paradise). The children did not know the meaning of the syllables or the words—even the experimenters knew only a few.

[1] A language spoken and written in Mexico from ancient times (see https://en.wikipedia.org/wiki/Nahuatl).

Fig. 3 Stimuli used in Set 1, for teaching, and in Sets 2–4, for probing

Set 1 Japanese	A1-B1 ko コ	A2-B2 ra ラ	C1-D1 shi シ	C2-D2 ma マ
Set 2 Nahuatl	E1-F1 tepec 	E2-F2 ameyalla 	G1-H1 coatl 	G2-H2 ollin 
Set 3 Nahuatl	I1-J1 tecpatli 	I2-J2 acatl 	K1-L1 mazatl 	K2-L2 mayahuel 
Set 4 Nahuatl	M1-N1 miquiztli 	M2-N2 nezotli 	O1-P1 omitl 	O2-P2 omeyocan 

The symbols were black, 3 x 3 cm, printed on covered white cards with plastic transparency 22 cm wide x 15 cm high. Each card contained the two visual comparisons of a conditional discrimination, printed at about 6 cm apart, symmetrical by means of the vertical axis of the card and about 3 cm from the bottom. Some cards also contained a visual sample stimulus, centered by respect to the vertical axis of the card, 3 cm from the top of the card and 3 cm above the comparisons.

Procedure

Overview

We taught first conditional discriminations AB and CD with the Japanese syllables of Set 1. The AB and CD conditional discriminations consisted of sound-printed syllable relations, which provided the basic skills for learning appropriately the third-order conditional discrimination CA–D–B.

Second, we probed the generalization of selecting comparisons according to three antecedent stimuli as in CA–D–B with another stimulus set: the Nahuatl words of Set 2. Thus, we taught sound–printed word relations with conditional discriminations EF and GH to provide the basic skills necessary for the emergence of the third-order conditional discrimination. Finally, we probed the GE–H–F third-order conditional discrimination. We repeated teaching additional sound–printed words relations with other Nahuatl words (IJ, KL, and IK–J–L discriminations and MN, OP, and MO–N–P conditional discrimination) in order to obtain two replications of the emergence of the third-order conditional discrimination.

Conditional Discriminations with Set 1

Auditory–visual conditional discrimination AB Auditory syllables “ko” (A1) and “ra” (A2) alternated as samples and the printed syllables corresponding to “ko” (B1) and “ra” (B2) were the comparisons. Selections of printed syllable B1 when the experimenter said “ko” and selections of printed syllable B2 when the experimenter said “ra” were considered correct. Selections of the alternative comparison were considered incorrect.

Auditory–visual conditional discrimination CD Auditory syllables “shi” (C1) and “ma” (C2) alternated as samples and the printed syllables corresponding to “shi” (D1) and “ma” (D2) were the comparisons. Selections of printed syllable corresponding to “shi” when the experimenter said “shi” and selections of printed syllable corresponding to “ma” when the experimenter said “ma” were considered as correct. Selections of the alternative comparison were considered as incorrect.

Auditory–auditory–visual–visual conditional discrimination CA–D–B The eight combinations of two C syllable sounds (either C1 or C2), two A syllable sounds (either A1 or A2), and two D printed syllables (either D1 or D2) were presented across trials as a three-stimuli sample. The two B printed syllables (B1 and B2) were the comparisons. The two spoken syllables C and A were intended to *indicate* to the child which printed syllable B to select in the presence of a printed syllable D (e.g., “shi-ko” [C1–A1]) was as to indicate “in the presence of the printed syllable corresponding to “shi,” select the printed syllable comparison corresponding to “ko”). This gave way to two trial types: (1) The printed syllable D was the one indicated by C (i.e., the printed syllable corresponding to “shi” [D1] was present in the trial together with “shi-ko” [C1–A1]); then, the correct comparison was the printed syllable indicated by A (here, the printed syllable corresponding to “ko” [B1]). (2) The printed syllable D was *unrelated* to the one indicated by C (i.e., the printed syllable corresponding to “ma” [D2] was present in the trial together with “shi-ko” [C1–A1]); then, the correct comparison was the printed syllable *unrelated* to the one indicated by A (here the printed syllable unrelated to "ko" [B2]). Such contingency was planned in this way so that that every stimulus in the sample would control comparison selection. As observed in Fig. 2, all combinations of C, A, and D stimuli were necessary for making comparison selection dependent upon all three C, A, and D stimuli presented in each trial (in the event that in a given trial the D stimulus was related to the C stimulus—as C1 and D1—both stimuli would have been irrelevant, because the correct B comparison would be the one indicated by A—i.e., B1 would be correct in the presence of A1, no matter what C or D stimuli would be present in the trial).

Conditional Discriminations with Set 2

Auditory–visual conditional discrimination EF Auditory words "tepec" (E1) and "ameyalla" (E2) alternated as samples and the printed symbols corresponding to tepec (F1) and ameyalla (F2) were the comparisons. Selections of printed symbol F1 when the experimenter said "tepec" and selections of printed symbol F2 when the experimenter said "ameyalla" were considered as correct. Selections of the alternative comparison were considered as incorrect.

Auditory–visual conditional discrimination GH Auditory words "coatl" (G1) and "ollin" (G2) alternated as samples and the printed symbols corresponding to coatl (H1) and ollin (H2) were the comparisons. Selections of printed symbol H1 when the experimenter said "coatl" and selections of printed symbol H2 when the experimenter said "ollin" were considered as correct. Selections of the alternative comparison were considered as incorrect.

