Discriminative Processes Involved in Reasoning: Emergence of Intraverbals[1,2]

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Abstract

Intraverbal emergence has been broadly studied. The aim of this paper was analyzing discriminative and related processes involved in that emergence. The variables and results of all known articles that demonstrated emergence were analyzed by comparing the discriminative and related procedures used by the researchers and the emergence outcomes. Discriminative processes involved in learning simple and conditional discriminations, the correlation between stimuli to establish stimulus-stimulus relations, the previous acquisition of the responses of the emergent intraverbals, the previous history with stimuli of the sort of the involved stimuli, the effect of repeating probes, the optimal sequence of teaching and probing, the negative transfer of learning a second response to the same stimulus, and the effects of symmetry were found to explain most emergence results. The lack of some of the related factors resulted in failures to obtain emergence. The successful procedures suggest techniques for promoting the emergence of intraverbals in typically developing children as well as in persons with learning difficulties or developmental delays. Because of the nature of intraverbals, most instances of emergence evidence reasoning.

***Key words**: Intraverbal, emergent relations, discrimination, categorization, stimulus equivalence, reasoning, deductive reasoning*

Resumen

La emergencia de intraverbales ha sido estudiada extensamente. El propósito de este artículo fue analizar procesos discriminativos y otros relacionados involucrados en esta emergencia. Las variables y resultados de todos los artículos conocidos que demostraron emergencia fueron analizados comparando los procedimientos discriminativos usados por los investigadores y los resultados de emergencia. Se encontró que procesos discriminativos involucrados en discriminaciones simples y condicionales, la adquisición

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previa de las respuestas de las intraverbales emergentes, la historia previa con estímulos del tipo de los estímulos involucrados, el efecto de repetir las pruebas, la secuencia óptima de enseñanza y prueba, la transferencia negativa de aprender una segunda respuesta ante el mismo estímulo y los efectos de la simetría explican la mayoría de los resultados de emergencia. La ausencia de los factores relacionados tuvo como resultado fracasos en la obtención de emergencia. Los procedimientos exitosos sugieren técnica para promover la emergencia de intraverbales en niños de desarrollo típico así como en personas con dificultades de aprendizaje o de retraso en el desarrollo. Debido a la naturaleza de las intraverbales, la mayoría de las instancias de emergencia evidencian razonamiento.

Palabras clave: *Intraverbal, relaciones emergentes, discriminación, categorización, equivalencia de estímulos, razonamiento, razonamiento deductivo*

Discriminative processes involved in reasoning: Emergence of intraverbals

Skinner (1957) defined intraverbals 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. This paper focus only on intraverbals in which the verbal response is topography-based (e.g., Michael, 1985; Sundberg & Sundberg, 1990; Vignes, 2007, Wraikat, Sundberg, & Michael, 1991) – therefore, it excludes studies that report emergence of intraverbals referring to operants in which a person is asked to select an item by providing its name (e.g., Braam & Poling, 1983). It extends those from Michael, Palmer, and Sundberg (2011) on multiple control in verbal behavior, Axe (2008) and Eikeseth and Smith (2013) on discriminative processes involved in *learning* intraverbals, Petursdottir and Carr (2011), and Sundberg and Sundberg (2011) on learning verbal skills, Raaymakers, Garcia, Cunningham, Krank, & Nemer-Kaiser (2019) on the emergence of verbal behavior, and that of Pérez-González (2019) on learning processes involved in reasoning because it directly addresses *emergence* processes of intraverbals. This paper does not assume a definition of reasoning, because it has not been defined in scientific terms; however, many instances of intraverbal emergence fit in what is dubbed as reasoning in lay terms. For example, they are similar to Aristotle's syllogisms as analyzed in the third treatise, *Prior Analytics*, of his logic compendium known as *Organon* (Aristóteles, 1982a, 1982b).

The purpose of the present paper is to analyze the literature on intraverbal emergence and extract the discriminative and derived process involved in emergence. Section 1 introduces the concept of emergence and summarizes all the studies published so far on the emergence of intraverbals. Section 2 analyzes discriminative processes involved in learning intraverbals that can affect emergence. Section 3 describes Sidman's analysis of stimulus equivalence and equivalence in intraverbals. Section 4 describes additional variables involved in intraverbal emergence. Section 5 describes developmental processes. Section 6 summarizes the findings and describes further research directions and applications.

1. Emergence of intraverbals.

Learning intraverbals are a necessary step in development. Procedures for teaching specific intraverbals have been analyzed; for example, a child can be taught to say "Moo" to, "What does a cow say?" Acquiring intraverbals after observation or derived from learning other operants results in a quite more sophisticated type of learning; for example, after learning that an animal presented in a picture is a cow by saying "cow" in its presence and learning to say "Moo" to the question, "What does this animal

say?," a child may further answer the question, "What does the cow say?" ("Moo"), without being explicitly taught to do so. This acquisition, derived from previous learning, is by definition emergent. The stimuli presented in an emergence probe have not been presented when the person learned the related operants. The operants that emerge are *new* in the sense that the person did never before receive the new combination of stimuli and, even so, the person produces a specific response that usually leads to the same type of consequences as the related, directly acquired, operants.

Emergence is unique in that, for example, a person acquires portions of verbal repertoire without being explicitly taught. The distinction between acquiring intraverbals by direct learning and by emergence is similar to the distinction between acquiring knowledge from learning by rote and acquiring that knowledge from deriving it from previous knowledge or from directly analyzing the world. Emergence, thus, plays an important role in human development. Although most adults can probably demonstrate the emergence of novel intraverbals, many processes that result in the emergence of novel skills are still unknown. All 52 studies that I know that have demonstrated emergence of topography-based intraverbals appear in Table 1. They have been grouped according to the intended purpose of its authors, regardless of functional commonalities across sections.

Table 1. Studies on the emergence of intraverbals with topography-based responses, age or studies conducted, diagnosis (if identified), and participants who demonstrated emergence in 80% or more of the probe trials over the total number of participants. The studies are grouped according to the categories explained in the text. Within categories, they are ordered by publication year.

