



Emergent Relations between Discriminative Stimuli, Responses, and Consequences in Intraverbals

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Abstract

We explored the emergence of relations between stimuli learned as discriminative, responses, and consequences with intraverbals. In Experiment 1, five 9- and 10-year-old children learned intraverbals that related a country (A) with a city (B)—e.g., “Name a city of Switzerland”; “Davos”—and that country with a predator animal (C). Correct responses were followed by saying the name of a feature of the city (T) or saying an animal preyed by the predator (U), respectively. The emergence of BC and CB intraverbals that relate the cities and the predators and that of intraverbals that relate the specific consequences to the cities (T-B and U-B) and to the prey animals (T-C and U-C) was probed with no differential consequences. All five children demonstrated the emergence of BC, CB, U-B, and U-C and four children also demonstrated the emergence of T-B and T-C. In Experiment 2, a simpler procedure that controlled a possible extraneous factor, was used with seven 7- and 8-year old children and they also demonstrated emergence. Thus, the emergence of verbal relations with elements taught as discriminative stimuli, responses, and consequences was demonstrated.

Keywords emergent relations · stimulus equivalence · intraverbals · verbal behavior · reasoning

Sidman (2000) analyzed stimulus equivalence as the establishment of functional equivalence among stimuli that participated in contingencies. According to him, the contingencies established in discriminations determine the formation of equivalence classes. In a typical conditional discrimination with selection-based responses, matching sample A1 to comparison B1 or matching sample A2 to comparison B2 results in reinforcement. This way, the two stimuli correlated with reinforcement become equivalent: A1 to B1, on one side, and A2 to B2, on the other side. Moreover, he stated that contingencies also establish a partition between equivalent stimuli A1 and B1, on one side, and equivalent

stimuli A2 and B2, on the other side—an interesting way to describe the outcomes from stimulus equivalence studies. Sidman argued that when responses and reinforcers in a conditional discrimination are common in A1-B1 trials and A2-B2 trials neither responses nor consequences can enter into a class because that would suppose that individual classes collapse as all stimuli become members of a unique class (e.g., a class with A1, B1, the response (selecting), the reinforcer, A2, and B2). He also argued that if responses and/or reinforcers were correlated with the stimuli, then they could become members of classes. For example, if response R1 to B1 in the presence of A1 were followed by reinforcer 1 (Ref1) and response R2 in to B2 in the presence of A2 were followed by reinforcer 2 (Ref2) then two classes comprised by antecedent stimuli, responses, and reinforcers could be formed: class A1-B1-R1-Ref1 and class A2-B2-R2-Ref2.

Sidman’s assumptions have received empirical demonstrations. First, studies demonstrated that reinforcers can be members of equivalence classes (e.g., Schenk, 1994). Teaching conditional discriminations AB and AC with specific reinforcers (e.g., A1-B1-Ref1 and A2-B2-Ref2) and conditional discriminations DE and DF with the same reinforcers (Ref1 and Ref2) produces the merger of the ABC and the DEF stimuli in three classes of six

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members plus the reinforcer (Johnson et al., 2014). Here the reinforcer functioned as a necessary element for linking the remaining elements, which was denominated a *node* (Fields et al., 1984; Fields & Verhave, 1987), but it is not the only way for a stimulus to enter into a class. This effect was replicated and extended by demonstrating emergence of relations that included stimuli taught as reinforcers. For example, Silveira et al. (2018) taught conditional discriminations AB, AC, DE, and DF with specific reinforcers (Ref) and demonstrated the emergence not only of equivalence relations among the ABCDEF stimuli, but also equivalence relations between stimuli taught as antecedent stimuli and stimuli taught as reinforcers Ref-B, Ref-C, Ref-E, and Ref-F.

Second, studies have demonstrated how responses can become members of the class. Most of or all these studies have focused upon verbal operants. For example, in the *naming* relation (e.g., Horne & Lowe, 1996), two operants are involved: the tact, which consists of saying a word in the presence of a nonverbal stimulus (in Skinner's terms; Skinner, 1957), and a selection-based discrimination in which the word is a stimulus and the nonverbal stimulus is selected. Studies on naming have demonstrated the emergence of the tacts after learning the selection-based discrimination and vice versa (e.g., Horne et al., 2004; Horne et al., 2006; Lipkens et al., 1993; Lowe et al., 2002; Lowe et al., 2005; Mahoney et al., 2011; Pérez-González et al., 2011; Pérez-González, et al. 2014b). Thus, these studies demonstrated class formation composed of nonverbal and verbal stimuli, in which the verbal stimuli functioned as stimuli and responses.

Most studies related to the inclusion of responses as members of stimulus classes, however, used intraverbals as operants. Intraverbals were defined by Skinner (1957) as verbal operants characterized by the emission of a verbal response after the presentation of a verbal stimulus that shows no point-to-point correspondence with the response. We assume that intraverbals are discriminated operants just as the remaining discriminated operants (e.g., tacts, selections) used in the studies cited above. Thus, we also assume that the laws that govern the acquisition of intraverbals are the same as in the remaining discriminations. Experimental data on acquisition and emergence of intraverbals are coherent with this assumption (see revisions of studies on intraverbal emergence by Pérez-González, 2019, 2020). What makes intraverbals characteristic is that elements function as stimuli and responses across discriminations; for example, a stimulus in an intraverbal is often a response in another intraverbal, like the word "Spain" that is part of the discriminative stimuli in the intraverbal, "Name the continent where Spain is" and is a response in the intraverbal, "Name a country of Europe." Because of this feature, most or all studies on emergence of intraverbals demonstrated equivalences among elements that have been learned as stimuli and responses.

Pérez-González et al. (2008) conducted a study with intraverbals that extended previous research on stimulus equivalence by incorporating specific responses to the classes. They taught intraverbals in which an element A was a stimulus and an element B was a response (e.g., A was "Argentina," B was "Buenos Aires," and the intraverbal was, "Name a city of Argentina"–"Buenos Aires") and intraverbals in which the B element was a stimulus and an element C was a response (e.g., "Name a park of Buenos Aires"). Participants demonstrated the emergence of symmetry BA, symmetry CB, transitivity AC, and equivalence CA intraverbals. An interpretation of these results is that classes formed by the names of a country, a city, and a park were formed, in which all the stimuli functioned as stimuli and responses across intraverbals. The results of studies that followed this one are coherent with this hypothesis (e.g., Belloso-Díaz & Pérez-González, 2015a; Carp & Petursdottir, Carp & Petursdottir, 2012, Carp & Petursdottir, 2015; Daar et al., 2015; Pérez-González, Belloso-Díaz, et al., 2014a; Pérez-González & Oltra, *in press*; Zaring-Hinkle et al., 2016).