Auditory–auditory–visual–visual conditional discrimination GE–H–F This conditional discrimination was analogous to conditional discrimination CA–DB. The eight combinations of two G spoken words (either G1 or G2), two E spoken words (either E1 or E2), and two H symbols (either H1 or H2) were presented across trials as a three-stimuli sample. The two F symbols (F1 and F2) were the comparisons. The two spoken words G and E were *indicated* to the child what printed word F to select in the presence of a printed word H (e.g., "coatl-tepec" [G1–E1]) was as to indicate "in the presence of the printed word corresponding to "coatl," select the printed word comparison corresponding to "tepec"). When the printed word H was the one indicated by G (i.e., the printed word corresponding to "coatl" [H1] was present in the trial together with "coatl–tepec" [G1–E1]); then, the correct comparison was the printed word indicated by E (here, the printed word corresponding to "tepec" [F1]). When the printed word H was *not* the one indicated by G (i.e., the printed word corresponding to "ollin" [H2] was present in the trial together with "coatl-tepec" [G1–E1]); then, the correct comparison was *not* the printed word indicated by E (here the corresponding to "tepec" [F1]), instead, the correct comparison was the other one (i.e., the corresponding to "ameyalla" [F2]).

Conditional Discriminations with Sets 3 and 4

With Sets 3 and 4, the conditional discriminations were analogous to Set 2, but the IJ, KL (in Set 3) and MN, OP (in Set 4), conditional discrimination were taught and IK–J–L and MO–N–P conditional discriminations were probed (in Sets 3 and 4, respectively). The stimuli appear in Fig. 3.

Setting

Sessions were conducted in a quiet room located at the upper floor of a public school in Oviedo. An experimenter (either an author or an assistant) and the child sat side by side in front of a table, with the experimenter slightly behind the child so that the child could not see him.

Instructions

We endeavored that verbal instructions did not influence performance; therefore, we reduced these to a minimum. The child was told in Spanish that she was to play a game with pictures and that the experimenter would not provide any further explanation at that time. She had just to do correctly all the time. Before the emergence probes, the experimenter told the child that no further explanations would be provided but she should try to be correct throughout.

Trial Procedure

In every trial, the experimenter placed the card with the visual stimuli on the table, in front of the child, and spoke the auditory stimulus or stimuli. Then he or she waited for the child's response for a period of about 10 s; the children always selected within that period. In the trials with programmed differential consequences, correct responses were followed by expressions such as, "Very good," "Excellent," or "Right," which functioned as reinforcers in this and other similar experiments conducted with this population (hereafter, *positive consequences*). Incorrect responses were followed by a short simple "No," which functioned as a punisher in this context (hereafter, *negative consequences*). In both cases, the card on the table was removed and the next trial followed. In the trials with no programmed differential consequences, all responses were followed by the removal of the card and the presentation of the next trial.

The left-right location of the comparisons was random, except for Phases 1 and 2 of teaching conditional discriminations AB, CD, EF, and GH, in which comparison 1 (e.g., B1) was on the left and comparison 2 (e.g., B2) was on the right.

The left–right location, however, was counterbalanced across four to eight trials.

Session Procedure

Sessions varied in duration according to the time available in the school and the phase of teaching or probing. Sessions were typically about 30 min long. At the end of each session the child received two to four collection stamps, roughly according to her performance on the teaching phases.

Specific Procedures

The teaching and testing was conducted in several phases; each one was typically composed of several steps. An overview of the characteristics of the phases appears in Table 1.

Procedures with Set 1: Teaching with Japanese Syllables

Phase 1: Teaching auditory–visual conditional discrimination AB For teaching single-sample conditional discriminations, we used the revised combined blocking procedure (Rodríguez-Mori & Pérez-González, 2005, which is a short version of a procedure useful to teach conditional discriminations to children with autism described by Pérez-González & Williams, 2002, and Williams et al., 2005). In *Step 1*, only sample A1 ("shi") was spoken to the child and the card with comparison B1 on the left and comparison B2 on the right was presented in all trials (i.e., the comparisons were at *fixed locations*). In the first two trials, the experimenter presented a prompt by telling the child "here" and pointing with the finger to the correct comparison. If the child anticipated the prompt (which was commonly observed after the second conditional discrimination) the trial was considered correct without prompt. After a criterion of three consecutive correct responses with no prompt, *Step 2* followed. Step 2 was as Step 1, except that only sample A2 ("ra") was presented. *Step 3* was as Steps 1 and 2, except that samples A1 ("shi") and A2 ("ra") were presented in a quasi-random sequence (they were random with the restriction that every sample appeared two times every four trials), there were no prompts and the next step started after the child responded correctly on 12 consecutive trials. *Step 4* was as Step 3 except that comparisons B1 and B2 were presented at random left–right locations, with the restriction that every combination of sample and locations of the B stimuli were presented four times every four trials (e.g., A1–[B1 B2], A1–[B2 B1], A2–[B1 B2], A1–[B2 B1]).

Phase 2: Teaching auditory–visual conditional discrimination CD This conditional discrimination was taught as conditional discrimination AB.

Phase 3: Teaching auditory–visual–visual conditional discrimination skills With this phase we aimed to teach two skills: (1) that the relations among the D and B stimuli varied according to other parameters; in other words, the correct relations had to be D1–B1 and D2–B2 on some occasions and D1–B2 and D2–B1 on other occasions; (2) that the auditory stimulus A (A1 or A2) indicated which visual comparison B was correct. The trial format was as in a visual–visual conditional discrimination with stimuli D as samples and stimuli B as comparison. The important novelty at this stage was that auditory syllables "ko" (A1) or "ra" (A2) prompted the correct comparison. We performed this procedure along 10 steps.

