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Emergence of a three-sample conditional discrimination as foundation for reasoning capabilities

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Abstract

We hypothesized that a three-sample conditional discrimination can emerge as a result of learning conditional discriminations with relational stimuli. After learning three first-order conditional discriminations AB, PQ, and CD, we taught a second-order conditional discrimination XAB in which X1 indicated selection of related stimuli (e.g., A1 and B1) and X2 of unrelated stimuli (e.g., A1 and B2). Then, we probed the emergence of conditional discriminations PQX and XCD in which the X stimuli were comparisons and contextual stimuli, respectively. Finally, a conditional discrimination was probed with stimuli P, Q, and C as samples and D1 and D2 as comparisons. When the P and Q stimuli were related (and related to X1 in PQX), all participants selected the D stimulus that was related to the C stimulus (D1 when C1 was present and D2 when C2 was present); when the P and Q stimuli were unrelated (and related to X2 in PQX), they selected the D stimulus unrelated to the C stimulus (D2 when C1 and D1 when C2), which demonstrated emergence based on the relations established among all stimuli. In Experiment 2, the teaching of XAB was omitted and only one in six participants demonstrated emergence, which indicated that relational stimuli X1 and X2 played an important role in emergence. Thus, a new type of emergence that mimics analogical reasoning was demonstrated. The obtained outcome suggests that this procedure provides a learning foundation for acquiring reasoning capabilities.

KEYWORDS
analogical reasoning, discriminations, emergence, human learning, reasoning, stimulus relations, verbal behavior

Complex verbal skills may be learned through the acquisition of conditional discriminations. A first-order conditional discrimination procedure consists of presenting at least two samples (e.g., A1 and A2) and two or more comparisons (e.g., B1 and B2) across trials and arranging contingences for selecting one of the simultaneously presented comparisons in the presence of one sample and not in the presence of the other sample (i.e., A1-B1 and A2-B2 relations are reinforced but A1-B2 and A2-B1 are not). Acquiring conditional discriminations leads to the appearance of novel relations—*emergence*. For example, after learning to relate A1 to B1 and B1 to C1 people show the emergence of a relation between A1 and C1. This phenomenon has been consistently shown to be foundational in the acquisition and generalization of language (e.g., Horne & Lowe, 1996; Sidman, 1971, 2009; Sidman & Cresson, 1973; Sidman et al. 1974; Spradlin et al., 1973).

Behavior in second-order conditional discriminations is under the control of three stimuli such that comparison selection depends both on the presence of a contextual stimulus and the sample plus the correct comparison (Sidman, 1986). An instance of a second-order conditional discrimination consisted of teaching a first-order conditional discrimination AB with two comparisons and then adding a contextual stimulus. In the presence of contextual stimulus X1, the same AB relations were reinforced—that is, selecting B1 in the presence of A1 and selecting B2 in the presence of A2. In the presence of

X2, the relations were reversed—selecting B2 in the presence of A1 and selecting B1 in the presence of A2 were reinforced. Then, a new conditional discrimination CD was taught and the contextual stimuli X1 and X2 were presented with CD. The second-order conditional discrimination XCD emerged (i.e., was acquired without explicit teaching), which demonstrated that stimuli X1 and X2 controlled the relations between the remaining stimuli instead of specific stimulus–stimulus relations (e.g., Carpentier et al., 2002, 2003b; Pérez-González, Álvarez, et al., 2015; Pérez-González, Díaz, et al., 2015; Pérez-González & Serna, 2003).

Behavior in conditional discriminations can be emitted in the presence of four stimuli that control responding (e.g., Pérez Fernández & García García, 2008; Pérez-González & Martínez, 2022; Wulfert et al., 1994). Pérez-González and Martínez (2022) first taught two conditional discriminations AB and CD. They then taught, with a multiple-step procedure, a conditional discrimination CAD-B, with three samples, using Japanese Katakana syllables and their phonetic correspondences. In this discrimination, three stimuli (e.g., C1, A1, D1) appeared on each trial and B1 and B2 served as comparisons. When the C and D stimuli in the sample were related[1] (i.e., when selections of a given comparison were reinforced in the presence of a sample—such as D1 in the presence of C1), the correct response was to select the B comparison that was related to A (e.g., if A1 was presented as third stimulus in the sample, the correct comparison was B1). When the C and D stimuli were *unrelated* (e.g., C1 and D2), the correct response was to select the B comparison that was unrelated to A (e.g., if A1 was presented as third stimulus in the sample, the correct comparison was B2). This conditional discrimination procedure demonstrated comparison selection dependent on the arrangement of the three stimuli in the sample in the sense that changing any of the sample stimuli altered the correct comparison (e.g., C1-A1-D1 controlled the selection of B1, but C1-A2-D1 controlled the selection of B2; moreover, the same happened when C2 was presented instead of C1 or D2 was presented instead of D1). With the goal of probing generalization with novel stimuli, the researchers taught two novel conditional discriminations such as EF and GH using Nahuatl printed symbols and their phonetic correspondences (unrelated to the Japanese syllables) and probed the GEH-F conditional discrimination with the Nahuatl stimuli. The two children participants demonstrated the emergence of the novel conditional discrimination. Therefore, the acquisition of a conditional discrimination with three samples made possible the emergence of another conditional discrimination with three samples in which all stimuli were unrelated to those used in the first conditional discrimination.

Similar conditional discrimination procedures with two and three samples have been designed for (a) demonstrating selections between two comparisons according to the relations previously established between the two stimuli presented as samples (Pérez-González, 1994); (b) demonstrating basic learning principles involved in joint (or common) control of two stimuli over comparison selection (Alonso-Álvarez & Pérez-González, 2006, 2013; Pérez-González & Alonso-Álvarez, 2008); (c) demonstrating further class membership according to the context (e.g., DeRosse & Fields, 2010; Junior & Matos, 1999; Rehfeldt, 2003); (d) classifying objects according to two criteria (Sigurdadóttir et al., 2012); (e) demonstrating emergence of intraverbals after teaching two sets of related operants with AB and AC elements (e.g., Belloso-Díaz & Pérez-González, 2015; Carp & Petursdottir, 2012, 2015; Pérez-González et al., 2008, 2014; Zaring-Hinkle et al., 2016—see reviews and analysis in Pérez-González, 2019, 2020); (f) illustrating putative principles involved in cognition as proposed by the advocates of relational frame theory (e.g., Steele & Hayes, 1991); and other purposes. The authors of these and similar studies pointed out the strong functional analogies between the procedures and results used and multiple *cognitive* phenomena such as establishing relations between words and objects according to contextual stimuli (e.g., Bush et al., 1989), responding "yes" and "no" in a generalized way (e.g., Pérez-González, 1994), instruction following (e.g., Pérez-González & Martínez, 2022), concept formation and classification (Wulfert et al., 1994), deductive reasoning (e.g., Belloso-Díaz & Pérez-González, 2015; Carp & Petursdottir, 2012, 2015; Pérez-González et al., 2008), and analogical reasoning (e.g., Barnes et al., 1997; Carpentier et al., 2003a, 2004; García et al., 2008; Pérez Fernández & García García, 2008; Ruiz & Luciano, 2011). In summary, many researchers have conceptualized their findings with complex conditional discriminations as providing the learning foundations of multiple *cognitive* phenomena.