Study & Experiment	Age, Diagnosis	Participants with Emergence
a. Reverse intraverbals		
Pérez-González, García-Asenjo, Williams, & Carnerero, 2007	Autism	**2 out of 2**
Petursdottir, Carp, Peterson, & Lepper, 2015	3.5-5.5 years	1 out of 10
Allan, Vladescu, Kisamore, Reeve, & Sidener, 2015	9-18 years, autism	3 out of 4
Dickes & Kodak, 2015	Autism	0 out of 3
Santos, Ma, & Miguel, 2015	Adults	**6 out of 6**
Pérez-González, Salameh, & García-Asenjo, 2018		
Part 1	6-7 years	9 out of 26
Part 2. Conditions 1 and 2	6-7 years	5 out of 8
Part 2. Conditions 3 and 4 (control)	6-7 years	2 out of 9
b. Equivalence in two languages		
Polson & Parsons, 2000		
Exp 1: English-French probe	Adults	1 out of 7*
Exp 2: English-French probe	Adults	3 out of 5*
Exp 3: French-English probe	Adults	**5 out of 5**
Petursdottir, Ólafsdóttir, & Aradóttir, 2008		
Post foreign tact	5 years	**2 out of 2***
Post foreign word selection	5 years	0 out of 2*
Petursdottir & Haflidadóttir, 2009		
Selection taught	5 years	0 out of 2*
Tact taught	5 years	1 out of 2*
Foreign taught	5 years	0 out of 2*
Dounavi, 2011		
Post foreign tact	Adults	**2 out of 2***
Post foreign-native intraverbal	Adults	0 out of 2*
Petursdottir, Lepper, & Peterson, 2014		
Exp 1	4-5 years	0 out of 4*
Exp 2	4-5 years	1 out of 4*

Dounavi, 2014		
Post foreign tact	Adults	**2 out of 2***
Post foreign-native intraverbal	Adults	0 out of 2*
May, Chick, Manuel, & Jones, 2019.	4-5 years	4 out of 6
Cortez, dos Santos, Quintal, Silveira, & de Rose, 2019	7-9 years	**6 out of 6**
Wu, Lechago, & Rettig, 2019		
Mand taught	Adults	3 out of 4*
Tact taught	Adults	2 out of 4*
Foreign-native intraverbal taught	Adults	0 out of 4*
Matter, Wiskow, & Donaldson, 2020		
Tact teaching Set 1	4-years	2 out of 4*
Tact teaching Set 2	4-years	0 out of 4*
Foreign-native teaching Set 1	4-years	0 out of 4*
Foreign-native teaching Set 2	4-years	0 out of 4*

c. Categorization

Chase, Johnson, & Sulzer-Azaroff, 1985	Adults	Mean 47-74 in 6 participants
Watkins, Pack-Teixeira, & Howard, 1989	Autism	Some (no % score)
Lipkens, Hayes, & Hayes, 1993	2 years	**1 out of 1**
Partington & Bailey, 1993; Exemplars	4 years	0 out of 4
Petursdottir, Carr, Lechago, & Almason, 2008	3 years	1 out of 5
Grannan & Rehfeldt, 2012	5 years, autism	**2 out of 2**
May, Hawkins, & Dymond, 2013	Adolescents autism	**3 out of 3**
Alós, Guerrero, Falla, & Amo, 2013	Adults	**10 out of 10**
Lechago, Carr, Kisamore, & Grow, 2015		
Categories	3-4 years	2 out of 6
Belloso-Díaz & Pérez-González, 2015b		
Exp 1. Teach 2 tacts	5-6 years	**3 out of 3**
Exp 2. Condition 1	5-6 years	3 out of 4
Exp 2. Condition 2	5-6 years	2 out of 3
Kodak & Padden, 2015.	3-4 years, autism	1 out of 2
Guerrero, Alós, & Moriana, 2015		
Exp 1	8-10 years	5 out of 6
Exp 2	8-10 years	**6 out of 6**
Smith et al., 2016	6-15 years, autism	**5 out of 5**
Belloso-Díaz & Pérez-González, 2016		
Exp 1. Condition Categories	6-7 years	**3 out of 3**
Exp 1. Condition Exemplars	6-7 years	2 out of 3
Exp 2. Condition Categories	6-7 years	**3 out of 3**
Exp 2. Condition Exemplars	6-7 years	2 out of 3
May, Downs, Marchant, & Dymond, 2016	4-5 years	**3 out of 3**
Shillingsburg et al, 2019		
Set 1	Autism	1 out of 6
Set 2	Autism	1 out of 6
Set 3	Autism	2 out of 4
DeSouza, Fisher, & Rodriguez, 2019	Autism	5 out of 5
Maldonado, Alós, & Povedano-Díaz, 2020		
Condition 1	6-12 years	1 out of 27
Condition 2	6-12 years	9 out of 27