Reinforcers have not been studied so far in the research on the emergence of intraverbals. Yet, reinforcers may play an important role in intraverbals. For example, in everyday use, asking a question generates an intraverbal response that is typically followed by a specific consequence. For example, if one asks a friend, "Where did you go on the weekend?" and she responds, "I went to the beach," that response prompts some comment from the first speaker related to the beach, such as, "Oh, how nice! Was the water warm?" This consequence to the friend's response is specific in the sense that if the response were different, such as, "I went to the mountains," the response prompted to the listener (i.e., the consequence for the friend's response) should be different, specific to the mountains, such as, "Oh, did you see eagles up there?" These consequences clearly contrast with a general response such as "Interesting!" or "Very good." The specific consequences to the friend's response allow continuing the conversation, whereas a general response likely finishes it. In that vein, it is also possible that the consequence for a child's response provided by the teacher can be related to the antecedent stimuli and the response so that it allows further verbal emergence. For example, the teacher can ask, "Where did you see the stork foraging?," the child may respond, "In the shallows," and the teacher can respond, "There are frogs there." After that, the child may deduce that the storks eat frogs (hence, demonstrating the emergence of intraverbals such as, "What do the storks eat?"—"Frogs"). Thus, whereas generalized reinforcement may follow intraverbals, some type of specific consequence is likely involved in many stances of intraverbals.

The goal of the present research was to explore the emergence of intraverbals with stimuli presented in learning trials as consequences. That emergence would be consistent with

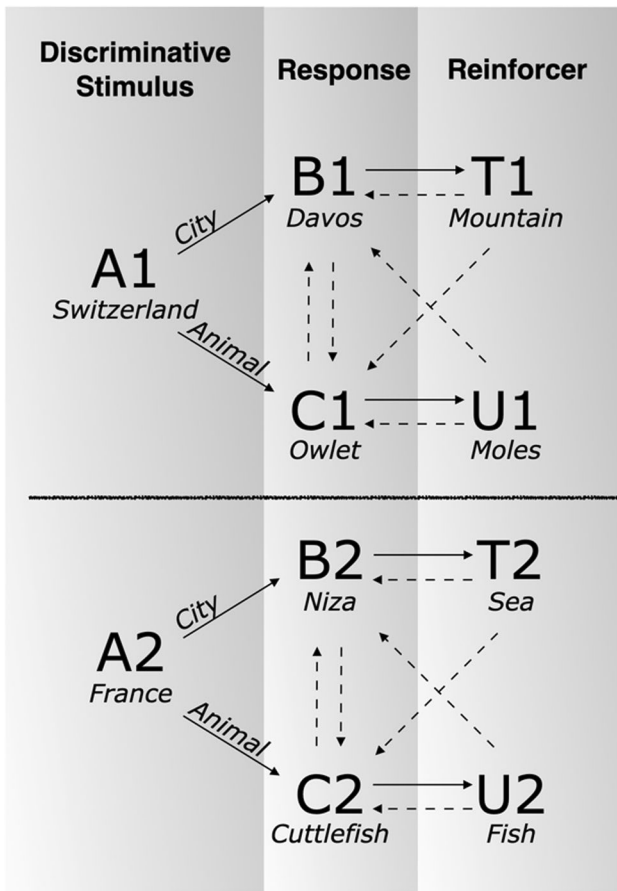


Fig. 1 Relations Taught (Solid Arrows) and Probed (Dotted Arrows). *Note.* The relations taught involved one discriminative stimulus, one response, and one reinforcer; thus, each one of the A1-B1-T1, A1-C1-U1, A2-B2-T2, and A2-C2-U2 relations was taught simultaneously. The labels above the arrows indicate the additional discriminative stimulus of the intraverbal. Notice that “cuttlefish” and “fish” do not sound similar in Spanish, because they are “sepia” and “peces,” respectively

class formation with discriminative stimuli, responses, and reinforcers. Thus, in Experiment 1, we taught AB and AC intraverbals with specific T and U stimuli as consequences and we probed the BC and CB intraverbals, with stimuli taught as responses, and the T-B, T-C, U-B, and U-C intraverbals, with stimuli taught as consequences and responses (see Figure 1). The B-C and C-B intraverbals were denominated *equivalence intraverbals*, staying consistent with Sidman and Tailby’s (1982) nomenclature regarding selection-based conditional discriminations because they may emerge after learning AB and AC and the emergent relations combine properties of symmetry and transitivity. These intraverbals typically emerge regardless of the specific reinforcers used for teaching them (e.g., Zaring-Hinkle et al., 2016; see also emergence of intraverbals of this sort when the A stimuli are nonverbal in Belloso-Díaz & Pérez-González, 2015b; Lipkens et al., 1993; May et al., 2013). The T-B and

U-C intraverbals share similarities with symmetry because they may result from learning the A-B-T and A-C-U conditional discriminations, respectively. After learning the B-T response-reinforcer relations in the A-B-T intraverbals, the T-B reinforcer-response relations may emerge. The same occurs with learning the C-U relations and the emergence of U-C. Notice that this type of emergence does not require nodes. For its part, the T-C and U-B intraverbals share similarities with transitivity. Given the learning of the A-B-T and the A-C-U relations, the T-C relations may emerge. The same occurs given the learning of the A-B-T and the A-C-U relations and the emergence of U-B. This type of emergence requires one node: node B for the emergence of T-C and node C for the emergence of U-B. In a second experiment, we aimed the same purpose with a simpler and refined procedure.

The present study had experimental nature. The stimuli used, however, were common names and relations. The reason for this use was that pilot studies with auditory stimuli and vocal responses with contrived stimuli were hard for the participants to learn (especially for children) and the emergence was less likely. Recent studies indicated that the nature of stimuli can affect emergence, for example Belloso-Díaz and Pérez-González (2015b, 2016) found that the emergence of symmetrical BA intraverbals after learning AB intraverbals was likely to occur with 5–7-year-old children when they learned tacts with B as responses and the stimuli were common. In contrast, Petursdottir et al. (2015) found that these relations did not emerge with contrived stimuli in 3.5–5.5-year-old children. These findings are coherent with the assumption that the type of stimulus (and/or age-related variables) can affect emergence. Stimulus equivalence evaluated with selection-based discriminations also occurs more likely with pictures or familiar stimuli than with abstract stimuli (e.g., Arntzen & Lian, 2010). For these reasons, we used common names and relations.