In Steps 1 to 3, we taught D1–B1 and D2–B2 relations. In *Step 1*, visual sample D1 appeared on all trials and B1 and B2 were the comparisons. In the first two trials, the experimenter said "ko" (A1) immediately after presenting the card with the visual stimuli. As the child had learned to select B1 in the presence of A1 in AB, we expected that the children would likely select B1. The goal was to remove the auditory stimulus A1 for the control of correct responding transfer from auditory stimulus A1 to visual stimulus D1. Hence, the A1 stimulus was presented the first two trials but it was not presented from the third trial onwards. After the child selected B1 in three consecutive trials, Step 2 started. *Step 2* was as in Step 1, except that the visual sample was D2, the correct comparison was B2, and the experimented said "ra" (A2) in the first two trials. The goal of *Step 3* was that the performance learned in Steps 1 and 2 continued when the two visual stimuli alternated. Thus, we did not present auditory stimuli, visual stimuli D1 and D2 alternated as samples, and B1 and B2 were the comparisons. Selections of B1 in the presence of D1 and selections of B2 in the presence of D2 were considered as correct responses. After four consecutive correct responses, the experiment continued in Step 4. Because the first participant, Elisa, did not reach criterion within eight trials in Step 3, Steps 1–3 were repeated several times with her. Moreover, the procedure was modified for the second participant: Steps 1–2 were presented with the comparisons at fixed locations, a new step (Step 2b) was added with the stimuli D1 and D2 alternating as samples and the comparisons at fixed locations, and the criterion in Steps 2a and 3 was making eight consecutive correct responses.

In *Steps 4 to 6*, we taught D1–*B2* and D2–*B1* relations. These steps were analogous to Steps 1–3, but selections of B2 in the presence of D1 and selections of B1 in the presence of D2 were considered as correct responses. Thus, spoken syllable "ra" prompted selections of B2 in the presence of D1 in Step 4 and spoken syllable "ko" prompted selections of B1 in the presence of D2 in Step 5. The criterion in Step 6 was to obtain three consecutive responses for the first participant and eight consecutive responses for the second participant.

Table 1 Conditions in each phase of the study

Step	Auditory samples	Visual sample & correct comparison	Location	Prompts	Criterion
Phase 1					
1	A1	B1	Fixed	2	3
2	A2	B2	Fixed	2	3
3	A1 or A2	B1 or B2	Fixed	-	12
4	A1 or A2	B1 or B2	Random	-	12
Phase 2					
1	C1	D1	Fixed	2	3
2	C2	D2	Fixed	2	3
3	C1 or C2	D1 or D2	Fixed	-	12
4	C1 or C2	D1 or D2	Random	-	12
Phase 3					
1	A1 (two first trials)	D1-B1	Random-Fixed		3
2	A2 (two first trials)	D2-B2	Random-Fixed		3
2b	None	D1-B1 or D2-B2	Fixed		8
3	None	D1-B1 or D2-B2	Random		4-8
4	A2 (two first trials)	D1 -B2	Random-Fixed		3
5	A1 (two first trials)	D2- B1	Random-Fixed		3
5b	None	D1-B2 or D2-B1	Fixed		8
6	None	D1-B2 or D2-B1	Random		4-8
7	A1 (first trial)	D1-B1 or D2-B2	Random	-	4
8	A2 (first trial)	D1-B1 or D2-B2	Random	-	4
9	A2 (first trial)	D1-B2 or D2-B1	Random	-	4
10	A1 (first trial)	D1-B2 or D2-B1	Random	-	4
Phase 4					
1	C1 - A1	D1-B1 or D2-B2	Random	-	3
2	C2 - A2	D1-B1 or D2-B2	Random	-	3
3	C1 - A2	D1-B2 or D2-B1	Random	-	3
4	C2 - A1	D1-B2 or D2-B1	Random	-	3
5	C1 - A1	D1-B1 or D2-B2	Random	-	3
6	C2 - A2	D1-B1 or D2-B2	Random	-	3
7	C1 - A2	D1-B2 or D2-B1	Random	-	3
8	C2 - A1	D1-B2 or D2-B1	Random	-	3
9	All C-A combinations	All D-B combinations	Random	-	15/16 *

*Probe. The 16 trials were presented

In Steps 7–10(1) the prompts were decreased and (2) the number of trials with a set of relations were reduced, with the purpose of making comparison selection more sensitive to brief presentations of the auditory syllables A1 or A2. Therefore, the prompts (the presentation of A1 or A2) presented in each step were reduced to just one and blocks of either the D1–B1 and D2–B2 relations or the D1–B2 and D2–B1 relations were presented with a criterion of only four consecutive correct responses (instead of a minimum of 3 + 3 + 4 = 10 or 3 + 3 + 8 = 14 trials in Steps 1–3 and in Steps 4–6, respectively). In Steps 7 and 8, the D1–B1 and D2–B2 relations were taught; in Steps 9 and 10, the D1–B2 and D2–B1 relations were taught (see details in Table 1). In *Step 7*, the experimenter said "ko" (A1), the visual sample was D1, and the correct comparison was B1 in the first trial. In *Step 8*, the experimenter said "ra" (A2), the visual sample was D2, and the correct comparison was B2 in the first trial. In *Step 9*, the experimenter said "ra" (A2), the visual sample was D1, and the correct comparison was B2 in the first trial. In *Step 10*, the experimenter said "ko" (A1), the visual sample was D2, and the correct comparison was B1 in the first trial. After the child reached criterion in Step 10, Steps 7–10 were repeated in a new order (7, 9, 8, and 10 with one participant and 9, 7, 8, and 10 with the other participant), with the purpose of alternating more often the two types of relations (D1–B1 and D2–B2, on one hand, and the D1–B2 and D2–B1, on the other).

Phase 4: Teaching the auditory–auditory–visual–visual conditional discrimination CA–D–B With this phase we attempted to teach to select comparisons B1 and B2 in the presence of D1 or D2 according to two syllables spoken by the experimenter. The auditory stimulus A indicated which visual comparison B was correct (as in Phase 3). In addition, the auditory syllable C indicated the visual sample D in which presence the visual comparison B indicated by A was correct, as explained above. See conditional discrimination CA–D–B in Fig. 2.