d. Transitive relations with three verbal elements

Pérez-González, Herszlikowicz, & Williams, 2008

Exp 1. With no Exemplars and Categories	6 years	1 out of 5
Exp 2. With Exemplars & Categories	6 years	**4 out of 4**
Exp 3. With Exemplars & Categories	6 years	**4 out of 4**
Carp & Petursdottir, 2012	6-7 years	6 out of 9
Carp & Petursdottir, 2015	5-7 years	3 out of 6
Pérez-González, Belloso-Díaz, Caramés-Méndez, & Alonso-Álvarez, 2014		
Exp 1. AB+BC	Adults	4 out of 6
Exp 2. AB+BC+Categories	Adults	2 out of 4
Exp 3. AB+BC+Exemplars	Adults	**4 out of 4**
Daar Negrelli, & Dixon, 2015	Autism	2 out of 3
Belloso-Díaz & Pérez-González, 2015a		
Condition 1. Categories first	6-7 years	4 out of 5
Condition 2. Categories later	6-7 years	1 out of 5
Zaring-Hinkle, Carp, and Lepper, 2016		
Exp 1. Linear protocol	Adults	2 out of 8
Exp 2. OTM protocol	Adults	6 out of 8
Pérez-González & Oltra, in press		
Exp. 1. AB+BC	7 years	3 out of 6
Exp. 2. AB+BC	6-7 years	4 out of 6
Exp. 3. AB+BC+Exemplars & Categories	7-8 years	**6 out of 6**
Exp. 4. AB+BC+Exemplars & Categories	6-7 years	**5 out of 5**
Pérez-González & Oltra, 2020		
Exp. 1. Cnd 1. AB+BC+Exemplars & Categories	7 years	**6 out of 6**
Exp. 1. Cnd 1. AB+BC +Exemplars	7 years	4 out of 6
Exp. 1. Cnd 2. AB+BC	7 years	1 out of 6
Exp. 2. Cnd 1. AB+BC+Exemplars & Categories	7 years	**4 out of 4**
Exp. 2. Cnd 1. AB+BC +Exemplars	7 years	2 out of 4
e. Intraverbals with non-verbal relations		
Pérez-González & García-Asenjo, 2016	3:2-3:10 years	**5 out of 5**
Devine, Carp, Hiett, & Petursdottir, 2016	3-5 years	mixed
f. Pairing and intraverbals		
Loughrey, Betz, Majdalany, & Nicholson, 2014	4 years, autism	**2 out of 2**
Vallinger-Brown & Rosales, 2014	4-7 years, autism	1 out of 3
Carnerero & Pérez-González, 2015		
Condition 1	Adults	3 out of 4
Condition 2	Adults	0 out of 4
Control condition	Adults	0 out of 4
Carnerero, Pérez-González, & Osuna, 2019		
Condition 1	Adults	3 out of 4
Condition 2	Adults	2 out of 4
Control condition	Adults	0 out of 3
g. Intraverbals with vocal responses after learning matching to sample or written relations		
Houmanfar, Hayes, & Herbst, 2005	Adults	**7 out of 7**
Lee & Sturmey, 2014	Autism	0 out of 3
O'Neill & Rehfeldt, 2014	Autism & learning disability	0 out of 2
O'Neill, Blowers, Jenson, & Rehfeldt, 2015	Learning disability	0 out of 3

* Score in the intraverbal with a foreign word as response.
Note 1: The participants were typically developing if no diagnosis is displayed.
Note 2: Boldface figures indicate that all participants demonstrated emergence.

(a) Six studies focused on how intraverbals can emerge after learning intraverbals with elements in the reverse stimulus-response functions (see Figure 1). For example, "Name the opposite of black"-"White" after learning "Name the opposite of white"-"Black." The processes involved do not require the verbal stimuli be related to non-verbal stimuli. In lay terms, the person who demonstrates the emergence does not need to know the meaning of the words.

(b) Ten studies analyzed the emergence of intraverbals that show equivalence between words in a native and a foreign language (see Figure 2). The person's skills expand upon the preexisting repertoire that includes relations between verbal stimuli and the non-verbal stimuli related to them (i.e., the objects or events referred to by the words). After learning to say the names of these non-verbal stimuli in a foreign language, intraverbals in which the stimulus is the word in the foreign language and the response is in the native language can emerge as well as the intraverbal with the word in the native language as stimulus and the word in the foreign language as response.

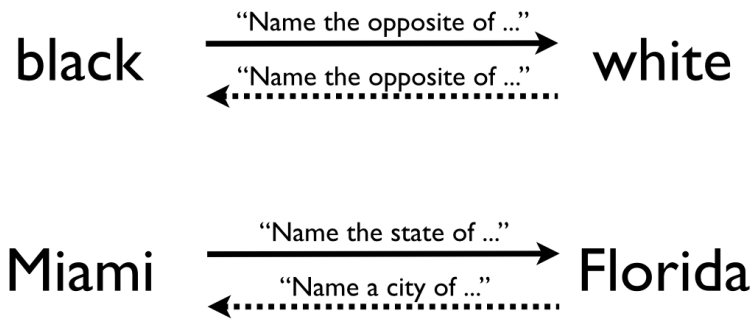

Figure 1. Intraverbals taught (solid arrows) and probed for emergence (dotted arrows) in the studies on reverse intraverbals (Category [a] in Table 1). Arrows go from the stimulus in the intraverbal to the response. On top of the arrows, other contextual cues that may work as functional stimuli or not are represented. The first intraverbal, thus, is, "Name the opposite of black"-"White."

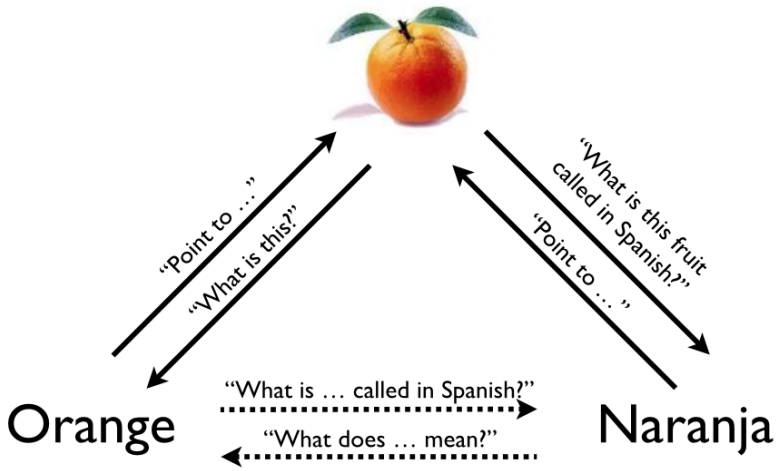

Figure 2. Verbal operants taught and probed for emergence in the studies on the equivalence between words in two languages (Category [b] in Table 1).

(c) Eighteen studies dealt with the emergence of intraverbals in categorization tasks, such as saying the name of a fruit or saying the category of an apple. The emergent intraverbals deal with verbal operants that relate the element (i.e., the apple), its name, and the category it belongs to (see Figure 3). The intraverbals are those with the verbal stimuli: the words of the object and the word of the category. These studies are of primary interest to teach these high order skills (or *capacities* – Greer & Ross, 2008) to people with learning disabilities or developmental delays (and to study how these capacities are acquired).