The *general goal* of the present study was to inquire into novel types of emergence with three-sample conditional discriminations that can be foundational to the acquisition of complex verbal (or *cognitive*) capabilities. We analyzed similarities between the stimulus relations observed in the Pérez-González and Martínez's (2022) study and those described with second-order conditional discriminations: First, Pérez-González and Martínez's (2022) results can be conceptualized in the following way: If two stimuli of the three-stimulus sample had been related to one another (e.g., A1 and B1), then the participant selected the comparison with that relation to the third stimuli (e.g., selected D1 in the presence of C1). That was possible in two ways: (a) If the A and B stimuli were *related*, then the correct D comparison was the comparison *related* to the C stimulus and (b) If the A and B stimuli were *unrelated*, then the correct D comparison was that

[1]The words "related" and "unrelated" are used through the text, meaning that the two stimuli had been learned as sample and correct comparison or as sample and incorrect comparison in simple conditional discriminations, respectively. This is because we do not speculate as to whether the two stimuli belong to a class given that symmetry or transitivity was not probed in most of the cited studies with the X stimuli. The effect of equivalence probes on more complex types of emergence requires additional research.

unrelated to the C stimulus. Therefore, the relations between two stimuli determine the relations between the third set of stimuli and the selected comparison, as when a person is asked, "Chimpanzee is to Africa like orangutan is to …" and responds, "Asia."

Second, other studies have shown that people can learn to select a specific stimulus based on the relation between two samples (e.g., Carpentier et al., 2002, 2003b; Pérez-González, 1994). For example, first A1 and B1 are related in first-order conditional discrimination AB; then, A1 and B1 (two related stimuli) are presented as samples and X1 and X2 are presented as comparisons; the correct comparison is X1; when A1 and B2 (two unrelated stimuli) are presented as samples, the correct comparison is X2. This assumption was demonstrated to be true when a new first-order conditional discrimination (PQ) was taught and X1 and X2 controlled these relations in a probe without reinforcement (PQX). Stimuli X1 and X2 play here the function of comparisons (whereas they are contextual stimuli in the studies on contextual control). Yet, X1 and X2 had identical relations with the remaining stimuli: In these studies, X1 was related to the relation between the two stimuli in the sample and X2 was related to the lack of that relation, exactly as in the cited studies on contextual control. Examples of this performance would be responding when asked, "Does the chimpanzee live in Africa?" and the correct response is "Yes" (A1B1-X1) and "Does the chimpanzee live in Asia?" and correct response is "No" (A1B2-X2).

Third, studies on contextual control have shown that in the presence of one contextual stimulus (e.g., X1) the correct comparison is the comparison related to the sample (i.e., X1 is linked to the relation between the sample and the correct comparison, such as when indicating in a verbal instruction "select the figure that goes together with that [the sample]" or "select the figure that is related to this [the sample]"), whereas in the presence of another contextual stimulus (e.g., X2) the correct comparison is that unrelated to the sample (i.e., X2 is linked to the lack of relation between the sample and the correct comparison, such as when indicating "they *do not* go together" or "they *are not* related"). People easily learn that type of conditional discrimination and generalize to novel stimuli with the same contextual stimuli (e.g., Alonso-Álvarez & Pérez-González, 2017, 2018; Pérez-González & Martínez, 2007; Pérez-González & Serna, 2003). Therefore, the contextual stimuli X1 and X2 indicate the relation between the sample and the selected comparison, as when a person is asked, "Where *does* the chimpanzee live?" and responding "Africa" ("does" has a function similar to X1) or "Where *does not* the chimpanzee live?" and responding another continent ("does not" has a function similar to X2). Notice also that X1 and X2 function as comparisons in PQX and as contextual stimuli in the later example. Even so, their relations with the relatedness or unrelatedness of the remaining stimulus is identical ("yes" and "does" are related to relatedness and "no" and "does not" to unrelatedness).

These three phenomena lead to the possibility of using relational stimuli X1 and X2 to link the specific stimuli presented in both cases. Thus, it is possible to *establish* a three-sample conditional discrimination; that is, it may not just be learned but would *emerge* without direct teaching. That could be possible by using the following procedures (see Figure 1): (a) Teaching first a first-order conditional discrimination (PQ) and then teaching an ABX-type of conditional discrimination (PQ-X). Thus, people can learn to select among X1 and X2 based on the relations between the two P and Q stimuli presented in the trial (as demonstrated by Pérez-González, 1994). (b) Teaching a second first-order conditional discrimination with novel stimuli (CD) and bring it under contextual control with X1 and X2 stimuli (X-CD). Thus, people can learn to select the stimulus D related to the stimulus C based on the presence of contextual stimuli X1 and X2 presented in the trial, respectively (such as in Pérez-González and Serna, 2003). (c) Presenting a three-sample conditional discrimination with the stimuli of the first and the second conditional discriminations, with the exclusion of the X1 and X2 stimuli (see PQC-D in Figure 1). We established the hypothesis that learning the first-order and second-order conditional discriminations described in (a) and (b) would suffice to produce the emergence of the three-sample conditional discrimination (PQC-D; described in [c]). This is because if the sample stimuli (P and Q) are related (thus, the learner had been taught to select X1 in their presence) in the presence of that stimulus X1, the stimulus related to the third sample (C) would prompt the selection of the D comparison related to the third sample (e.g., would select D1 in the presence of C1). Conversely, If the first two stimuli were unrelated (e.g., P1 and Q2) and the learner was taught to select X2, then X2 would prompt the selection of the comparison unrelated to the third sample stimulus (e.g., selecting *D2* in the presence of C1). We also hypothesized that after learning the two second-order conditional discriminations with the X stimuli, presenting the X stimuli in the three-sample conditional discrimination would not be necessary. The *main goal* of the present study was to explore the emergence of a three-sample conditional discrimination after learning first-order and second-order conditional discriminations with relational stimuli. The procedure was designed to make possible the emergence of the three-sample conditional discrimination based solely on the relations previously established between pairs of the presented stimuli even though the three-sample conditional discrimination was not taught before.

EXPERIMENT 1

Method

Participants

Six male adults, ages 23 to 26, acquaintances of the third experimenter (with fictitious names Darío, Jerónimo,

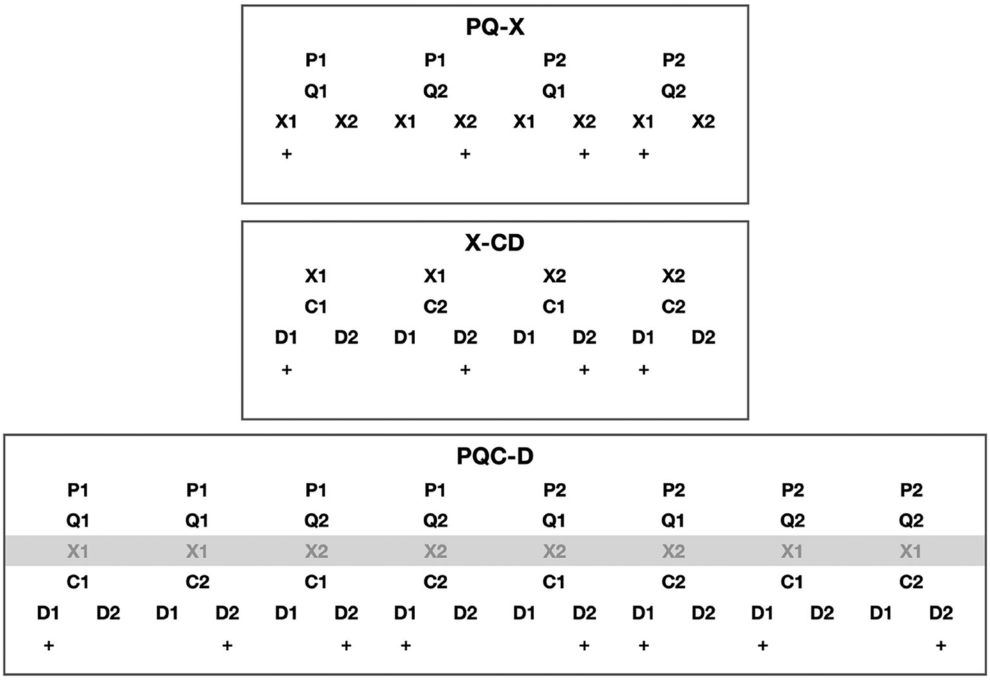

FIGURE 1 Conditional discriminations PQX, XCD, and PQC-D probed. The stimuli on the top of each discrimination were the samples, and the two stimuli at the bottom were the comparisons. Plus signs indicate which selection was considered correct for the comparisons. In PQC-D, stimuli X1 and X2, shaded with a gray background, were not presented. They indicate the comparison selected in PQX, which can serve as a contextual stimulus for selecting D1 or D2 according to the C stimulus present.