We performed this procedure with differential consequences along 9 Steps. In *Steps 1–8*, a combination resulting of interrelating C1 or C2 with A1 or A2 was presented in all trials (e.g., C1 and A1). Moreover, D1 or D2 alternated randomly across trials as well as the location of the B stimuli, with the restriction that each D and B location combination was presented every four trials. The criterion to advance to the next trial was to respond correctly in three consecutive trials.

After a child reached criterion in Step 8, Steps 1–8 were repeated in a random order, until at least five steps were completed with no errors. After this criterion was accomplished, Step 9 was presented.

Step 9 had just 16 trials. The eight combinations of auditory syllables C1 or C2, auditory syllables A1 or A2, and visual stimuli D1 or D2 were presented twice, once with B1 on the left and B2 on the right and once with the reverse B1 and B2 locations. The eight combinations appear in Fig. 1. All 16 combinations were randomly presented. If the child obtained 15 out of 16 correct responses, Set 2 began. If not, Step 9 was repeated for a maximum of three times.

Procedures with Sets 2–4: Teaching the Prerequisites and Probing with Nahuatl Words

The procedure with Set 2 had three phases: in Phases 1 and 2 we taught the auditory–visual conditional discriminations *EF* and *GH*. They were taught just as conditional discriminations AB and CD with Set 1. In Phase 3, we probed the *auditory–auditory–visual–visual conditional discrimination GE-H-F;* the 16 trials were presented as conditional discrimination CA–D–B, except that child's responses were not followed by differential consequences. The procedure with Sets 3 and 4 were analogous to that with Set 2, but conditional discriminations IJ and KL were taught and conditional discrimination IK–J–L was probed in Set 3, and conditional discriminations MN and OP were taught and conditional discrimination MO–N–P was probed in Set 4).

Additional Data Recording and Interobserver Agreement

All precautions were taken in order to prevent potential cueing from the experimenter. Another experimenter (the other author or the assistant) was present in the room on some sessions to record data in order to calculate interobserver agreement. Moreover, some sessions were videotaped, especially these with the emergence probes. Careful observations by the second experimenter and subsequent analysis of the tapes indicated that the children's behavior was always controlled by the experimental stimuli and not by other sources. Data for interobserver agreement was recorded in 531 of a total of 1,173 trials (45.3%). A total of 315 trials corresponded to of Elisa (58% of those that she received recorded in four of nine sessions) and 216 trials corresponded to Marta (37% of those that she received recorded in two of four sessions). The two observers agreed (i.e., they recorded the same response) on 530 trials. Thus, interobserver agreement [(agreements / (agreements + disagreements) x 100] was 99.8%. The procedure was conducted according to the experimental plan with the exception that the experimenter presented four additional trials in Step 7 of Phase 4 for Marta and that he presented a consequence after a correct response (i.e., a putative reinforcer) in the first trial of the probe with the second Nahuatl set (Set 3) for Elisa; for that reason, Elisa received an additional probe with a third Nahuatl set.

Results

Elisa

Learning with Set 1

In *Phases 1 and 2*, Elisa learned the *AB and CD auditory–visual conditional* discriminations with no errors, in just 69 trials. In *Phase 3*, with the *auditory–visual–visual conditional discrimination,* she learned with no errors in Steps 1 and 2, but she failed to master Step 3; therefore, Steps 1–3 were repeated until she reached criterion on Steps 1–3 by the fourth cycle. Thereafter, she learned Steps 4 and 5 but did not master Step 6; therefore, Steps 4–6 were repeated. She reached criterion on all steps. Thereafter, she learned the discriminations of Steps 7–10. These steps were repeated in a different order; Elisa went through these steps with no errors. In *Phase 4,*with the *auditory–auditory–visual–visual conditional discrimination CA–D–B*, she reached criterion on Steps 1–8 with just one error; then, these steps were repeated in a different order.

She reached criterion in all steps with no errors in three of them. Overall, she responded with no errors in seven out of eight steps with the D1–B1 and D2–B2 relations and in four out of eight steps with the D1–B2 and D2–B1 relations. Thus, she reached criterion to advance to Step 9. In Step 9, she responded correctly to all 16 probe trials.

Generalization to Set 2

Elisa learned the *auditory–visual conditional discriminations EF and GH* with no errors, in just 65 trials. In the probe of the *auditory–auditory–visual–visual conditional discrimination GE–H–F,* she responded correctly to all 16 probe trials (see Fig. 4).

Generalization to Set 3

Elisa learned the *auditory–visual conditional discriminations IJ and KL* with no errors, in just 65 trials. In the *emergence probe of the auditory–auditory–visual–visual conditional discrimination* IK–J–L, she responded correctly to all 16 probe trials. The first response, however, was followed by a positive consequence due to an experimenter's mistake. Because 14 of the 16 remaining trials had different sample combinations, we believe that this potential reinforcement had little influence in the remaining trials of the test. In any case, with the purpose of having complete evidence of emergent responding, we decided to conduct an additional generalization probe, with Set 4.

Generalization to Set 4

Elisa learned the *auditory–visual conditional discriminations MN and OP* with no errors, in just 62 trials. In Step 2, with the M2–N2 relations she responded before the experimenter provided the prompt, the first response is likely to have been produced by exclusion (e.g., Stromer, 1986, 1989) after learning to select comparison N1 to M1 in Step 1. In the emergence probe of the *auditory–auditory–visual–visual conditional discrimination MN–O–P,* she responded correctly to 7 of the 16 probe trials. An analysis of her performance showed that she responded correctly in five of the first eight trials and that performance decreased to two correct responses in the next eight trials. On the next day, we programmed to present Step 4 of conditional discrimination MN and OP (Phases 1 and 2). Elisa made 7 out of 12 correct responses in Step 4 of conditional discrimination MN; thus, the session continued on Step 1 of this conditional discrimination. She mastered conditional discrimination MN from Step 1 to Step 4 in 53 trials. Thereafter, the session continued on Step 4 of conditional discrimination OP and she made 12 out of 12 correct responses. In the probe of conditional discrimination MO–N–P, she made 12 correct responses in 16 trials. An analysis of her performance in two halves showed that she responded correctly in five of the eight the first trials and seven of the next eight trials. Thus, correct responding was increasing. We immediately repeated the probe of conditional discrimination MO–N–P and Elisa responded correctly to all 16 trials.