(d) Nine studies dealt on the emergence of intraverbals with three verbal elements that are related to one another, such as a country, a city of that country, and a park of that city (see Figure 4). Reasoning tasks in which a person has to make a transitive inference such as if A goes with B and B goes with C, then A goes with C involve emergence processes of this type. For example, intraverbals such as, "Name the country of El Botánico"-"Argentina" may emerge after learning the intraverbals, "Name a city of Argentina"-"Buenos Aires" and, "Name a park of Buenos Aires"-"El Botánico."

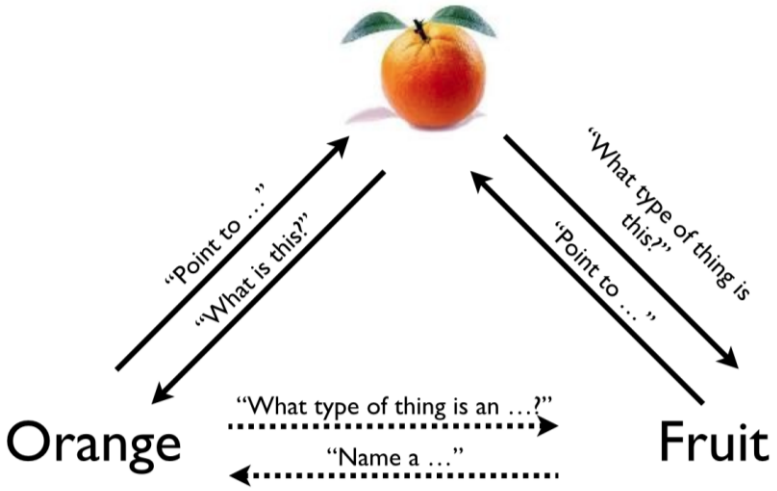

Figure 3. Verbal operants taught and probed for emergence in the studies on categorization (Category [c] in Table 1). Two verbal stimuli are related to a single non-verbal stimulus: the name and the category it belongs to. For a person to emit the name ("Orange") or the category ("Fruit"), however, a contextual cue is necessary; in the example, the cues are "What is this?" for saying the name and, "What type of thing is this?" for saying the category.

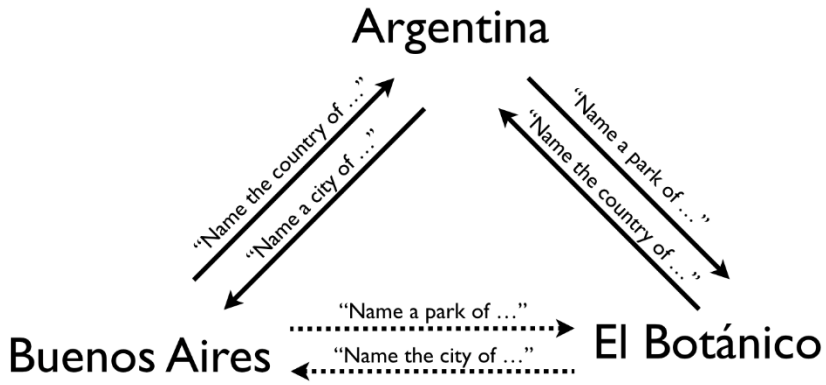

Figure 4. Intraverbals taught and probed for emergence in the studies on transitive relations (Category [d] in Table 1).

(e) Two studies aimed to investigate emergence of intraverbals after learning relations between non-verbal stimuli. For example, Pérez-González and García-Asenjo (2016) studied how children

demonstrate the emergence of intraverbals of the sort, "Name the opposite of old"-"New" after observing pictures of an old and a new object and being able to relate one of these pictures as opposite of the other one (see Figure 5).

(f) Four studies demonstrated the emergence of intraverbals after observing two stimuli paired together; for example, after adults listened sounds of musical instruments, its names, and the countries they belong to (see Figure 6).

(g) Four studies demonstrated the emergence of intraverbals after learning to match stimuli in matching-to-sample procedures with stimuli related to the verbal stimuli of the intraverbals, or demonstrated the emergence of intraverbal skills after learning to read sentences with the vocal verbal stimuli of the intraverbals.

The emergence demonstrated so far, however, was *far from perfect* (see third column of Table 1) because (a) not all participants demonstrated emergence in most studies, (b) often emergence was not demonstrated in all trial probes. These results contrast with studies conducted on emergence (see a revision by Arntzen, 2012). The causes for the differences found in the results in both areas may be that (a) in most studies on stimulus equivalence the responses were selection-based and in intraverbals the responses are topography-based, and (b) the discriminative processes involved in intraverbals are more complex.