Sancho, Dionisio, Marco, and Cecilio) volunteered for participating in a psychology experiment and signed a consent form. They were graduate or undergraduate students from a major university. All of them spoke Spanish as first language and received the instructions in Spanish. They did not receive any material reward.

Stimuli

The stimuli were 14 arbitrary shapes (see Figure 2), about 2.8 × 1.5 cm. They were presented in a 17.5- × 31-cm screen. In addition, there was an emoticon of a smiling face with a diameter of 5.7 cm and another one of a sad face with a diameter of 6.5 cm.

Procedure

Setting and apparatus

The experiment took place in a quiet room at the house of the experimenter (the third author) or at the university campus. The sessions were conducted with an HP laptop computer, provided with a Windows 10 operating system. The procedure was implemented with the PsychoPy v2021.1.2 application for stimulus generation and experimental control in Python, which presented the stimuli and recorded the participant's responses.

Instructions

The experimenter presented the computer to the participant with a welcome screen with the following text:

> *Hello!*
> *We welcome you to this study, which is not on intelligence or personality, but on learning.*
> *We thank you for your collaboration and we expect you will enjoy it.*
> *The computer will inform you when the session ends.*
> *For continuing, press the space bar.*

After the participant pressed the space bar, the following instructions appeared on the screen:

> *Your task is to select one of the pictures that appear in the lower portion of the screen after paying attention to everything that appears on the upper part.*
> *Sometimes, only one picture will appear, which is the one that you have to select.*
> *If you want to select the picture on the left, you should press the "C" key.*
> *If you want to select the picture on the right, you should press the "M" key.*
> *If your selection is correct, this symbol will appear*: [A yellow smile face emoticon]

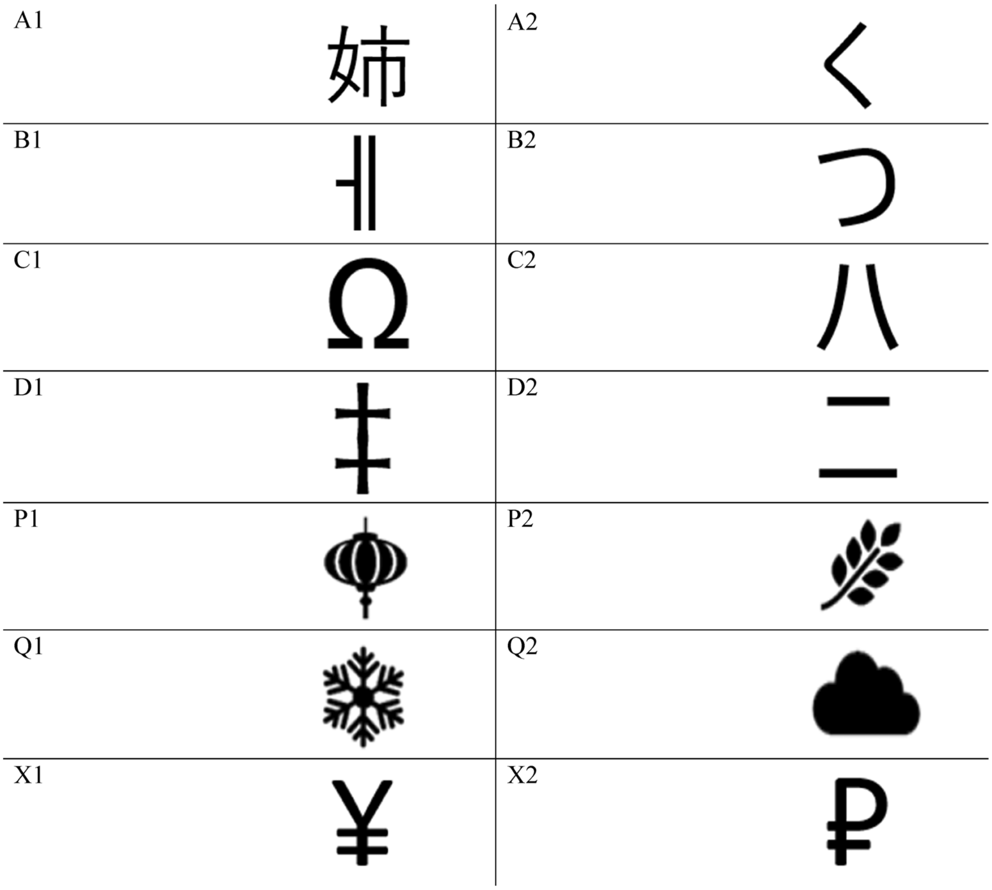

FIGURE 2 Stimuli used in the experiments

> *If it is incorrect, this symbol will appear:*
> [A red sad face emoticon]
> *Sometimes, you will not be informed of whether your selection was correct or incorrect, but you should try to respond correctly.*
> *If you have any doubts, ask the researcher now, as once the session starts it will no longer be possible.*
> *To start, press the space bar.*

The experimenter supervised the first few trials from behind the participant and then left the room, and the participant stayed working alone until the end of the session.

Overview

See Table 1 for an overview of the procedure. First, we taught a first-order conditional discrimination (AB), probed its symmetrical relation (BA), and taught a second-order conditional discrimination XAB with the X stimuli as contextual stimuli. The purpose of teaching AB and XAB was to teach the functions of X1 and X2 as contextual stimuli. The reason to conduct symmetry probes of the first-order conditional discriminations (such as BA) was to facilitate further the emergence of relations with X1 and X2 as comparisons because symmetry facilitates responding to X1 and X2 when these stimuli are taught and probed as comparisons (Pérez-González, 1994). Second, we taught a second first-order conditional discrimination PQ, probed its symmetrical relation QP, and probed the emergence of conditional discrimination XPQ, in which the X stimuli were contextual stimuli (see Figure 1). Third, we taught a third first-order conditional discrimination CD and probed its symmetrical relation DC. Fourth, we probed the emergence of PQX, in which X1 and X2 were comparisons, and probed the emergence of the XAB-type conditional discrimination XCD, in which X1 and X2 were contextual stimuli. We expected that the PQX conditional discrimination would emerge after the emergence of the XPQ conditional discrimination similarly to Experiment 2 in Pérez-González and Serna (2003) and that the XCD conditional discrimination would emerge for the same reason as XPQ. Finally, we probed the emergence of the PQC-D three-sample conditional discrimination. Through the entire procedure, we probed relations instead of teaching them, whenever possible, because we considered emergence to be a clearer demonstration of complex verbal skills and more similar to the *cognitive* instances for which the conditional discriminations are presumably providing the foundation.