Experiment 1

Method

Participants

Five children who attended fourth grade in a public primary school in Oviedo, Spain, participated—with an age range from 9 years, 3 months to 10 years, 1 month (they appear in Table 1). Participants were randomly selected among the children of two school classrooms. None had received any diagnosis by the psychologist at the school; thus, it was assumed that all of them were typically developing. A sixth child participated but he exhibited disruptive behaviors and

Table 1 Names (Fictitious) and Ages of the Participants of Experiment 1

Name	Age (years, months)
<i>Cristina</i>	9 y, 8 m
<i>María</i>	9 y, 10 m
<i>Nico</i>	9 y, 3 m
<i>Álvaro</i>	9 y, 11 m
<i>Ana</i>	10 y, 1 m

conducted in Spanish. We used six intraverbals that relate countries (Switzerland [A1] and France [A2]) to a city (Davos [B1] and Niza [B2]) and to a predator that lives close to that city (owl [C1] and cuttlefish [C2]). They were taught with consequences referring to features of the cities (mountain [T1] and sea [T2]) and animals preyed by the predators (moles [U1] and fish [U2]). The intraverbals are presented in Table 2. The resulting intraverbals were

Table 2 Intraverbals Used in Experiment 1 and Its Translation into English (in italics)

Type of intraverbal	Antecedent stimuli	Response	Reinforcement
A1 B1 T1	Dime una ciudad de Suiza <i>Name a city of Switzerland</i>	Davos <i>Davos</i>	Sí, Davos está en la montaña <i>Yes, Davos is in the mountain</i>
A2 B2 T2	Dime una ciudad de Francia <i>Name a city of France</i>	Niza <i>Niza</i>	Sí, Niza está en el mar <i>Yes, Niza is by the sea</i>
A1 C1 U1	Dime un animal de Suiza <i>Name an animal of Switzerland</i>	Mochuelo <i>Owlet</i>	Sí, los mochuelos comen topos <i>Yes, owlets eat moles</i>
A2 C2 U2	Dime un animal de Francia <i>Name an animal of France</i>	Sepia <i>Cuttlefish</i>	Sí, las sepias comen peces <i>Yes, Cuttlefish eat fish</i>
B1 C1 probe	Dime un animal de Davos <i>Name an animal of Davos</i>	Mochuelo <i>Owlet</i>	
B2 C2 probe	Dime un animal de Niza <i>Name an animal of Niza</i>	Sepia <i>Cuttlefish</i>	
C1 B1 probe	¿En qué ciudad hay mochuelos? <i>Name a city that has owlets</i>	Davos <i>Davos</i>	
C2 B2 probe	¿En qué ciudad hay sepias? <i>Name a city that has cuttlefish</i>	Niza <i>Niza</i>	
T1 B1 probe	¿En qué ciudad hay montañas? <i>Name a city that is in the mountains</i>	Davos <i>Davos</i>	
T2 B2 probe	¿En qué ciudad hay mar? <i>Name a city that is by the sea</i>	Niza <i>Niza</i>	
T1 C1 probe	¿Qué animal hay en la montaña? <i>Name an animal that lives in the mountain</i>	Mochuelo <i>Owlet</i>	
T2 C2 probe	¿Qué animal hay en el mar? <i>Name an animal that lives in the sea</i>	Sepia <i>Cuttlefish</i>	
U1 B1 probe	¿En qué ciudad hay topos? <i>Name a city that has moles</i>	Davos <i>Davos</i>	
U2 B2 probe	¿En qué ciudad hay peces? <i>Name a city that has fish</i>	Niza <i>Niza</i>	
U1 C1 probe	¿Qué animal come topos? <i>What animal eats moles</i>	Mochuelo <i>Owlet</i>	
U2 C2 probe	¿Qué animal come peces? <i>What animal eats fish</i>	Sepia <i>Cuttlefish</i>	

lack of attention and did not maintain the learned relations in the probes; for that reason, his data are not presented here.

Materials and Stimulus Relations

The stimuli were components of targeted intraverbals. All the stimuli were in Spanish and all the procedures were

the following: (1) Four taught intraverbals: the two A-B-T Country-City-Feature and the two A-C-U City-Predator-Prey; (2) four probed intraverbals with responses from the taught intraverbals: the two B-C City-Predator, and the two C-B Predator-City intraverbals. Consistent with Sidman and Tailby (1982), they were named *equivalence intraverbals*

because they may emerge after learning AB and AC, regardless of the specific reinforcers used to teach them. (3) Eight probed intraverbals with responses and reinforcers of the taught intraverbals: the two T-B Feature-City, the two U-C Prey Animal-Predator, the two T-C Feature-Predator, and the two U-B Prey Animal-City intraverbals. The T-B and U-C intraverbals share similarities with symmetry because they may result from learning the A-B-T and A-C-U conditional discriminations, respectively. The T-C and U-B intraverbals share similarities with transitivity, because each one requires learning both the A-B-T and A-C-U conditional discriminations (e.g., T-C requires learning the TA relation in A-B-T and also the AC relation in A-C-U; thus, A is the node).

Procedures

Variables and Design

The dependent variables were the defined correct responses in each type of probed intraverbal (B-C, C-B, T-B, T-C, U-B, and U-C). The independent variable was the effect of learning the A-B-T and the A-C-U intraverbals. Thus, the design included an AB intra-participant design replicated with five people. With three participants who did not demonstrate emergence in the first probe, another independent variable was the effect of reviewing the taught intraverbals—hence, another AB intra-participant design was in place.

Data Recording, Interobserver Agreement, and Procedural Integrity

One observer (an experienced college student) was present in all sessions to take data independently for the purposes of computing interobserver agreement and procedural fidelity. The observer recorded 671 responses out of 718 (93.5%) emitted by all five participants and the correct presentations of the trials—stimuli and consequences. The experimenter and the observer agreed on all 671 trials. Thus, interobserver agreement ($\text{agreements}/[\text{agreements} + \text{disagreements}] \times 100$) was 100%. The observer verified the integrity of the procedure by recording whether the experimenter presented the antecedent and consequent stimuli according to the predetermined experimental plan. The experimenter presented the stimuli according to the experimental plan in all trials.

Setting

The sessions were conducted in a quiet classroom at a public school of Oviedo, Spain, provided with tables, chairs, boards, and other materials. Only the experimenter, the child, and an observer were present during the sessions.

General Procedures

All the procedures were conducted in Spanish, in a single session with each child. At the onset of the session, the experimenter told the child, “Now, I will ask you some questions. You have to respond the best you can. Sometimes, I will tell you if you are correct or not.” Correct responses were the responses consistent with all the presented stimuli, as depicted in Fig. 1 and Table 2, and they would be considered correct in everyday life. Responses were correct if the child gave the correct response within 5 s after the instruction. Only the first response was considered (e.g., if the child emitted a response and immediately emitted another one, only the first response was considered and evaluated). Responses were considered incorrect if the child said the wrong word or after 5 s had elapsed. In probe trials, the experimenter did not present any differential consequence. After each child’s response, the experimenter wrote the response in a recording sheet and continued to the next trial. The session with a child finished after the child met the criterion in a postintervention probe phase with the U and T stimuli or, after a maximum of three postintervention probe phases.