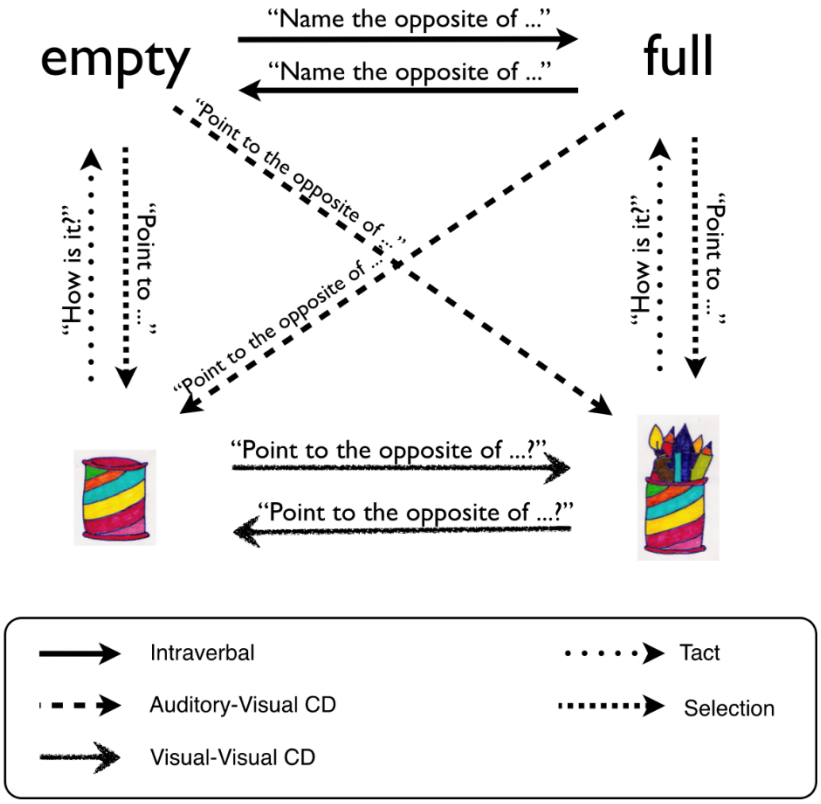

Figure 5. Verbal operants taught and probed for emergence in the studies with relations with verbal and non-verbal stimuli (Category [e] in Table 1). The intraverbals probed for emergence appear at the top of the figure.

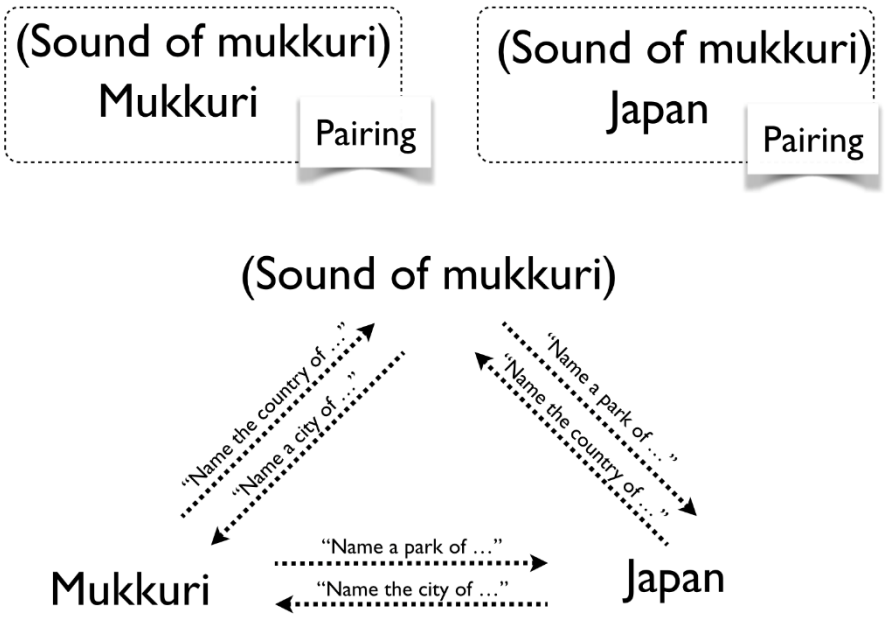

Figure 6. Intraverbals taught and probed for emergence in the studies on the emergence of intraverbals after observing stimuli presented together or paired (Category [f] in Table 1). After listening the sound of a musical instrument paired with its name (left) and paired with the country it belongs to (right) all the relations diagramed below can emerge.

2. Discriminative processes

Simple discriminations. A simple discrimination is an operant in which the response is produced in the presence of the antecedent stimulus and it is not produced in the absence of that stimulus (Skinner, 1938). The most basic procedure for acquiring a discrimination consists of reinforcing the behavior in the presence of the stimulus and extinguishing the behavior in the absence of that stimulus. In a study inspired by Skinner conducted by Reynolds (cfr., Terrace, 1966), pigeons key presses were reinforced with a variable interval schedule during a period of 3 minutes in the presence of a red light on and the presses were extinguished during a second period of 3 minutes in the presence of a green light. The pre-trained pigeons started pressing the key when the light was red and that behavior decreased gradually when the period with the green started (an extinction curve). The behavior recovered after the period with the red light started again. Over several cycles, the extinction occurred more rapidly until the pigeon pressed the key at a high rate when the light was red but pressed the key at a lower rate when the light was green. Thus, the correlation between the red light and the possibility of getting the reinforcer (by pressing the key) allowed the pigeon to learn the discrimination. In general terms, that correlation between the antecedent stimulus and the reinforcement is necessary for the acquisition of the discrimination (see Figure 7). The antecedent stimulus that produced the response was denominated *discriminative stimulus* (S^D) or positive stimulus (S+) and the antecedent stimulus that did not produce the response was denominated *delta stimulus* (S^Δ) or *negative stimulus* (S-). A complementary description of a simple conditional discrimination is that it consists of the resulting skill of establishing a three-term contingency procedure. The discriminative stimulus is the first term, the response is the second term, and the reinforcer is the third term.

If two stimuli are jointly presented in all occasions, then the results on the discrimination may not be straight. The more basic process, and the process that very likely initially occurs in any organism, has

been documented in a classical study by Reynolds (1961). He taught two pigeons a discrimination between a white triangle on a red background and a white circle on a green background. Notice that pecks to a compound formed by two stimuli, the triangle shape and red color, were followed by food and pecks to the compound formed by the other two stimuli, the circle shape and the green color, were followed by nothing. The pigeon could learn either one of these behaviors: (a) He could learn to peck a triangle form and do not to peck a circle form. In other words, the pigeon can learn to discriminate forms. (b) The pigeon could learn to peck in the presence of a red color and do not to peck the presence of a green color. In other words, the pigeon could learn to discriminate colors. (c) The pigeon could learn to peck both triangle shapes and red colors and do not to peck circle shapes or green colors.