TABLE 1 Overview of procedure

Discrimination & phase	Samples	Comparisons & location	Trials	Taught/Probe
AB				
1	A1	B1 & B2 fixed	2 + 3	Taught
2	A2	B1 & B2 fixed	2 + 3	Taught
3	A1 or A2	B1 & B2 fixed	8	Taught
4	A1 or A2	B1 & B2 random	8	Taught
BA*				
5	B1 or B2	A1 & A2 random	8	**Probe**
XAB				
6	X1 A1 or X1 A2	B1 & B2 random	12	Taught
7	X2 A1 or X2 A2	B1 & B2 random	12	Taught
8	X1 A1, X1 A2, X2 A1, or X2 A2	B1 & B2 random	12	Taught
PQ				
9	P1	Q1 & Q2 fixed	2 + 3	Taught
10	P2	Q1 & Q2 fixed	2 + 3	Taught
11	P1 or P2	Q1 & Q2 fixed	8	Taught
12	P1 or P2	Q1 & Q2 random	8	Taught
QP*				
13	Q1 or Q2	P1 & P2 random	8	**Probe**
XPQ*				
14	X1 P1, X1 P2, X2 P1, or X2 P2	Q1 & Q2 random	12	**Probe**
CD				
15	C1	D1 & D2 fixed	2 + 3	Taught
16	C2	D1 & D2 fixed	2 + 3	Taught
17	C1 or C2	D1 & D2 fixed	8	Taught
18	C1 or C2	D1 & D2 random	8	Taught
DC*				
19	D1 or D2	C1 & C2 random	8	**Probe**
PQX*				
20	P1 Q1, P1 Q2, P2 Q1, or P2 Q2	X1 & X2 random	12	**Probe**
XCD*				
21	X1 C1, X1 C2, X2 C1, or X2 C2	D1 & D2 random	12	**Probe**
PQC-D*				
22	P1 Q1 C1, P1 Q1 C2, P1 Q2 C1, P1 Q2 C2, P2 Q1 C1, P2 Q1 C2, P2 Q2 C1, or P2 Q2 C2	D1 & D2 random	16	**Probe**

Note. For Trials, an entry of 2 + 3 indicates that the criterion with prompts was two consecutive correct responses and the criterion with no prompt was three. Asterisks indicate the discriminations that were probed. Probes appear in bold.

Teaching first-order conditional discrimination AB

It was taught with a variation of the procedures designed by Rodríguez-Mori and Pérez-González (2005; based on Pérez-González & Williams, 2002), which had served for teaching conditional discriminations with no or very few errors in many previous studies. The procedure was the following (see Table 1, Phases 1–4): In Phase 1, sample A1 was presented at the top of the screen and comparison B1 was presented at the left bottom location; comparison B2 was not presented for prompting selections of B1. After two consecutive correct responses, comparison B2 was presented at the right bottom location as well. Correct responses were followed by the presentation of the emoticon of a smile for 1 s; incorrect responses were followed by the emoticon with a sad face for 1 s. After three consecutive correct responses with B1 and B2 present, the computer moved on to Phase 2. Phase 2 was similar to Phase 1, but the sample was A2 and the correct comparison was B2. In Phase 3, samples A1 and A2 were presented randomly across trials, with the requirement that each sample was presented twice every four trials. After eight consecutive correct responses, the computer moved on to Phase 4. Phase 4 was similar to Phase 3, but comparisons B1 and B2 were presented randomly at either of the two bottom locations, with the requirement that each comparison appeared two times on the left and two times on the right every four trials.

Probing symmetry BA

The probe was conducted in a single eight-trial phase (see Phase 5 in Table 1). The samples (e.g., B1 or B2) and the location of the comparisons (e.g., A1 and A2) varied randomly, with the restriction that each of the two samples appeared twice every four trials and each comparison appeared twice on each location every four trials. All responses were followed by the intertrial interval and the start of the next trial (i.e., no differential consequences were presented in the probes). Selections of B1 to A1 and of B2 to A2 were considered correct. The criterion for passing a probe was 7/8 correct responses.

Teaching second-order conditional discrimination XAB

See Phases 6–8 in Table 1. In Phase 6 stimulus X1 appeared on every trial at the top of the screen along with an A stimulus and the B stimuli. Samples A1 and A2 and comparisons B1 and B2 appeared as in Phase 4 of the AB teaching. Stimulus B1 was correct in the presence of A1, and B2 was correct in the presence of A2—just as in teaching AB. After 12 consecutive correct responses, the computer went on to Phase 7. Phase 7 was similar to Phase 6, but stimulus X2 appeared on every trial instead of X1. Stimulus B2 was correct in the presence of A1 and B1 was correct in the presence of A2. Because X2 is presented for the first time with no prompts, typically the participant makes one or a few incorrect responses before starting to respond correctly (e.g., Pérez-González & Martínez, 2007), a fact that is considered part of an effective procedure for teaching a second-order conditional discrimination. Phase 8 was also similar to Phases 6–7, but stimuli X1 and X2 were presented randomly across trials with the restriction that the four X-A combinations were presented every four trials. After 12 consecutive correct responses, the computer moved on to the next phase.

Teaching first-order conditional discrimination PQ and probing symmetry QP

See Phases 9–12 and Phase 13, respectively, in Table 1. In conditional discrimination PQ, the samples were P1 and P2 and the comparisons were Q1 and Q2. Conditional discrimination PQ was taught with analogous procedures to those used for teaching AB. In symmetry QP, the samples were Q1 and Q2 and the comparisons were P1 and P2. Selections of P1 to Q1 and of P2 to Q2 were considered correct. Symmetry QP was probed as symmetry BA.

Probing second-order conditional discrimination XPQ

It was probed in just one phase with 12 trials (see Phase 14 in Table 1). The samples presented in each trial were X1 or X2 and P1 or P2. The comparisons were Q1 and Q2. The samples and the location of the comparisons varied randomly with the restriction that the four combinations of samples (i.e., X1P1, X1P2, X2P1, and X2P2) appeared once every four trials and each comparison appeared two times on each location every four trials. The criterion for considering a probe was passed was to make 10 out of 12 correct responses.

Teaching first-order conditional discrimination CD and probing symmetry DC

See Phases 15–18 and Phase 19, respectively, in Table 1. In conditional discrimination CD, the samples were C1 and C2 and the comparisons were D1 and D2. Conditional discrimination CD was taught with procedures analogous to those used for teaching AB. In symmetry DC, the samples were D1 and D2 and the comparisons were C1 and C2. Selections of C1 to D1 and of C2 to D2 were considered correct. Symmetry DC was probed as symmetry BA.

Probing second-order conditional discrimination PQX

It was probed in just one phase with 12 trials (see Phase 20 in Table 1 and upper panel of Figure 1). The samples presented in each trial were P1 or P2 and Q1 or Q2. The comparisons were X1 and X2. The samples and the location of the comparisons varied randomly, with the restriction that the four combinations of samples (i.e., P1Q1, P1Q2, P2Q1, and P2Q2) appeared once every four trials and each comparison appeared two times on each location every four trials. Correct responses were as in XAB. The criterion for considering a probe was passed was to make 10 out of 12 correct responses.

Probing second-order conditional discrimination XCD

It was probed in just one phase with 12 trials (see Phase 21 in Table 1 and middle panel of Figure 1). The samples presented in each trial were X1 or X2 and C1 or C2. The comparisons were D1 and D2. The samples and the location of the comparisons varied randomly, with the restriction that the four combinations of samples (i.e., X1C1, X1C2, X2D1, and X2D2) appeared once every four trials and each comparison appeared two times on each location every four trials. The criterion for considering a probe was passed was to make 10 out of 12 correct responses.