Procedure Overview

The children (1) received a preintervention probe of all the intraverbals, (2) learned the A-B-T and the A-C-U intraverbals, and (3) received probes of the B-C and C-B intraverbals. Then, steps (2) and (3) were reviewed if the child did not reach criterion in the probes of step (3), until receiving a maximum of three review-probe cycles. All children reached criterion within the three probes. Thereafter, step (2) was reviewed and the children (4) received probes of the T-B, T-C, U-B, and U-C intraverbals. If a child did not reach criterion in the probes of step (4) then the A-B-T and the A-C-U intraverbals were reviewed again (step 2) and step (4) was repeated. Then the experiment finished.

Preintervention Probe All the intraverbals to be taught and probed (see Table 2) were presented once. The child was told that the experimenter was not going to tell him/her whether the answers were correct or not.

Teaching the A-B-T and A-C-U Intraverbals The A-B-T intraverbals were taught in three phases. In phase 1, the experimenter asked, “Name a city of Switzerland” (A1). In the first two trials, she provided the correct response, “Davos” (B1—a prompt). From the third trial on, the experimenter no longer provided the prompt. Correct responses were followed by expressions such as, “Yes, Davos is in the mountains” (T1). Incorrect responses were followed by the experimenter saying “No” followed by the correct response

(a correction; e.g., “No, Davos”). After three consecutive unprompted correct responses, the experiment advanced to phase 2. Phase 2 was similar to phase 1, but the experimenter asked, “Name a city of France” (A2), the correct response was, “Niza” (B2), and the consequence for correct responses was, “Yes, Niza is by the sea.” Phase 3 was similar to phases 1 and 2, but the two questions (A1 and A2) were randomly presented across trials, with the restriction that each question was presented twice every four trials, and prompts were never provided. After the child demonstrated eight correct consecutive responses, the experiment continued with the A-C-U intraverbals. The A-C-U intraverbals were conducted with a similar procedure, but the questions, “Name an animal of Switzerland” (A1) and, “Name an animal of France,” (A2), the responses “Owlet” (C1) and “Cuttlefish” (C2), and the consequences, “Yes, owlets eat moles” (U1) and “Yes, cuttlefish eat fish” (U2) were in place. After the child reached criterion, the intraverbal probes were presented. When the A-B-T and A-C-U intraverbals were reviewed, only phase 3 was presented.

Probe of the Taught and the Equivalence Intraverbals Each one of the taught A-B-T and A-C-U intraverbals and the BC, and CB equivalence intraverbals was presented twice. The responses did not receive differential consequences; thus, the T or U stimuli were not presented. The criterion for passing this probe was to make 14 out of 16 correct responses.

Probe of the Intraverbals with Stimuli Taught as Consequences Each one of the T-B, T-C, U-B, and U-C intraverbals was presented twice, with no differential consequences. The criterion for passing this probe was to make 15 out of 16 correct responses.

Results

Preintervention Probe, Learning of the A-B-T and A-C-U Intraverbals

All children made zero correct responses in the preintervention probe. All children learned the A-B-T and A-C-U intraverbals in 28 to 48 trials. Four children made 0–3 errors, and the remaining child (Ana) made 12 errors. The three children who did not reach criterion in the first probe of the emergence of the BC and CB equivalence intraverbals (Nico, Álvaro, and Ana) reviewed phase 3 of the A-B-T and A-C-U intraverbals; they mastered these phases with 0–3 errors.

Probe of Taught and Equivalence Intraverbals

The results appear in Table 3. All five children made 14 or 16 correct out of 16 responses in this probe. Cristina made

Table 3 Correct Responses Out of 4 Trials in All Relations Presented in the Probes of the Equivalence Intraverbals of Experiment 1

Participant	Taught		Probed	
	AB	AC	BC	CB
<i>Cristina</i>	4	4	4	4
<i>María</i>	4	3	4	4
<i>Nico</i>	1	3	2	1
	1	4	0	0
	4	4	4	3
<i>Álvaro</i>	0	4	0	0
	2	4	4	0
	4	4	4	3
<i>Ana</i>	0	4	3	0
	3	4	3	4
	3	4	4	3

Data are presented according to the order of presentation, left to right and top to bottom.

16 correct responses (in the first probe), three children made 15 (María in the first probe, and Nico and Álvaro in the third probe), and Ana made 14 correct in two consecutive probes (the second and the third probe). All five children made seven or eight responses correct in the eight trials of each one of the BC and CB intraverbals in the last probe.

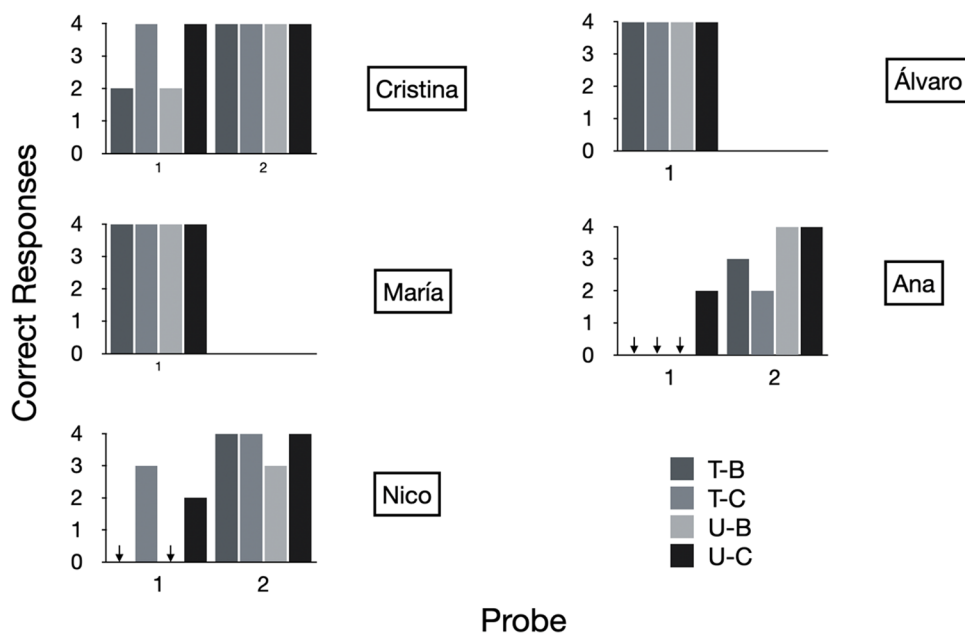
Probe of the Intraverbals with Stimuli Taught as Consequences

The results appear in Figure 2. Four of the five children made 15 or 16 correct responses in the probes with the T-B, T-C, U-B, and U-C intraverbals (María and Álvaro in the first probe and Cristina and Nico in the second probe). The fifth child, Ana, made 13 correct responses. In the second probe with the T-B and the T-C intraverbals, she made all eight correct responses with the U-B and the U-C intraverbals, but she made five out of eight correct responses in the T-B and T-C intraverbals.