Marta

Learning with Set 1

In *Phases 1 and 2,* Marta learned the AB and CD *auditory–visual* conditional discriminations with no errors, in just 67 trials. In *Phase 3, with the auditory–visual–visual conditional discrimination skills,* she learned Steps 1–6 with all correct responses except for two errors, in just 59 trials. Thereafter, she learned the discriminations of Steps 7–10. These steps were repeated in a different order; Marta went through these steps in 91 trials, with 61 correct responses. She made errors in four of the eight steps. In *Phase 4,* with the *auditory–auditory–visual–visual conditional discrimination CA–D–B,* Marta reached criterion on Steps 1–8, although with errors in four of the eight steps; then, these steps were repeated in a different order. She reached criterion in all steps with no errors in four of them. Steps 1–8 were repeated again in a different order. She also reached criterion with no errors in four of them. Steps 1–8 were repeated once more in a different order one more time. She also reached criterion with no errors in

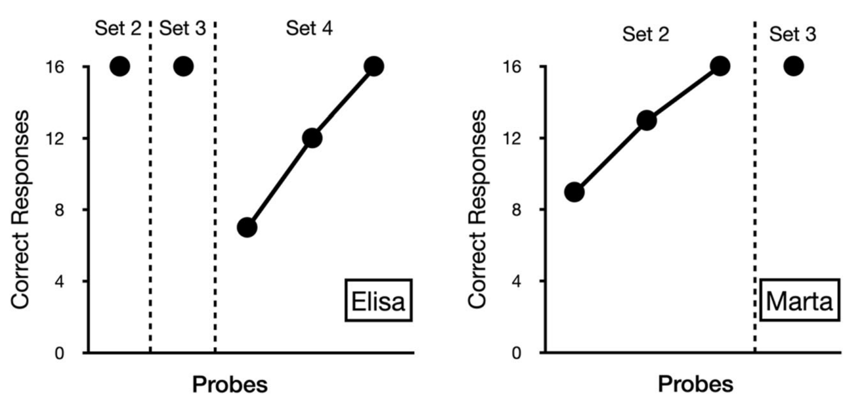


Fig. 4 Results in the generalization probes of the CAD-B conditional discrimination

four of them. Again, Steps 1–8 were repeated once more in a different order. This time, she responded with no errors in five of the eight steps; thus, she reached criterion to advance to Step 9. In Step 9, she made all 16 correct responses.

Generalization to Set 2

Marta learned the *auditory–visual conditional discriminations EF and GH* with no errors, in just 64 trials. In the emergence probe of the *auditory–auditory–visual–visual conditional discrimination GE–H–F,* Marta responded correctly to 9 of the 16 probe trials (see Fig. 4). Therefore, the probe was repeated again; she responded correctly to 13 of 16 trials. The probe was repeated again and she responded correctly to all 16 trials.

Generalization to Set 3

Marta learned the *auditory–visual conditional discriminations IJ and KL* with no errors, in just 64 trials. In the emergence probe of the *auditory–auditory–visual–visual conditional discrimination IK–J–L*, she responded correctly to all 16 probe trials.

Discussion

The initial goal of the present study was to explore learning a third-order conditional discrimination. The two children learned the conditional discriminations with Japanese syllables with few errors. They learned the simple conditional discriminations AB and CD almost without errors. They learned the third-order conditional discrimination with errors, but both children reached the mastering criterion for this conditional discrimination. These results indicate that such complex procedure, which involved a number of steps, was useful for teaching this conditional discrimination to the 8-year-old children who participated.

The main goal of the present study was to explore emergence of novel third-order conditional discriminations. Both children demonstrated the emergence of the novel third-order conditional discriminations with Nahuatl words as stimuli with two stimulus sets. These results demonstrated the emergence of this type of conditional discrimination. The emergence shown by the participants of the present study provides some novel characteristics in comparison with the types of emergences demonstrated so far. The most interesting novelty is that the emergent conditional discriminations do not share any stimulus with the first third-order conditional discrimination. Instead, the taught and probed third-order conditional discriminations share the context (including the physical arrangement) as well as the set of relations of each pair of stimuli in the conditional discrimination (e.g., the first auditory stimulus related to the sample and the second auditory stimulus related to a comparison; the selection of the comparison indicated by the second auditory stimulus only if the visual sample is related to the first auditory stimulus). This set of relations is the key factor that made possible the emergence of the third-order-conditional discriminations with Nahuatl stimuli. In stimulus equivalence, the stimuli of the emergent conditional discrimination have been taught before and have been related to common stimuli (*nodes*—e.g., A1 is related to C1 because A1 was related to B1 and B1 was related to C1; B1 is the node). Two cases similar to the one of the present research are the yes–no relations shown by Pérez-González (1994) and contextual control (e.g., Pérez-González & Serna, 2003). In these two research reports, comparisons or contextual stimuli were taught with stimulus sets A and B, and they were probed with stimulus sets C and D. The key factor was that stimuli C and D did not have any direct or indirect relation to stimuli A and B; even though, transfer was possible because the contextual stimuli were the same in the taught and the probed conditional discriminations. Serna and Pérez-González (2003) demonstrated another case in which the stimuli tested and probed were different. They taught the XAB conditional discriminations and probed the YCD conditional discriminations. The participants showed consistent responding. The performance varied, however, among participants: some participants, for example, related C1 to D1 and C2 to D2 in the presence of contextual stimulus Y1 and the other participant related C1 to D2 and C2 to D1 in the presence of that contextual stimulus. This performance was possible because there were two ways to respond consistently according to the contextual stimulus. In the present study, however, the participants showed accurate, predicted performance, in a unique way. This type of emergence was possible with the third-order conditional discriminations used here.