Probe of the three-sample conditional discrimination PQC-D

See Phase 22 in Table 1 and bottom panel of Figure 1. It was probed in one phase with 16 trials. The samples were P1 or P2, Q1 or Q2, and C1 or C2, and D1 and D2 were the comparisons. Each one of the eight sample combinations was presented once with the D1 comparison on the left and the D2 comparison on the right and once with D2 on the left and D1 in the right. The 16 combinations were presented in a random order. The criterion for passing a probe type was 14/16 correct responses.

Results

All six participants learned the first-order and second-order conditional discriminations with 92% to 99%

correct responses in 115 to 163 trials. They finished the session in a range of 12:29 min to 18:44 min. They made all 8 correct responses in the BA, QP, and DC symmetry probes. They also made 11 or 12 out of 12 correct responses in the XPQ, PQX, and XCD probes, except for Cecilio, who made 9 and 10 correct responses in the first and the second PQX probe, respectively. See complete results in Appendix A.

The results in the PQC-D probe appear in Figure 3. Five participants made 14–16 correct responses in the first probe; the remaining participant (Dionisio) made 9 correct responses. All six participants responded correctly to 15 or 16 trials in the second probe.

Discussion

The goal of Experiment 1 was to probe the emergence of the three-sample conditional discrimination when that discrimination was presented for the first time. All participants learned AB and XAB. Then they learned PQ and showed the emergence of XPQ; then they learned CD and they received probes in which the P and Q stimuli were presented with the X stimuli as comparisons (i.e., PQX); the CD stimuli were presented with X stimuli as contextual stimuli and they demonstrated emergence (i.e., XCD). Finally, the PQC-D conditional discrimination was probed. All six participants demonstrated emergence on that probe as well. Therefore, these results demonstrated the emergence of this three-sample conditional discrimination with stimuli that had been presented in relations with the X stimuli. This type of emergence has not been previously reported.

EXPERIMENT 2

Experiment 1 demonstrated the emergence of the targeted three-sample conditional discrimination based solely on the relations previously established between pairs of the presented stimuli. We supposed that the final performance was made possible by learning the second-order conditional discrimination with stimuli X1 and X2. In Experiment 2 we sought to determine whether that conditional discrimination was necessary for producing this type of emergence. We hypothesized that if the XAB conditional discrimination was not taught, then the XPQ, PQX, and XCD conditional discriminations were unlikely to emerge; moreover, if these conditional discriminations did not emerge, the PQC-D three-sample conditional discrimination, too, was unlikely to emerge. Conversely, after teaching XAB, we hypothesized that all second-order and three-sample conditional discriminations would emerge.

Method

The participants were six adults of the same characteristics and circumstances as those of Experiment 1 (whose fictitious names were Ignacio, Sara, Macarena, Magdalena, Octavio, and Jessica). Two sessions were presented. In the first session, the procedures were identical to those of Experiment 1 except for the following: First, Phases 6–8 (see Table 1), corresponding to teaching of XAB, were omitted. Second, although unlikely, failure of emergence in the PQC-D probe could hypothetically occur because fewer trials had been presented than in Experiment 1. Therefore, at least 60 extra trials of the AB conditional discrimination were programmed. Thus, after Phase 6, Phase 4 was repeated five times. A postexperimental analysis revealed that all six participants received more trials than did five of the participants of Experiment 1. In the second session, the procedures of Experiment 1 were used. Thus, the extra trials of AB presented in the first session were not presented and the XAB conditional was introduced.

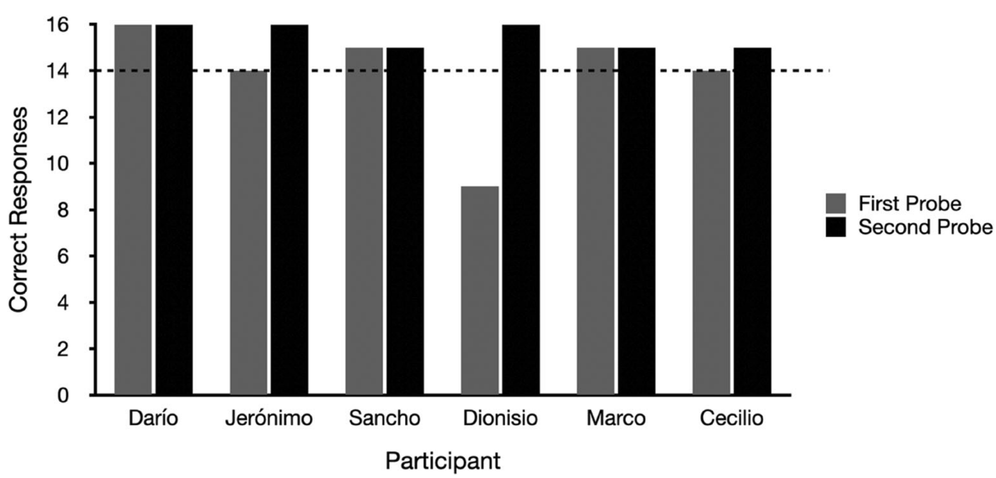

FIGURE 3 Results in the PQC-D discrimination probes of Experiment 1. Horizontal lines signal the emergence criterion.

Results

In the first session, all six participants learned and reviewed the conditional discriminations with 57% to 100% correct responses, in 78 to 369 trials (most errors were from participant Sara). They completed the session in 12:32–17:36 min. In the second session, they responded correctly with 91% to 99% correct responses, in 118–134 trials. They completed the session in 11:34–26:00 min. See complete results in Appendix B.

The results of the PQX, XCD, and PQC-D probes appear in Figure 4. In the first session, prior to teaching XAB, all six participants responded at around chance level (i.e., 6 ± 1 correct responses) in the XPQ, PQX, and XCD conditional discriminations. They also responded around chance level (i.e., 8 ± 1 correct responses) in the emergence probe of the three-sample conditional discrimination PQC-D. When the PQX, XCD, and PQC-D conditional discriminations were probed again within that session, five participants responded with similar scores;