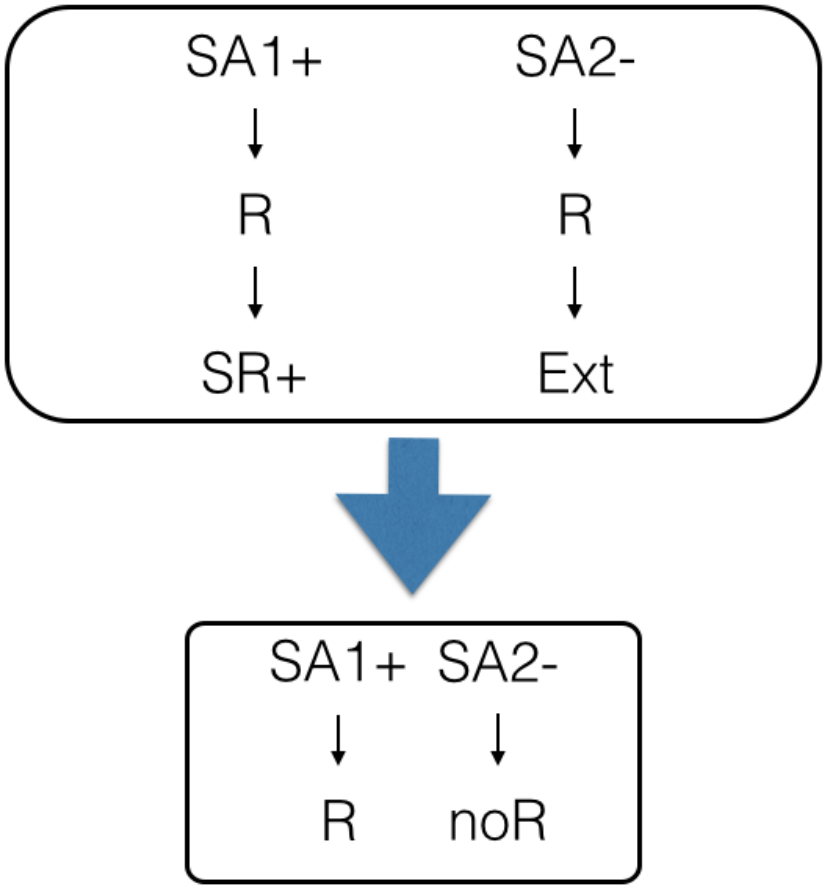

Figure 7. The procedure to teach a simple discrimination (top panel) and the resulting operant. In the presence of stimulus A1 the response is produced, whereas in the presence of stimulus A2 the response is not produced.

Once the pigeons learned the discrimination, Reynolds probed these options by presenting trials with either a triangle shape (with no color background), a circle shape (with no color background), a red color background alone (with no shape), or a single green color background (with no shape). None of the two pigeons discriminated both colors and shapes. Instead, one pigeon pecked only the triangle and did not peck the circle shape or any of the colors; the second pigeon pecked only the red color and did not peck the green color or any of the shapes. In other words, one pigeon learned to discriminate shapes and the second pigeon learned to discriminate colors. The reason for that no pigeon learned to discriminate both colors and shapes is very likely that just learning one of the two discriminations was enough to get the food. There was not a correlation between both colors and shapes, on one side, and reinforcement, on

the other side (see Figure 8). In conclusion, when two stimuli are presented together, it is possible that just one acquires control over behavior and the other one does not. Very likely, this can happen when learning intraverbals with two antecedent verbal stimuli in which the verbal response could be correct by attending to just one of these stimuli. (Overselectivity may occur –see Axe, 2008, for an analysis in intraverbals). Therefore, procedures like the later, if they are presented, should be presented with caution (see below a precision on this process regarding acquisition of capacities along development).

Simple discriminations in intraverbals. Intraverbals in which the antecedent stimuli function as a single stimulus to produce the verbal response are simple discriminations. For example, suppose a child acquires the two following intraverbals: "What is your name?"-(Name) and, "How old are you?"-(Age). The antecedent stimuli in each intraverbal work as a unit to produce the response. From these data, although the antecedent stimuli in each intraverbal can be divided into several parts, knowing what part of the antecedent stimuli is the factor that produce the response is impossible without additional analysis. Because the antecedent stimuli work as a single stimulus, these intraverbals are simple discriminations. The learning principles stated above apply to the acquisition of intraverbals like these. See detailed examples on intraverbals that are simple discriminations and examples on the distinction between simple and conditional discriminations in Axe (2008). Moreover, usually we refer to a discrimination when two stimuli are alternatively presented (or a single stimulus is alternatively presented and removed). When dealing with intraverbals, however, this operant is defined as a single response to a single stimulus. Therefore, considering an intraverbal as a discrimination in the context in which other stimuli are presented and the responses to these are different, makes sense. In pure terms, two or more intraverbals make up just one discrimination.