Discriminative Processes

Emergence was possible by learning first-, second-, and third-order conditional discriminations. In other words, this complex verbal behavior was the result of purely discriminative process. In particular, the children learned first the first-order conditional discriminations that established sound–visual stimulus relations, in the form of selecting visual stimuli in the presence of a given auditory stimulus (in Phases 1 and 2). Thereafter, they learned to respond to comparisons in the presence of auditory and visual stimuli (in Phase 3). In these phases, the children likely learned three general skills that may be critical: *first,* they learned that the relation between the visual sample and the comparisons varied across steps, i.e., D1 was with B1 on some occasions (such as Steps 1, 7, and 8 of Phase 3) and D1 was with B2 on other occasions (such as Steps 2, 9, and 10 of Phase 3). *Second*, in Phase 3, they learned that the auditory stimuli worked as prompts for the correct comparison, in the sense that they indicated the correct comparison on each occasion; for example, "ko" (A1) indicated that comparison B1 was correct. Thus, at this time the children learned that the auditory stimulus indicated the correct comparison. *Third*, in Phase 4, the children learned that comparisons depended upon the two auditory stimuli. An auditory stimulus was correlated to the comparison (such as it was learned in the previous phase), and that the other auditory stimulus was related to the sample. In this regard, the two children learned this conditional discrimination somewhat faster than those of Phase 3; it is likely that the children also learned in Phase 3 a general skill to select the symbol indicated by the sound, which could have facilitated responding dependent upon the two sounds. Further research should be directed to answer these questions.

Types of Relations between Stimuli

We presented the relations between pairs of stimuli like *related* and *unrelated* for the sake of simplification. There are at least two types of processes that may be involved in the acquisition of the first- and third-order conditional discriminations and in the observed emergences. First, participants had learned both sample–correct comparisons and sample–incorrect comparisons. Carrigan Jr. and Sidman (1992) theorized that learners of a conditional discrimination could learn control by *positive* (correct comparison) or *negative* stimuli (incorrect comparison) in the presence of a particular sample. Further, Johnson and Sidman (1993) demonstrated control by negative stimuli. Likewise, class formation by l, exclussion of positive stimulsihas also been demonstrated (e.g., Plazas & Villamil, 2018). Second, it is possible that the participants had learned just control by positive stimuli (e.g., A1 to B1 in AB). Then, in half of the trials of conditional-discrimination CA–D–B, when the sample D of the trial *was not* the one indicated by C (e.g., D2 was not related to C1 in conditional discrimination CD), the correct comparison was the comparison alternative to the one indicated by A (e.g., C1 and A1 were the auditory samples and D2 the visual sample in that trial, then the correct comparison was B2, because D2 was not the stimulus related to C1 in CD—and B1 was related to A1 in AB); therefore, the correct comparison was the alternative stimulus to B1—which is B2). This type of selection is due to an exclusion process (e.g., Stromer, 1986, 1989; see also a recent demonstration by Alonso-Álvarez & Pérez-González, 2017). It is important to notice that selection by exclusion could be necessary here in order for all stimuli in the sample to accomplish a function regarding comparison selection (if the D stimulus were always the one related to C, then comparison selection would be determined only by stimulus A—hence, that would be a simple conditional discrimination). Which process operated in the present experiment it is impossible to know. Further research could address this question.

Types of Third-Order Conditional Discriminations and Types of Emergence

Third-order conditional discriminations are discriminations that are conditionally controlled by the discriminative stimuli and three additional (*conditional*) stimuli. The minimum arrangement is the one shown in the present study; here, selection between the B discriminative stimuli was controlled by the C, A, and D stimuli presented on each trial. Because two stimuli of each type C, A, and D are necessary across trials, this brings up the number of combinations to 2 x 2 x 2 = 8 combinations for ensuring that comparison selection depends upon each one of the three stimuli presented in each trial. Other combinations are possible, such as those used by Wulfert et al. (1994), which had three comparisons (described above).

According to the procedures used for teaching and probing, several types of emergence arise with third-order conditional discriminations. *First,* it is likely that a third-order conditional discrimination could be taught and that equivalent stimuli can accomplish the same function as one that has been taught. For example, after learning ABC–Dthird-order and A–J (A1–J1 and A2–J2) simple conditional discriminations, the J stimuli can replace the A stimuli in that they could produce the same selections as the A stimuli: if selections of D2 were reinforced in the presence of A1, B2, and C1, then D2 will be also selected in the presence of J1, B2, and C1 (in which J1 replaces A1 in the taught discrimination). This type of emergence has not been demonstrated so far with third-order conditional discriminations, to our knowledge, but it has been demonstrated with second-order conditional discriminations (e.g., Bush et al., 1989; Dougher & Markham, 1994; Lynch & Green, 1991). *Second,* a more complex type of emergence has been demonstrated by Wulfert et al. (1994): After teaching third-order conditional discriminations Tone–Background–A–B and Tone–Background–A–C, they replaced an A, B, or C stimulus with another stimulus of its same class, but the classes varied according to the context (tone and background). Therefore, for example, B3 replaced B1 in the presence of a context and D1 replaced B1 in the presence of another context. Because of this, the resulting type of emergence is more complex than just stimulus substitution (as in the first type). *Third,* the type of emergence shown in the present study cannot be explained by stimulus substitutability. Instead some more complex is necessary, such as the set of relations explained above. Yet, more types of emergence could probably result from learning third-order conditional discriminations.