Discussion

The main goal of Experiment 1 was to explore the emergence of relations with stimuli that had been presented as discriminative stimuli, responses, and consequences in intraverbals. Four of the five children demonstrated emergence of all four probed intraverbals. One more child did so with the two intraverbals that involved the T stimuli as consequences and some instances of emergence, although slightly above

Fig. 2 Correct Responses out of 4 Trials in the Probes of the Intraverbals with Stimuli Taught as Consequences of Experiment 1. *Note.* Arrows indicate zero correct responses



50%, with those that involved the U stimuli. Therefore, these results demonstrate the emergence of operants composed of stimuli taught as discriminative stimuli, responses, and reinforcers in the format of intraverbals. Thus, the phenomenon appears to be robust.

The results of the present experiment replicate previous studies on the emergence of the intraverbals, in which the emergence of BC and CB intraverbals after learning operants with a nonverbal or verbal stimulus as sample and B or C as comparisons (i.e., AB and AC): Lipkens et al. (1993) demonstrated this type of emergence with a 2-year-old child. May et al. (2013) did so with people with autism, and Beloso-Díaz and Pérez-González (2015b) and Zaring-Hinkle et al. (2016) demonstrated this process with adults.

The procedure used in this experiment can limit the conclusions regarding the role of the consequences in forming stimulus relations because the experimenter repeated the response given by the child together with the specific consequence (e.g., she said, “Yes, Davos is in the mountain,” where “Davos” echoed the child’s response). Because of that, one possibility was that the observed emergence was a result of the child’s hearing the word related to the response and that of the consequence paired (i.e., “Davos” and “mountain”). In fact, studies on verbal emergence demonstrated that presenting two stimuli paired sufficed for producing relations between these stimuli (e.g., Cahill & Greer, 2014; Carnerero & Pérez-González, 2014; Carnerero et al., 2019; Longano & Greer, 2015; Omori & Yamamoto, 2013; Pérez-González et al., 2011, 2014a, 2014b; Ramirez & Rehfeldt, 2009; Rosales et al., 2012; Shanman, 2013; Takahashi et al., 2011). Moreover, related studies conducted in the context of teaching verbal behavior skills demonstrated that

sentences like that sufficed for producing verbal relations in the research area of *instructive feedback* (e.g. Caldwell et al., 1996; Carroll & Kodak, 2015; Delmolino et al., 2013; Loughrey et al., 2014; Reichow & Wolery, 2011; Werts et al., 1995), even if these sentences were presented in the intertrial interval while the participant was consuming an edible, a procedure similar to that used in the present study. Therefore, the results of the present study could have been observed even if the experimenter presented the consequent sentence in a different moment of the trial or during the intertrial interval. In such a case, the stimuli presented as consequences in the present study would be related to the discriminative stimuli even if they were not presented as consequences. This interpretation was addressed in the next experiment.

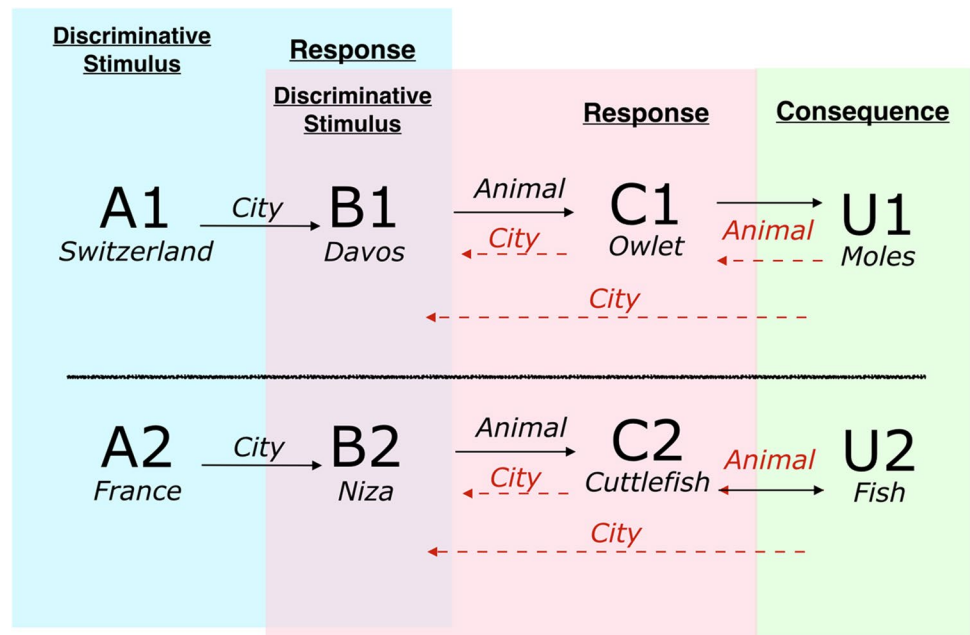
Experiment 2

The goal of experiment 2 was to continue exploring emergence of relations among verbal stimuli, responses, and consequences with procedures that could ensure that the resulting emergence would have been produced because one stimulus was presented as a specific consequence. For that, a simplified procedure was used that involved the experimenter presenting the specific consequence alone, i.e., without repeating the child’s response. Thus, emergences between the discriminative stimulus emitted by the experimenter and the consequence, on the one hand, and between the response emitted by the child and the consequence emitted by the experimenter, on the other hand, were explored.

Table 4 Names (Fictitious) and Ages of the Participants of Experiment 2

	Age (years, months)
Cecilia	7 y, 5 m
Bartolo	7 y, 10 m
Demetrio	7 y, 7 m
Lorenzo	7 y, 5 m
Jenaro	7 y, 10 m
Lina	7 y, 7 m
Carmena	8 y, 1 m

Fig. 3 Relations Taught (Solid Black Arrows) and Probed (Dotted Red Arrows) in Experiment 2. Note. The A-B relations (cyan background) involved a discriminative stimulus and a response, the B-C relations (pink and green backgrounds) involved a discriminative stimulus, a response and a consequence. The labels above the arrows indicate the additional discriminative stimulus of the intraverbal. Notice that “cuttlefish” and “fish” does not sound similar in Spanish because they are “sepia” and “peces,” respectively



intraverbals were taught with no specific consequences.¹ Moreover, the B-C-U City-Predator-Prey intraverbals were taught, with specific consequences related to the animals preyed by the predators. The intraverbals are presented in Figure 3 and Table 5. We probed a portion of the possible stimulus–response–consequence relations that could result from that teaching in order to make the task simpler for the participant children. The resulting intraverbals were: (1) Four taught intraverbals: the A-B Country-City and the B-C-U City-Predator-Prey intraverbals. (2) Two probed

Method

Participants

The participants were seven children who attended second grade in a public primary school in Oviedo, Spain, with an age range of 7 years, 5 months to 8 years, 1 month (see Table 4). They were randomly selected from children in a school classroom. None had received any diagnosis by the psychologist at the school; thus, it was assumed that all of them were typically developing. An eighth child participated but she did not maintain the learned relations when they were intermixed (see below); for that reason, her data are not presented here.