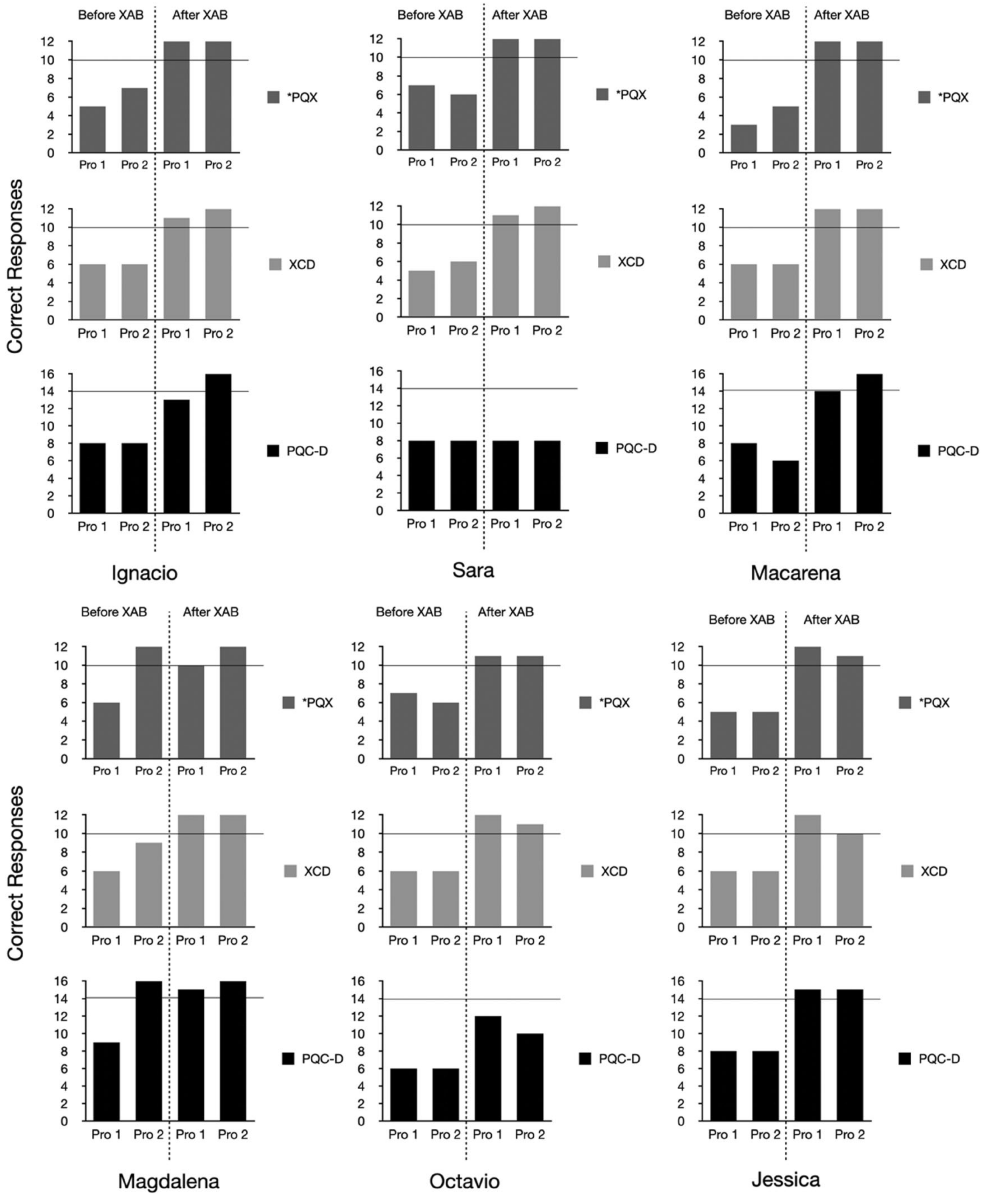

FIGURE 4 Results in the PQX, XCD, and PQC-D probes of Experiment 2 in the first session, before teaching XAB, and the second session, after teaching XAB. "Pro" refers to the probes in each session. Horizontal lines signal the emergence criterion.

however, one participant, Magdalena, made all correct responses in the PQX probe, made 9 correct out of 12 responses in XCD, and made all 16 correct responses in the PQC-D probe.

In the second session, after learning XAB, all six participants made 10 or more correct responses, out of 12, in the XPQ, PQX, and XCD emergence probes. In the first emergence probe of the PQC-D three-sample conditional discrimination, five participants made 13 to 16 correct responses out of 16. When the probe was presented the second time, all five participants made 15 or 16 correct responses. The remaining participant (Octavio) responded at chance level (i.e., 8 correct responses) the two times that the probe was presented.

Discussion

The main goal of the Experiment 2 was to determine whether learning the XAB conditional discrimination is necessary for the emergence of the PQX, XCD, and, specially, the PQC-D conditional discriminations. Before learning the XAB, none of the participants showed emergent relations in the first probe and five out of six participants also failed in the second probe. These results clearly contrast with those of Experiment 1 in which all six participants demonstrated emergence of all probed relations. Moreover, when the XAB conditional discrimination was introduced in the second session, five out of six participants then demonstrated the emergence of all probed conditional discriminations. These results confirm the assumption that teaching XAB played an important role in the emergence of the PQC-D conditional discriminations.

A surprising result was that participant Magdalena demonstrated the emergence of the PQX and the PQC-D conditional discriminations in the second probe of the first session, before XAB had been taught. Yet an explanation is possible: After learning the PQ conditional discrimination and passing the QP symmetry probe, she was presented with the PQX probe that consisted of presenting one P and one Q stimulus as samples and two novel stimuli as comparisons. Even though no feedback was provided, the setting was enough for prompting the selection of the correct comparison in the presence of two related stimuli and to correctly select the other comparison in the presence of the other two combinations—with unrelated stimuli. The emergence of the PQX conditional discrimination could have been enough to bring about correct responding on most trials of the emergence probe of the XCD conditional discrimination and then facilitate the emergence of the PQC-D conditional discrimination. This phenomenon of consistently assigning specific comparisons to specific sample combinations in the absence of feedback has been demonstrated before with first- (Williams et al., 1995) and second-order (e.g., Serna & Pérez-González, 2003) conditional discriminations—generalized conditional responding. Further replications would be necessary to confirm this hypothesis.

GENERAL DISCUSSION

The present research demonstrated for the first time the emergence of a three-sample conditional discrimination after learning and demonstrating emergence with second-order conditional discriminations with relational stimuli (i.e., X1 and X2). The acquisition of the first-order conditional discriminations AB, PQ, and CD plus the second-order conditional discrimination (XAB) seems to have been sufficient for the participants to demonstrate the emergence of novel second-order conditional discriminations with the X stimuli functioning as comparisons (in PQX) and as samples (in XCD). Moreover, the initial teaching plus the emergent relations resulted in the emergence of the novel three-sample conditional discrimination. This type of emergence was observed across two experiments in 11 out of 12 participants.

It was also demonstrated that teaching XAB plays an important role in the emergence of the three-sample conditional discrimination, as observed in Experiment 2. The surprising result of one participant in that experiment indicated that three-sample emergence could be obtained even when the XAB conditional discrimination was not explicitly taught. However, the fact that only one in six participants had demonstrated such emergence suggests that the likelihood of such emergence is very low.

The types of emergence demonstrated in the present studies might serve in problem solving, reasoning, and other high-level verbally mediated skills or capabilities. Particularly, they may very likely be involved in analogical reasoning: Many studies have demonstrated emergence of equivalence-equivalence relations, and they have been presented as evidence of analogical reasoning (e.g., Barnes et al., 1997; Carpentier et al., 2003a, 2004; García et al., 2008; Pérez Fernández & García García, 2008; Ruiz & Luciano, 2011). The present study replicated the basic phenomena found in these studies with the following variations: First, the final probe in most of the previous studies consisted of presenting two-stimulus samples and comparisons (e.g., A1B1 as sample and B2C2 and B2C3 as comparisons)—similar to presenting, "Chimpanzee Africa" and asking to select between "Giraffe Asia" and "Orangutan Asia." An exception was the study by Pérez Fernández and García García (2008), which used the equivalence-equivalence procedure plus a second procedure in which they presented probes with three single-stimulus samples and two single-stimulus comparisons—that is, a three-sample conditional discrimination as in the present study, similar to requesting, "Chimpanzee is to Africa like orangutan is to …" and the correct response is "Asia."

They found emergence with both procedures, but all participants showed more instances of emergence in the equivalence-equivalence probes than in the conditional discrimination probes, which suggests that emergence is more likely with the first procedure. This fact enhances the importance of the emergence found in the present study.

A second variation was that most previous equivalence-equivalence studies first established equivalence relations among A, B, and C stimuli. Later, these same stimuli were used in the equivalence-equivalence probes. An exception was the study by Ruiz and Luciano (2011). They taught ABC relations and probed equivalence-equivalence relations; then they established two additional classes FGH and MNO (denominated "domains"—i.e., unrelated to one another). Finally, they probed equivalence-equivalence with two F, G, or H stimuli in the sample and two M, N, or O stimuli in each comparison and all 10 participants demonstrated emergence. They presented their outcome as an example of cross-domain analogies and presented those as more genuine analogies akin to those found in everyday life and particularly in metaphors. The present study replicates that important feature because the P and Q stimuli, on one hand, and the C and D stimuli, on the other hand, belonged to two different domains.