Limitations and Further Research

The present study describes mainly a demonstration for getting this type of emergence. Further studies should replicate the procedures as well as analyzing variables that can influence learning of third-order conditional discriminations and the emergence processes described here. An interesting endeavor is to analyze further whether the basic discriminative processes described here are enough for learning complex verbal behavior, or if some other verbal behavior processes are necessary for learning this type of discrimination and influence the type of demonstrated emergence. Moreover, they should devise alternative, more efficient, procedures for teaching these discriminations and studying their impact on emergence.

Applications

The children of the present study learned conditional discriminations that are functionally identical to following instructions in Japanese; for example, the "shi-ko" expression spoken by the experimenter was equivalent to say, "if you see 'shi,' then select 'ka,' and children behaviors were consistent with following such instruction. Thereafter, the children followed instructions with the same context with the novel words in Nahuatl; for example, "ollin–tepec," equivalent to "if you see 'ollin,' then select 'tepec.'" Therefore, the children followed novel instructions—the only skills that the children probably needed to learn before the probe in order to follow the new instructions in Nahuatl were the word–symbol relations of the specific stimuli. Thus, the present study can be applied to teaching children to follow instructions. Moreover, the type of emergence shown in the present study was possible for the type of relations established among the stimuli. Therefore, processes that involve teaching and generalization of stimulus relations could benefit from the present study. One such field is that of analogical reasoning, in which the relations among two or more stimuli allow the establishment of relations among stimuli not directly related to the former stimuli.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40732-021-00461-2.

Acknowledgements This research was supported by a grant from the University of Guadalajara and grants SEJ2006-08055, from Ministerio de Ciencia y Tecnología, and PSI2009-08644, from Ministerio de Ciencia e Innovación, Spain, to the first author. The authors thank Tamara Valdés-Martín for its help in recording data for interobserver agreement and the principal and teachers of "Dolores Medio" public school in Oviedo, for their collaboration in the research.

Availability of Data Raw data is available in paper. Spreadsheet data available in electronic format.

We confirm that the information provided is accurate.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. This research was supported by a grant from the University of Guadalajara and grants SEJ2006-08055, of the Ministerio de Ciencia y Tecnología, and PSI2009-08644, of the Ministerio de Ciencia e Innovación, Spain, to the first author.

Declaration

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors. Informed consent was obtained from the parents of all participants included in the study.

References

Alonso-Álvarez, B., & Pérez-González, L. A. (2017). Contextual control over equivalence and exclusion explains apparent arbitrary applicable relational responding in accordance with sameness and opposition. *Learning & Behavior, 45*, 228–242. https://doi.org/10.3758/s13420-017-0258-1.

Alonso-Álvarez, B., & Pérez-González, L. A. (2018). Analysis of apparent demonstrations of responding in accordance with relational frames of sameness and opposition. *Journal of the Experimental Analysis of Behavior, 110*, 213–228. https://doi.org/10.1002/jeab.458.

Arntzen, E. (2012). Training and testing parameters in formation of stimulus equivalence: Methodological issues. *European Journal of Behavior Analysis, 13*(1), 123–135.

Arntzen, E., & Lian, T. (2010). Trained and derived relations with pictures versus abstract stimuli as nodes. *The Psychological Record, 60*(4), 659. https://doi.org/10.1007/BF03395738.

Bush, K. M., Sidman, M., & de Rose, T. (1989). Contextual control of emergent equivalence relations. *Journal of the Experimental Analysis of Behavior, 51*(1), 29–45. https://doi.org/10.1901/jeab.1989.51-29

Carpentier, F., Smeets, P. M., & Barnes-Holmes, D. (2000). Matching compound samples with unitary comparisons: Derived stimulus relations in adults and children. *The Psychological Record, 50*(4), 671–685. https://doi.org/10.1007/BF03395377.

Carpentier, F., Smeets, P. M., & Barnes-Holmes, D. (2002a). Establishing transfer of compound control in children: A stimulus control analysis. *The Psychological Record, 52*(2), 139–158. https://doi.org/10.1007/BF03395420.

Carpentier, F., Smeets, P. M., & Barnes-Holmes, D. (2002b). Matching functionally-same relations: Implications for equivalence-equivalence as a model for analogical reasoning. *The*

Psychological Record, 52(3), 351–312. https://doi.org/10.1007/BF03395435.

Carrigan Jr., P. F., & Sidman, M. (1992). Conditional discrimination and equivalence relations: A theoretical analysis of control by negative stimuli. *Journal of the Experimental Analysis of Behavior, 58*(1), 183–204. https://doi.org/10.1901/jeab.1992.58-183.

Dougher, M. J., & Markham, M. R. (1994). Stimulus equivalence, functional equivalence, and the transfer of function. In S. C. Hayes, L. Hayes, M. Sato, & K. Ono (Eds.), *Behavior analysis of language and cognition* (pp. 71–90). Context Press.

Harlow, H. F. (1949). The formation of learning sets. *Psychological Review, 56*(1), 51–65. https://doi.org/10.1037/h0062474.

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65*(1), 185–241. https://doi.org/10.1901/jeab.1996.65-18.

Johnson, C., & Sidman, M. (1993). Conditional discrimination and equivalence relations: Control by negative stimuli. *Journal of the Experimental Analysis of Behavior, 59*(2), 33–347. https://doi.org/10.1901/jeab.1993.59-333.

Junior, J. L., & Costa, G. G. (2003). Efeitos das respostas de observação diferenciais sobre a aprendizagem de relações condicionais com estímulos complexos [Effects of differential observing responses over the learning of conditional relations with complex stimuli]. *Psicologia: Reflexão e Crítica, 16*(1), 71–84.