Materials and Stimulus Relations

The stimuli were some of those used in experiment 1. We used four intraverbals that relate the countries, cities, and predators that live close to that city used in experiment 1. In the present experiment, however, the A-B Country-City

intraverbals with responses from the taught intraverbals: the C-B Predator-City intraverbals. They were denominated symmetrical intraverbals, because the B and C elements switched the stimulus–response functions of the taught BC intraverbals. (3) Four probed intraverbals with responses and reinforcers of the taught intraverbals: two U-B Prey Animal-City and two U-C Prey Animal-Predator intraverbals. The U-B and U-C intraverbals share similarities with symmetry because they may result from learning the B-C-U conditional discriminations. In these intraverbals, the U stimuli used as consequences in the B-C-U intraverbals were stimuli; in the U-B intraverbals, the response was the stimulus

¹ The A-B intraverbals were presented for being consistent with the procedure of experiment 1. Notice that including B responses can facilitate the emergence of relations with the B stimuli as responses. For example, in A-B, the child was taught to respond “Davos” when asked for a city in, “Name a city of Switzerland” that can facilitate responding to, “Name a city that has owlets” in the C1-B1 probe—if the child does not learn to respond to “city,” they may not respond in the emergence probes.

Table 5 Intraverbals Used in Experiment 2 and Its Translation into English (in italics).

Type of intraverbal	Antecedent stimuli	Response	Reinforcement
A1 B1	Dime una ciudad de Suiza <i>Name a city of Switzerland</i>	Davos <i>Davos</i>	Bien. <i>Correct</i>
A2 B2	Dime una ciudad de Francia <i>Name a city of France</i>	Niza <i>Niza</i>	Bien. <i>Correct</i>
B1 C1 U1	¿Qué animal hay en Davos? <i>Name an animal of Davos</i>	Mochuelo <i>Owlet</i>	Bien. Comen topos <i>Correct. They eat moles</i>
B2 C2 U2	¿Qué animal hay en Niza? <i>Name an animal of Niza</i>	Sepia <i>Cuttlefish</i>	Bien. Comen peces <i>Correct. They eat fish</i>
C1 B1 probe	¿En qué ciudad hay mochuelos? <i>Name a city that has owlets</i>	Davos <i>Davos</i>	
C2 B2 probe	¿En qué ciudad hay sepias? <i>Name a city that has cuttlefish</i>	Niza <i>Niza</i>	
U1 B1 probe	¿En qué ciudad hay topos? <i>Name a city that has moles</i>	Davos <i>Davos</i>	
U2 B2 probe	¿En qué ciudad hay peces? <i>Name a city that has fish</i>	Niza <i>Niza</i>	
U1 C1 probe	¿Qué animal come topos? <i>What animal eats moles</i>	Mochuelo <i>Owlet</i>	
U2 C2 probe	¿Qué animal come peces? <i>What animal eats fish</i>	Sepia <i>Cuttlefish</i>	

of B-C-U and in the U-C intraverbals, the response was the response in the B-C-U intraverbals.

Procedures

All procedures were identical to those used in experiment 1 except for the following.

Variables and Design

The dependent variables were the scores of correct responses in each type of intraverbal (A-B, B-C, C-B, U-B, and U-C) in probe trials. The independent variables were the effect of learning the A-B and the B-C-U intraverbals within each participant and the effect of reviewing the taught intraverbals with six participants. Thus, the design included two AB intra-participant designs replicated with six people and one AB design with one more participant.

Data Recording, Interobserver Agreement and Procedural Integrity

The two experimenters were present in all sessions to take data independently for the purposes of computing the interobserver agreement and procedural fidelity. The observer recorded responses to all 1,054 trials and the correct presentations of the trials—stimuli and consequences. The experimenter and the observer agreed on all but three responses. Thus, interobserver agreement ($\text{agreements}/[\text{agreements} +$

$\text{disagreements}] \times 100$) was 99.7% (range across children 97.8%–100%). The observer verified the integrity of the procedure by recording whether the experimenter presented the antecedent and consequent stimuli according to the predetermined experimental plan. The experimenter presented the stimuli according to the experimental plan in all trials.

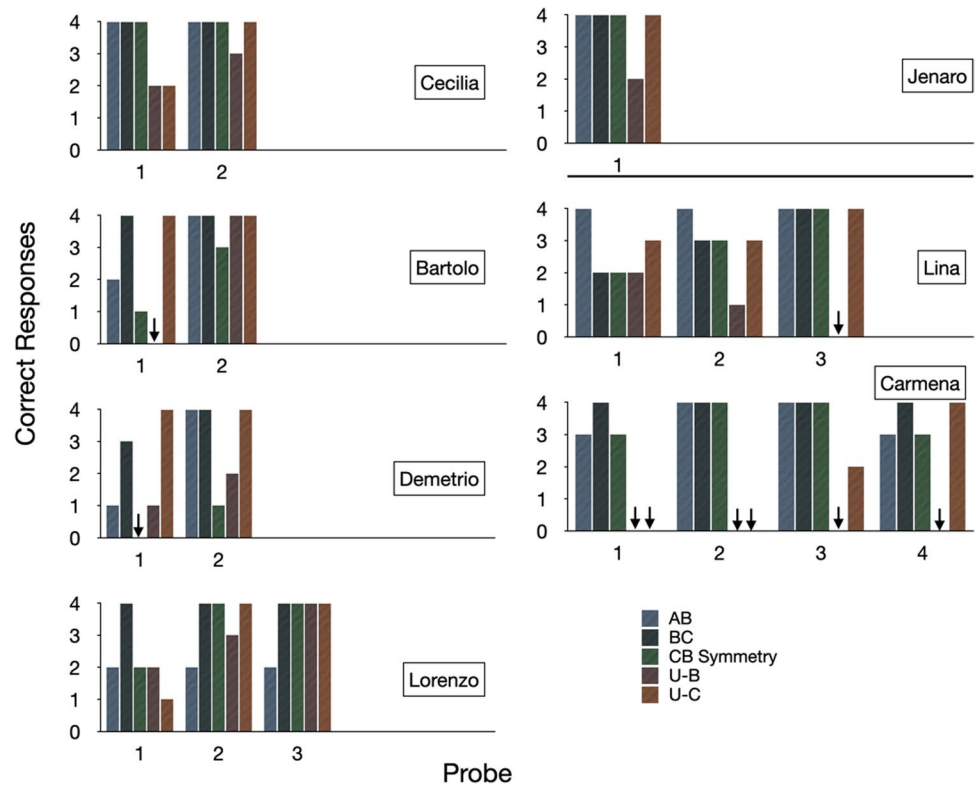
Procedure Overview

The children (1) received a preintervention probe of all the intraverbals, (2) learned the A-B and the B-C-U intraverbals, and (3) received a probe of all the intraverbals. Then, steps (2) and (3) were reviewed if the child did not reach a criterion of all correct responses in the last two trials of each U-B and U-C probes of step (3) and showed no increases in correct responding, until receiving a maximum of five probes.