A third difference from previous research is that the procedures used in the present study were simpler than in previous studies of equivalence-equivalence or analogical reasoning in that they yielded the targeted emergence both in relatively few trials and in a short period. Moreover, several factors that so far have been considered important or necessary in previous studies for facilitating emergence were not required (e.g., number of trials to criterion in the taught discriminations, probes for transitivity). Further, some variables that have been identified as relevant for the final performance, such as overtly tacting the stimuli or selecting them upon hearing their names—listener skills—(see Cordeiro et al., 2021; Meyer et al., 2019; Miguel et al., 2015) were not necessary when people learn with the procedures of the present study, as demonstrated by the fact that tacting or that type of selecting was not taught.

Within the context of the previous studies, the present study suggests that the final performance of the three-sample conditional discrimination represents a type of analogical reasoning identical or very similar to that obtained in the studies with equivalence-equivalence probes. It suggests that performances like those demonstrated in analogical reasoning probes can be produced by (a) teaching very basic, two-stimulus relations (e.g., AB conditional discriminations; thus, no need of adding BC relations), (b) probing only the symmetry relation (e.g., without probing transitivity), (c) learning the XAB-type second-order conditional discriminations with X1 and X2 as relational stimuli, (d) probing the relations with these relational stimuli as contextual stimuli and comparisons.

Among these variables, only the effect of learning the XAB conditional discriminations was tested in the present study. The effect of teaching or probing the additional relations remains to be studied. We tested for symmetry relations because previous studies suggest that doing so may be necessary for some persons to demonstrate the emergence of the PQX conditional discriminations when the X stimuli are presented as comparisons (e.g., Pérez-González, 1994; see an analysis in Pérez-González, 2019, 2020).

Other complex verbal skills, beyond analogical reasoning, can result from experiences such as those described here with conditional discriminations. For example, following commands such as "If you see a star, then select the circle" has the same functional relations as the PQC-D conditional discrimination: "star" would be P1, the picture of a star would be Q1, the word "circle" would be C1, and the picture of the circle would be D1; the other comparison such as square would be D2—the order of Q and C (inverted in this example) very likely would not make any difference (see a similar example in Pérez-González & Martínez, 2022).

The present study suggests that tacting the stimuli or the relations aloud is not necessary for the final emergence. This fact again contrasts with the studies that suggest the opposite (Cordeiro et al., 2021; Meyer et al., 2019; Miguel et al., 2015). As mentioned above, the difference in the results could have been due to the type of procedures used, which suggests that the necessity of tacting the stimuli or the relations aloud is limited to the complex procedures used in most equivalence-equivalence studies. Therefore, tacting aloud seems unnecessary when the procedure is streamlined as in the present study. Of special interest, however, are the following considerations: First, the effects of the naming capability (i.e., the tact and the listener skill) found in the studies cited above and the possible effect of symmetry in the present study might be related in some way, as both involve some kind of symmetry (see a description of the similar effects they produce in Pérez-González, 2019, 2020). In the present study, symmetry of all three taught first-order conditional discriminations was probed. Second, Cordeiro et al. (2021), Meyer et al. (2019), and Miguel et al., (2015) found that when the participants were taught to vocalize "same" or "different" according to the relation between the sample stimuli, they showed more instances of emergence than those who were not requested to do so. The effect of this type of vocalization could be similar to that of learning to select X1 (very similar to "same") and X2 (very similar to "different") in the present study, even though X1 and X2 were not presented in the final probe and no response related to these stimuli was required from or observed in the participants.

The outcomes of the present study cannot be explained by stimulus equivalence: First, an explication based on equivalence among single stimuli (i.e., a class including P1, Q1, C1, D1, and X1) would require that X1 or X2 serve as a node between P and Q stimuli, on one hand, and C and D stimuli, on the other hand (i.e., P1 and Q1 are related to X1 and X1 is related to C1 and D1, so P1 and Q1 are related to C1 and D1). However, X1 was equally related to any other stimulus, such as P1 and P2 or to C1 and C2—that is, X1 was correct as often when P1 was present as when P2 was present. Therefore, X1 could not be part of a class with any other stimulus because all stimuli would collapse into a single class and no stimulus partitions and thus no classes would appear (Sidman, 1986). The same happens with X2. Therefore, an interpretation based on equivalence between single stimuli is impossible here (see discussions on the X stimuli in Pérez-González, 1994, and Sidman, 1986). The second possibility is that compound stimuli could form classes: It can be argued that equivalence among PQ, X, and CD could explain the PQC-D emergence. For example, P1Q2 was related to X2 in PQX and X2 was related to C2D1 in XCD; therefore, a class among P1Q2, X2, and C2D1 would have been formed. This would explain the transitivity relation between P1Q2 and C2D1. Consequently, this one and similar relations could explain the PQC-D emergence. This interpretation fails to consider the following arguments: (a) if two-stimulus compounds instead of single stimuli formed the classes, a huge number of compounds is in place, which makes it implausible to form equivalences with them; (b) XPQ, PQX, and XCD had been probed for emergence and emerged, and this fact cannot be accounted for by stimulus equivalence, in which the baseline relations need to be taught (i.e., AB and BC need to be taught for AC to emerge); and (c) the C and D stimuli never were presented as compounds; instead, one C stimulus was presented as a sample and the two D stimuli were presented as comparisons in each trial. In conclusion, that hypothesis appears very weak. Instead, the conceptualization that the X1 stimulus comes to be related to any pair of related stimuli and X2 to any pair of unrelated stimuli appears as more parsimonious. Moreover, this conceptualization explains the emergence of XPQ, PQX, and XCD, on one hand, and does not need any further elaboration regarding CD compounds because the C and D stimuli accomplish the same functions in the XCD and the PQC-D conditional discriminations, on the other hand.

The present study suggests further research to analyze the role of each element used in the procedure. Moreover, further analysis of the relations between the probes used in the present experiment and those used in the previous equivalence-equivalence studies could be of interest. In summary, the fact that the present procedures result in the emergence of a three-sample conditional discrimination with the use of relational stimuli can open a new way for studying more complex verbal capabilities, referred to as cognitive skills by mainstream psychologists. Finally, the present study could serve to inspire techniques to explore the possibility of establishing reasoning capabilities in people who lack them as well as being used in psychotherapy.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

ETHICS APPROVAL

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. Informed consent was obtained from all participants included in the study.