Junior, J. L., Costa, G. G., Gonsales, L. F. S., & Golfeto, R. M. (2001). Aprendizagem e emergência de relações condicionais com estímulos modelos complexos [Learning and emergence of conditional relations with complex sample stimuli]. In H. J. Guilhardi, M. B. Pinho Madi, P. Piazzon Queiroz, & M. C. Scoz (Eds.), *Sobre comportamento e cognição: Expondo a variabilidade* (pp. 401–421). ESETec Editores Asociados.

Lynch, D. C., & Green, G. (1991). Development and crossmodal transfer of contextual control of emergent stimulus relations. *Journal of the Experimental Analysis of Behavior, 56*(1), 139–154. https://doi.org/10.1901/jeab.1991.56-139.

Meehan, E. F., & Fields, L. (1995). Contextual control of new equivalence classes. *The Psychological Record, 45*(2), 165–182. https://doi.org/10.1007/BF03395927.

Pérez-González, L. A. (1994). Transfer of relational stimulus control in conditional discriminations. *Journal of the Experimental Analysis of Behavior, 61*(3), 487–503. https://doi.org/10.1901/jeab.1994.61-487.

Pérez-González, L. A., Álvarez, E., Calleja, A., & Fernández, A. (2015). Transfer of three functions of contextual stimuli in conditional discriminations. *The Psychological Record, 65*(2), 277–287. https://doi.org/10.1007/s40732-014-0104-1.

Pérez-González, L. A., Díaz, E., Fernández-García, S., & Baizán, C. (2015). Stimuli with identical contextual functions taught independently become functionally equivalent. *Learning & Behavior, 43*(2), 113–128. https://doi.org/10.3758/s13420-014-0166-6.

Pérez-González, L. A., & Martínez, H. (2007). Control by contextual stimuli in novel second-order conditional discriminations. *The Psychological Record, 57*(1), 117–143. https://doi.org/10.1007/BF03395568.

Pérez-González, L. A., & Serna, R. W. (1993). Basic stimulus control functions in the five-term contingency. *Experimental Analysis of Human Behavior Bulletin, 11*, 52–54.

Pérez-González, L. A., & Serna, R. W. (2003). Transfer of specific contextual functions to novel conditional discriminations. *Journal of the Experimental Analysis of Behavior, 79*(1), 395–408. https://doi.org/10.1901/jeab.2003.79-395.

Pérez-González, L. A., Spradlin, J. E., & Saunders, K. J. (2000). Learning-set outcome in second-order conditional discriminations. *The Psychological Record, 50*(1), 429–442. https://doi.org/10.1007/BF03395364.

Pérez-González, L. A., & Williams, G. (2002). Multi-component procedure to teach conditional discriminations to children with autism. *American Journal on Mental Retardation, 107*(1), 293–301. https://doi.org/10.1352/0895-8017(2002)107<0293:MPTTCD>2.0.CO;2.

Plazas, E. A., & Villamil, C. W. (2018). Formation of new stimulus equivalence classes by exclusion. *Journal of the Experimental Analysis of Behavior, 109*(2), 380–393. https://doi.org/10.1002/jeab.322.

Rodríguez-Mori, M., & Pérez-González, L. A. (2005). A simple procedure to teach conditional discriminations to children. *Experimental Analysis of Human Behavior Bulletin, 23*, 3–6https://static1.squarespace.com/static/5a77014bdc2b4a0bdb3e3ea0/t/5bc10a8e53450a8a5a3c568e/1539377806110/Mori_Perez+2005.pdf.

Saunders, K. J., & Spradlin, J. E. (1990). Conditional discrimination in mentally retarded adults: The development of generalized skills. *Journal of the Experimental Analysis of Behavior, 54*(1), 239–250. https://doi.org/10.1901/jeab.1990.54-239.

Saunders, K. J., & Spradlin, J. E. (1993). Conditional discrimination in mentally retarded adults: Programming acquisition and learning set. *Journal of the Experimental Analysis of Behavior, 60*(1), 571–585. https://doi.org/10.1901/jeab.1993.60-571.

Serna, R. W., & Pérez-González, L. A. (2003). An analysis of generalized contextual control of conditional discriminations. *Journal of the Experimental Analysis of Behavior, 79*(1), 383–393. https://doi.org/10.1901/jeab.2003.79-383.

Sidman, M. (1986). Functional analysis of emergent verbal classes. In T. Thompson & M. D. Zeiler (Eds.), *Analysis and integration of behavioral units* (pp. 213–245). Lawrence Erlbaum Associates.

Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Authors Cooperative.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37*(1), 5–22. https://doi.org/10.1901/jeab.1982.37-5.

Stromer, R. (1986). Control by exclusion in arbitrary matching to sample. *Analysis & Intervention in Developmental Disabilities, 6*(1), 59–72. https://doi.org/10.1016/0270-4684(86)90006-6.

Stromer, R. (1989). Symmetry of control by exclusion in human's arbitrary matching to sample. *Psychological Reports, 64*(1), 915–922. https://doi.org/10.2466/pr0.1989.64.3.915.

Tonneau, F. (2001). Equivalence relations: A critical analysis. *European Journal of Behaviour Analysis, 2*(1), 1–33. https://doi.org/10.1080/15021149.2001.11434165.

Williams, G., Pérez-González, L. A., & Queiroz, A. B. M. (2005). Using a combined blocking procedure to teach color discrimination to a child with autism. *Journal of Applied Behavior Analysis, 38*(1), 555–558. https://doi.org/10.1901/jaba.2005.65-04.

Wulfert, E., Greenway, D. E., & Dougher, M. J. (1994). Third-order equivalence classes. *The Psychological Record, 44*(1), 411–439. https://doi.org/10.1007/bf03395924.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.