Preintervention Probe All the intraverbals to be taught and probed were presented once. The child was told that the experimenter was to ask some questions and that they should not be worried, because even many adults do not know the correct answers to these questions, and that the experimenter was not going to tell them whether the answers were correct or not.

Teaching the A-B and B-C-U Intraverbals The A-B intraverbals were taught in a similar way to the A-B-T intraverbals of experiment 1, except for that the experimenter said “Correct!” (“¡Bien!” in Spanish), “Excellent!” or similar

Fig. 4 Correct Responses Out of 4 Trials in All Relations Presented in the Probes of Experiment 2. *Note.* Arrows indicate zero correct responses



expressions for correct responses and that prompts were presented just in the first trial of phases 1 and 2 (i.e., no differential consequences were provided for correct responses B1 and B2). The B-C-U intraverbals were taught like the A-C-U intraverbals of experiment 1 except for the following: First, the experimenter provided just one prompt in phases 1 and 2; second, in the prompted trials the experimenter did not provide consequences for echoing the response just prompted; third, correct responses C1 and C2 were followed by, “Correct, it eats moles”, or “Correct, it eat fish,” respectively—the reason for this procedure was not to present the child the response and the specific consequence in the same utterance. In addition to the three phases for teaching A-B and B-C-U, a new phase (phase 7) was presented in which the four intraverbals of A-B and B-C-U were randomly presented every four trials. There were not prompts, the consequences were the respective consequences programmed for teaching A-B and B-C-U and the criterion for advancing to the postintervention probe was to make eight consecutive correct responses.

Postintervention Probe It was identical to the preintervention probe, except that it was presented twice, for a total of 20 trials, with 2 trials of each taught and probed intraverbal.

Results

Preintervention Probe and Learning of the A-B and B-C-U Intraverbals

All children made zero correct responses in the preintervention probe. All children learned the A-B-T and A-C-U intraverbals in 56 to 105 trials. Six children learned within 76 or fewer trials, and the remaining child (Lorenzo) did not reach criterion in the phase in which all A-B and B-C-U intraverbals were intermixed, then the experimenters presented again phase 3 of the A-B learning and returned to the intermixing phase. Finally, the child met criterion with a total of 105 teaching trials.

Emergence of the CB Intraverbals

The results of the emergence probes appear in Figure 4. Four children (Cecilia, Lorenzo, Jenaro, and Lina) made all four correct responses in the last four trials. Bartolo and Carmena made three, including the last two trials. Demetrio made only one correct response.

Probe of the Intraverbals with Stimuli Taught as Consequences

Five children (Cecilia, Bartolo, Demetrio, Lorenzo, and Jenaro) made all four correct responses in the last four trials of the emergence probe with the U-B and U-C intraverbals. The two remaining children (Lina and Carmena) made all correct responses in the probe of the U-C intraverbals and made all incorrect responses of the U-B intraverbals.

Discussion

All seven children demonstrated the emergence of intraverbals with stimuli previously taught as consequences. Five children demonstrated the emergence of the intraverbals in which one stimulus (B1 or B2) was formerly presented as a response (in the A-B intraverbal) and as a stimulus (in the B-C-U intraverbal). All seven children demonstrated the emergence of the intraverbals in which one stimulus (C1 or C2) was formerly presented as a response. Therefore, this type of emergence with stimuli formerly presented as reinforcers appears to be robust.

Unlike in experiment 1, the results of experiment 2 cannot be interpreted as emergence that result of two stimuli paired by being presented simultaneously by the experimenter. Instead, the present experiment demonstrated intraverbal emergence by relating a response provided by the participant with a consequence presented by the experimenter.

Two children demonstrated more instances of emergence with stimuli formerly presented as response and consequence (U-C) than with stimuli formerly presented as stimuli (U-B). One of them demonstrated all correct responses in the eight trials with U-C presented along four probes, whereas they made just one correct response in the eight trials of the C-B probe.

General Discussion

The present results expand the demonstration of types of intraverbals that can emerge. In the research area of the intraverbals, this study demonstrates, for the first time, the emergence of verbal relations with stimuli taught as consequences. In the research area of stimulus equivalence and stimulus relations, however, the formation of classes with stimuli taught as consequences had already been demonstrated (e.g., Johnson et al., 2014; Schenk, 1994; Silveira et al., 2018); in that context, the present study extends these findings to verbal operants.

Regarding emergence with stimuli learned as responses, the present study once more replicates the finding that verbal operants emerge with stimuli taught as discriminative stimuli and responses, as observed in studies of *naming* and

the emergence of intraverbals. This study is the first one to demonstrate the emergence of relations composed by stimuli that have been taught as responses and as consequences.

The learning processes involved in the emergence of verbal relations of the type of the intraverbal seem to be identical to those involved with relations with contrived stimuli and selection-based responses, because a few discriminative principles suffice to explain most results (Pérez-González, 2020). This is not surprising given that the type of task is more affected by procedural variables than by the type of stimulus, as analyzed by Pérez-González (2019). In fact, that analysis suggests that the main variable that affects the emergence of intraverbals, in relation to traditional studies on stimulus equivalence and stimulus relations with selection-based responses, is related to the previous acquisition of the responses of the probed relations. This has been demonstrated by the increase of emergence when echoics (e.g., Pérez-González et al., 2011) or operants with that response (e.g., Belloso-Díaz & Pérez-González, 2015b, 2016) were previously learned.