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APPENDIX A: Results of Experiment 1

		Participant											
		Darío		Jerónimo		Sancho		Dionisio		Marco		Cecilio	
Phase	Relations or Discrimination	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total
AB & BA													
1	A1-B1	2	2	2	2	2	2	2	2	2	2	2	2
		3	5	3	3	3	3	3	3	3	3	3	3
2	A2-B2	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
3	A1-B1 & A2-B2	8	8	8	8	8	8	8	8	8	8	8	8
4	A1-B1 & A2-B2	8	8	8	8	8	8	8	8	8	8	8	8
5	*BA	8	8	8	8	8	8	8	8	8	8	8	8
XAB													
6	X1 A1 - B1 & X1 A2 - B2	12	12	12	12	12	12	12	12	12	12	12	12
7	X2 A1 - B2 & X2 A2 - B1	18	20	12	13	12	13	18	20	12	13	12	13
8	XAB	18	19	21	23	12	12	16	17	12	12	33	39
PQ & QP													
9	P1-Q1	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
10	P2-Q2	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
11	P1-Q1 & P2-Q2	8	8	8	8	8	8	8	8	8	8	8	8
12	P1-Q1 & P2-Q2	8	8	8	8	8	8	8	8	8	8	8	8
13	QP*	8	8	8	8	8	8	8	8	8	8	8	8
XPQ PROBE													
14	XPQ*	11	12	12	12	12	12	12	12	12	12	12	12
CD & DC													
15	C1-D1	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	4
16	C2-D2	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	4
17	C1-D1 & C2-D2	8	8	14	15	8	8	8	8	8	8	8	8
18	C1-D1 & C2-D2	8	8	8	8	8	8	8	8	8	8	24	27
19	DC*	8	8	8	8	8	8	8	8	8	8	8	8
PQX PROBE													
20	PQX*	12	12	12	12	12	12	12	12	12	12	9	12
XCD PROBE													
21	XCD*	12	12	12	12	11	12	12	12	12	12	12	12
FINAL PROBE PQC-D													
22	PQC-D*	16	16	14	16	15	16	9	16	15	16	14	16
PQX PROBE													
20	PQX*	11	12	11	12	12	12	12	12	12	12	10	12
XCD PROBE													
21	XCD*	12	12	12	12	12	12	11	12	12	12	12	12
FINAL PROBE PQC-D													
22	PQC-D*	16	16	16	16	15	16	16	16	15	16	15	16
Total Trials		240	247	242	249	227	231	232	243	228	231	259	279
Time		18:44		14:52		13:16		12:29		16:30		15:33	

Note. When two files appear for a discrimination, the first one refers to the prompted trials and the second one to the unprompted trials. Asterisks indicate probe trials. Time is indicated in minutes and seconds.

APPENDIX B: RESULTS OF EXPERIMENT 2

		Participant											
		Ignacio				Sara				Macarena			
		S1		S2		S1		S2		S1		S2	
Phase	Relations or Discrimination	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total
AB & BA													
1	A1-B1	2	2	2	2	2	3	2	2	2	3	2	2
		3	3	3	3	3	4	2	2	3	3	3	3
2	A2-B2	2	2	2	2	2	3	3	3	2	2	2	2
		3	3	3	3	3	3	2	2	3	3	3	3
3	A1-B1 & A2-B2	8	8	8	8	134	283	3	3	9	10	8	8
4	A1-B1 & A2-B2	8	8	8	8	8	10	8	8	8	8	8	8
5	*BA	8	8	8	8	8	8	8	8	8	8	8	8
4.1	AB	12	12			12	12			12	12		
4.2	AB	12	12			12	12			12	12		
4.3	AB	12	12			12	12			12	12		
4.4	AB	12	12			12	12			12	12		
4.5	AB	12	12			12	12			12	12		
XAB													
6	X1 A1 - B1 & X2 A2 - B2			21	22			20	21			12	12
7	X2 A1 - B2 & X2 A2 - B1			12	14			12	14			12	13
8	XAB			14	15			18	24			13	15
PQ & QP													
9	P1-Q1	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
10	P2-Q2	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
11	P1-Q1 & P2-Q2	8	8	8	8	8	8	9	11	8	8	8	8
12	P1-Q1 & P2-Q2	8	8	8	8	13	14	8	8	8	8	8	8
13	QP*	8	8	8	8	8	8	8	8	7	8	8	8
XPQ PROBE													
14	*XPQ	6	12	11	12	6	12	11	12	5	12	12	12
CD & DC													
15	C1-D1	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
16	C2-D2	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
17	C1-D1 & C2-D2	8	8	8	8	10	11	8	8	10	11	8	8
18	C1-D1 & C2-D2	8	8	8	8	9	10	8	8	8	8	8	8
19	DC*	8	8	8	8	8	8	8	8	8	8	8	8
PQX PROBE													
20	*PQX	5	12	12	12	7	12	12	12	3	12	12	12

(Continues)

		Participant											
		Ignacio				Sara				Macarena			
		S1		S2		S1		S2		S1		S2	
Phase	Relations or Discrimination	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total
XCD PROBE													
21	*XCD	6	12	11	12	5	12	12	12	6	12	12	12
FINAL PROBE PQC-D													
22	PQC-D*	8	16	13	16	8	16	8	16	8	16	14	16
PQX PROBE													
20	*PQX	7	12	12	12	6	12	12	12	5	12	12	12
XCD PROBE													
21	*XCD	6	12	12	12	6	12	12	12	6	12	12	12
FINAL PROBE PQC-D													
22	PQC-D*	8	16	16	16	8	16	8	16	6	16	16	16
Total		208	254	236	245	342	545	222	250	203	260	229	234
Time		*22:45*		*17:36*		26:00		*14:32*		11:34		*13:27*	

		Participant											
		Magdalena				Octavio				Jessica			
		S1		S2		S1		S2		S1		S2	
Phase	Relations or Discrimination	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total
AB & BA													
1	A1-B1	2	3	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
2	A2-B2	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
3	A1-B1 & A2-B2	8	8	8	8	8	8	8	8	8	8	8	8
4	A1-B1 & A2-B2	8	8	8	8	8	8	8	8	8	8	8	8
5	*BA	8	8	8	8	8	8	8	8	8	8	8	8
4.1	AB	12	12			12	12			12	12		
4.2	AB	12	12			12	12			12	12		
4.3	AB	12	12			12	12			12	12		
4.4	AB	12	12			12	12			12	12		
4.5	AB	12	12			12	12			12	12		
XAB													
6	X1 A1 - B1 & X2 A2 - B2			12	12			12	12			14	16
7	X2 A1 - B2 & X2 A2 - B1			12	12			12	14			12	13
8	XAB			16	17			12	12			16	19
PQ & QP													
9	P1-Q1	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	4	5
10	P2-Q2	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3

		Participant											
		Magdalena				Octavio				Jessica			
		S1		S2		S1		S2		S1		S2	
Phase	Relations or Discrimination	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total	Correct	Total
11	P1-Q1 & P2-Q2	8	8	8	8	8	8	8	8	8	8	8	8
12	P1-Q1 & P2-Q2	8	8	8	8	8	8	13	14	8	8	8	8
13	QP*	8	8	8	8	8	8	7	8	8	8	8	8
XPQ PROBE													
14	*XPQ	6	12	12	12	7	12	12	12	6	12	12	12
CD & DC													
15	C1-D1	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	4	3	3
16	C2-D2	2	2	2	2	2	2	2	2	2	2	2	2
		3	3	3	3	3	3	3	3	3	3	3	3
17	C1-D1 & C2-D2	8	8	8	8	8	8	8	8	8	8	8	8
18	C1-D1 & C2-D2	8	8	8	8	8	8	8	8	8	8	8	8
19	DC*	8	8	8	8	8	8	8	8	8	8	8	8
PQX PROBE													
20	*PQX	6	12	10	12	7	12	11	12	5	12	12	12
XCD PROBE													
21	*XCD	6	12	12	12	6	12	12	12	6	12	12	12
FINAL PROBE PQC-D													
22	PQC-D*	9	16	15	16	8	16	15	16	8	16	15	16
PQX PROBE													
20	*PQX	12	12	12	12	6	12	12	12	5	12	11	12
XCD PROBE													
21	*XCD	9	12	12	12	6	12	11	12	6	12	10	12
FINAL PROBE PQC-D													
22	PQC-D*	16	16	16	16	8	16	16	16	8	16	15	16
Total		226	255	231	235	210	254	231	238	255	232	244	
Time		*20:07*		*14:34*		*16:27*		*12:34*		*14:56*		*12:32*	