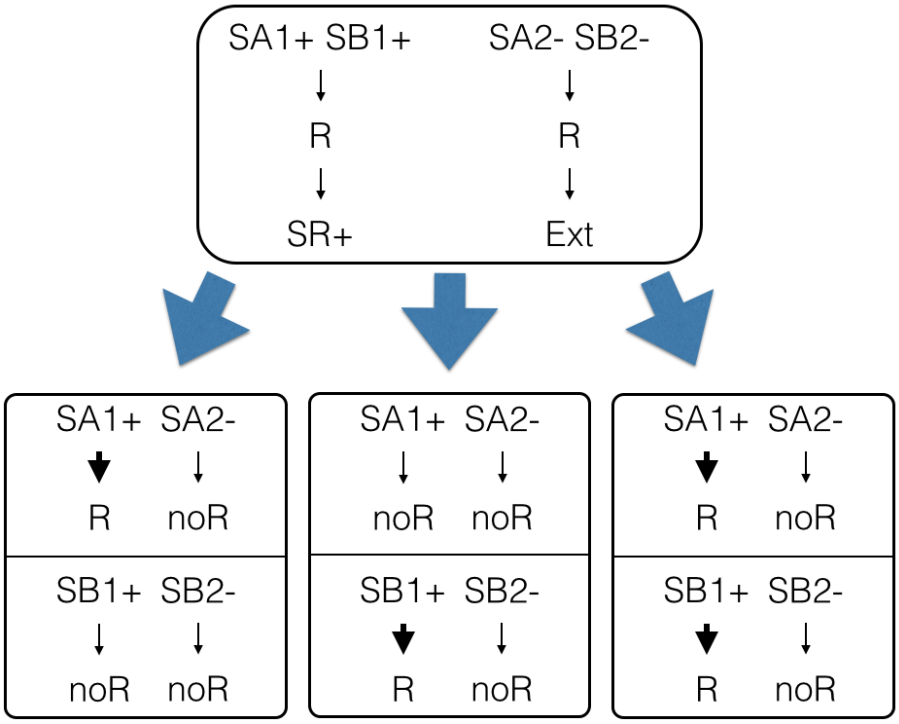

Figure 8. Possible outcomes when two stimuli (A1 and B1) are presented simultaneously when the response is reinforced (top panel). After reaching an acquisition criterion, when each stimulus is presented in insolation, the person (or non-human animal) can produce the response in the presence of only one stimulus (bottom panel left and center) or in the presence of the two stimuli (right panel).

Conditional discriminations. A "typical" conditional discrimination consists of selecting among two or more comparison stimuli in the presence of an additional stimulus that is presented as a sample. Over trials, several samples alternate with a quasi-random sequence. The correct comparison on each trial depends upon the specific sample presented. Examples of conditional discriminations are selecting the appropriate pictures while the teacher says their names, matching names to pictures, and identity matching to sample tasks in which a child matches cubes according to the color. In all these cases, the child has to select the comparison that is related to the presented sample (e.g., has to select the picture that corresponds with the spoken name). Conditional discriminations with topography-based behavior also exist (see below).

For teaching a *typical* conditional discrimination, with selection-based responses, the more basic procedure consists of presenting the samples quasi-randomly over trials and the comparisons at quasi-random locations, and then reinforce the selection of the comparison related to the sample presented in the trial and do not reinforce the selection of the alternative comparisons (e.g., Pérez-González, 2001 –see Figure 9).

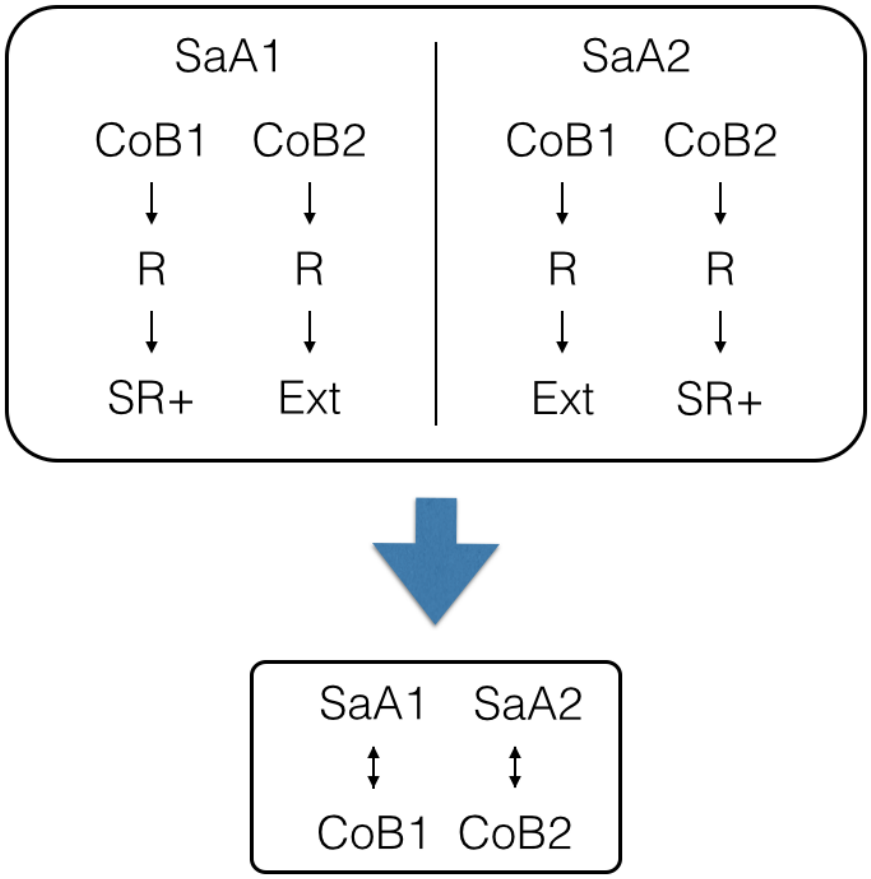

Figure 9. Procedure to teach a conditional discrimination (top panel) and the resulting operants. The correlation between A1 and B1 (on one hand) and between A2 and B2 (on the other hand) establishes the relations between the correlated stimuli (bottom panel).

For example, presenting pictures of a car, a doll, and a bear on a table, ask the child to pick either one by spoken its name (such as the doll) and reinforce the child's selection of the corresponding picture (the doll in this case) and do not reinforce the selection of the alternative pictures (the car or the bear). In

this example, a correlation between specific combinations of samples and comparisons and the reinforcer exists (see Figure 9). Attending to both the sample and the comparison is necessary to warrant a correct performance. Virtually all the studies on stimulus equivalence (see a revision by Arntzen, 2012), and those with more elaborated types of conditional discriminations (e.g., Pérez-González, 1994) present contingencies this way.

Conditional discriminations in intraverbals. Intraverbals in which two or more elements of the antecedent stimuli affect the response can require conditional discrimination responding; therefore, responding is the result of *multiple control*. At least three types of intraverbals have been described that require conditional discriminations. For example, Eikeseth and Smith (2013) described examples of intraverbals that are conditional discriminations such as, "If your name is Charly, say your ABCs", because the function of, "Say your ABCs" as discriminative stimulus is altered by the function of the first stimuli ("If your name is Charly"). Eikeseth and Smith described also and examples of intraverbals that are produced by compound stimuli, such as, "Name a red fruit." The response is produced by compound stimuli because two stimuli separately taught, "red" and "fruit," evoke the response. A third example of intraverbal is, "Name a city of Argentina"-"Buenos Aires." In my opinion, the three types of discrimination are conditional discriminations and need to be taught with procedures that assure that the response is under the control of, at least, the two relevant stimuli (i.e., your name and ABC, red and fruit, and Argentina and Buenos Aires). This point is important because the functions of samples and comparisons in conditional discriminations are identical in people with sophisticated verbal skills.