An interesting question is why putative reinforcers enter into the classes. According to Sidman (2000), it may be sufficient that reinforcers correlate with antecedent stimuli. This seems insufficient for contingencies to affect class formation: stimuli and responses can correlate because the apparition of two stimuli together (e.g., A1 and B1) is a requirement for the response to be reinforced. A similar process occurs with stimuli and responses (e.g., responding R1 in the presence of A1), because that response in the presence of that stimulus is also a requirement for reinforcement. With reinforcers, the same cannot be true because the occurrence of the reinforcer is not a requirement for reinforcement. One possible explanation is that the stimuli that are presented together can enter into classes. In fact, studies on stimulus equivalence with selection-based responses have already demonstrated the formation of classes after persons observed the apparition of two stimuli in close succession (e.g., Leader et al., 1996; Leader & Barnes-Holmes, 2001). Moreover, stimuli paired together result in function transfer (Freitas et al., 2020; Tonneau et al., 2006; Tonneau & González, 2004). Stimuli presented together also result in the emergence of topography-based discriminations, such as tacts and intraverbals (e.g., Cahill & Greer, 2014; Carnerero & Pérez-González, 2014, 2015; Carnerero et al., 2019; Longano & Greer, 2015; Omori & Yamamoto, 2013; Pérez-González et al., 2011; Pérez-González, Belloso-Díaz, et al., 2014a; Pérez-González, Cereijo-Blanco, & Carnerero, 2014b; Ramirez & Rehfeldt, 2009; Rosales et al., 2012; Shanman, 2013; Takahashi et al., 2011). Thus, it is possible that stimulus relations observed between a discriminative stimulus or a response and a consequence is due to the same processes than when two stimuli are presented together. Notice that in the first case two stimuli are presented together either in

succession or simultaneously whereas in the second case, the consequent stimulus is presented right after the discriminative stimulus is presented and the response is emitted. Thus, a generalized skill or capability (Greer & Ross, 2008) related to attending to two stimuli presented together, even if no response other than attending is required and no differential reinforcement is applied, acquired through development, may suffice for learning both stimulus–stimulus relations and discriminative stimulus–reinforcer relations (see all studies cited above). Further studies should clarify whether the relations established between the stimuli presented as consequences and the discriminative stimulus or the response is due to presenting the two stimuli together or if some factor specific to the nature of the consequent stimulus presented in an operant is involved in emergence.

The effect just discussed can operate regardless of the fact that the used consequence is a reinforcer or not. In fact, in contrast with other studies, in the present study we did not evaluate the reinforcer effects of the specific consequences. The only fact known by the experimenters in that regard is that using words such as “Yes,” “Correct!” served to maintain correct responses. In fact, saying “Correct!” or a similar expression was necessary because in a pilot study of experiment 2, in which the only consequence was to present the targeted stimulus (i.e., the experimenter just said, “They eat moles” when the child said “Owlet” to the question, “Name an animal of Davos”), and the child responded as if that consequence were a correction, as in the next question. Therefore, with these data the more plausible conclusion is that sentences such as “Correct!” are reinforcers, but the sentence that followed it was not. As said, this fact did not preclude the formation of reliable relations between these stimuli and the discriminative stimuli and responses used.

The data of the present study, together with those from the studies on pairing stimuli and those on instructive feedback cited above suggest a parsimonious explanation of the studies on stimulus equivalence with reinforcers, which were conducted with humans: The stimuli used, even though they had been evaluated as reinforcers, could have entered into classes, or served as nodes to establish classes, just because they were presented as consequences; therefore, it is likely that they should have accomplished these functions even if they were not reinforcers. Further studies can explore this hypothesis.

A parsimonious description of the process involved in experiment 2 is that a relation was established between a stimulus (a *word*) spoken by speaker (the experimenter) and another stimulus spoken by the listener (the participant child). The demonstration of that emergent relation is unique in that it, to our knowledge, has not been described before. Therefore, it is possible that, throughout a conversation, relations can be established not only among stimuli presented by the speaker (e.g., *words*), but also among stimuli presented

by the speaker and stimuli produced by the listener own responses. This finding is worth further exploration and can open a new topic of research.

One child (Demetrio) demonstrated emergence of relations between a stimulus presented as a consequence and a response (U-C) but he did not demonstrate emergence between a stimulus presented as a response and a stimulus (C-B). This result is interesting because it suggests that, at least for some children, the emergence of an intraverbal with a stimulus presented as a consequence may be more effective for producing equivalence than an intraverbal with a stimulus taught as response. More research is necessary to explore that hypothesis.

Another interesting question is whether the stimuli used in the present study demonstrated equivalence. In typical studies with contrived stimuli, purely arbitrary relations, and selection-based discriminations, the experimenter can arrange any type of relation and check pure stimulus equivalence. When designing studies on intraverbals, however, the experimenter deals with many restrictions, like in the present study in which a purpose of the experimenters was that the involved relations resemble some used in everyday life. In the context of the present study, the stimuli may seem equivalent (e.g., Switzerland, Davos, mountains, owlets, and moles) and separated from those of the other class (i.e., the stimuli related to France). In everyday life, however, the relations are more complex. For example, France has mountains, owlets, and moles. Thus, in order to expand the present studies, more complex relations should be taken into account. For example, studies on intersecting classes demonstrate how particular stimuli are related to a first set of stimuli on some trials and are related to a second set of stimuli in other trials, according to the context (Alonso-Álvarez & Pérez-González, 2006, 2011, 2013; Mackay et al., 2011; Pérez-González & Alonso-Álvarez, 2008). For example, Cervantes is related to Goya in a context of nationalities and is related to Balzac in a context of disciplines. In those cases, contextual cues, either as explicit (i.e., verbal) or implicit (i.e., the relations among the comparisons presented in selection-based studies) stimuli seem necessary. Further studies can analyze these hypotheses.

The design allowed to identify factors that result in intraverbal emergence. The control was similar to most stimulus on stimulus equivalence. It, however, included a preintervention probe that is not typically used in stimulus equivalence studies. Notice that the probability that a person (even an adult) can relate moles with Davos or cuttlefish with Niza in the absence of a context is remote. Even if a participant responds like if he/she were randomly selected a city among the two cities used in the study (Davos and Niza), the probability of a person to make all selections correct would be extremely low. Moreover, the results were replicated across 12 children (5 children

in experiment 1 and 7 children in experiment 2). Moreover, virtually no incorrect response consisted of saying the other stimulus of a category (i.e., saying Niza instead of Davos in response to a question of saying a city). Another advantage was that the study was conducted with most participants in one 30-min session; this excluded maturity effect or possible effects of learning some relations during extra-experimental time. Therefore, the design served for the present demonstration. Other designs with the possibility of more stringent control that allow to increase control and overcoming the inherent limitations of the AB designs, however, could be used, such as multiple-baseline designs. In such a case, it should be considered that repeating probes before introducing a factor of the independent variable can result in fewer instances of emergence than if that factor were introduced before the first probe (e.g., Belloso-Díaz & Pérez-González, 2015a).

The present study could have suffered the limitation of using intraverbals that were unlikely to be produced in an everyday setting. They served for the purposes of the present study. Further studies, however, would need to use more common intraverbals.

The present study has various applications. For example, the results suggest a quick way to teach verbal relations by just presenting stimuli as part of the reinforcing consequences. It is likely that the procedures can be used for teaching persons with developmental delays and learning difficulties to help them to acquire emergent capabilities.

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Declarations

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

Ethical Standards 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.

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