Several intraverbals are necessary for responding according to a conditional discrimination (as in simple discriminations). Each of the two relevant stimuli of an intraverbal must be presented in a context in which alternatives to each one of the two stimuli are presented. For example, the intraverbal, "Name a city of Argentina"-"Buenos Aires" should be presented with other intraverbals in which "city" is replaced by other stimulus (e.g., "park"; "Name a park of Argentina" -"El Botánico"), and the same occurs with "Argentina" (e.g., "Uruguay"; "Name a city of Uruguay"-"Montevideo"). In typical studies, for these methodological reasons, the four stimulus combinations are presented in intraverbals (i.e., "city" and "park" with "Argentina" and "Uruguay").

3. Emergence: Sidman's analysis of stimulus equivalence

Basic procedure and formation of equivalence. The most basic process of emergence is very likely produced when a stimulus accomplishes the same function as other stimulus and, then, those two stimuli become equivalent. Stimulus equivalence has been initially described by Sidman (e.g., Sidman & Tailby, 1982) and it followed hundreds of studies (see revisions in Arntzen, 2012; Arntzen, & Lian, 2010; and Sidman, 1994). The basic phenomenon can be illustrated as follows: (a) Two conditional discriminations that share common elements are learned. For example, the AB conditional discrimination with samples A1 and A2 and comparisons B1 and B2 is taught, such that B1 is correct in the presence of A1 and B2 is correct in the presence of A2. The CB conditional discrimination in which the samples are C1 and C2 and the comparisons are B1 and B2 is similarly taught. (b) Novel conditional discriminations are presented in a probe without instructions or reinforcement; for example, the AC conditional discrimination in which A1 or A2 are presented as samples and C1 and C2 are presented as comparisons. (c) Typically, humans demonstrate consistent selections in the probed conditional discrimination –e.g., they select C1 in the presence of A1 and C2 in the presence of A2. (d) A way to conceptualize the results is that the stimuli have been partitioned in two separate classes in which the stimuli in each class share the

same function, are exchangeable form one another or, in other words, are equivalent (i.e., A1, B1, and C1 are equivalent). According to a parsimonious analysis of the process (shared with Sidman, 2000) the correlation between each sample and the correct comparison causes that two related stimuli become members of the same class. Of special importance for the analysis of topography-based intraverbals is that if a stimulus and a response correlate, the stimulus and response can become members of the same class.

Stimulus equivalence and intraverbals. Most demonstrations of emergence of intraverbals require equivalence relations among verbal stimuli. Equivalence is evident when participants are required to say a name in another language. For example, Petursdottir, Ólafsdóttir, & Aradóttir (2008) probed intraverbals like, "What is orange in Spanish?"-"Naranja." The stimuli "orange," "naranja," and the actual orange are equivalent. Thus, the emergence involved in this study is similar to that demonstrated in stimulus equivalence. In other cases, the relations can be more complex, but some kind of equivalence is involved. For example, Pérez-González, Herszlikowicz, and Williams (2008) taught and probed intraverbals involving the stimuli "Argentina," "Buenos Aires," and "El Botánico" (a park in Buenos Aires) and similar stimuli related to Uruguay. Although these stimuli belong to three categories, these stimuli are related to one another and they form a single class, different from the stimuli related to Uruguay. Thus, it is very likely that the variables involved in the emergence of equivalence relations apply to the emergence of intraverbals of this sort. The key variable is very likely the correlation needed to present the stimuli; for example, Argentina and Buenos Aires must be correlated, at the same time than these stimuli are discriminated from alternative stimuli, such as Uruguay and Montevideo, which must themselves are also correlated. Moreover, because intraverbals seem to involve more complex relations than operants with selection-based responses, additional variables may also be involved in the emergence of intraverbals. An important variable is that in the discriminations that are taught and those whose emergence denotes equivalence two stimuli are presented and the response is the result of the common control of the two stimuli presented. For example, "Name a city of Argentina"-"Buenos Aires" (with the stimuli "city" and "Argentina") and "Name the country of El Botánico"-"Argentina (with the stimuli "country and "El Botánico"). When the relevant relations are taught this way, the targeted related intraverbals typically emerge (e.g. Pérez-González et al, 2008). In another study, Shillingsburg Frampton, Cleveland, and Cariveau (2019) taught picture-habitat (e.g., "Where does this live"+Picture of a fish – "Sea") and habitat-picture (e.g., "Who lives in the sea"-Pointing to a fish) relations and probed the name-habitat (i.e., "Where does a fish live?"-"Sea") and the habitat-name (i.e., "Who lives in the sea"-"Fish") intraverbals. The participants were six children with autism who had tacts of the objects in the pictures and selected them on command. Notice (a) that all the relations were multiple-controlled and (b) that the relevant stimuli in the taught and the probed relations were identical. The authors mostly taught the habitat-picture relation first, probed all relations, taught the picture-habitat relations, and probed all relations again. They observed (a) that the habitat-name intraverbals emerged with four of the six participants after they learned the habitat-picture relation (two participants demonstrated emergence with the first stimulus set, and two with the third), and (b) that the name-habitat intraverbals emerged with five of the six participants after learning the picture-habit relation, *but not before*. Therefore, the participants demonstrated the emergence of each type of intraverbal (name-habitat and habitat-name) only when the stimuli presented in the intraverbals had been presented in the taught intraverbals. These data confirms that teaching conditional discriminations establishes correlations and these result in equivalence relations when the required discriminations are taught and the probed discriminations have stimuli taught in these discriminations.

Alternative procedures to produce stimulus equivalence: Matching to sample with compound stimuli. Other procedures serve for establishing stimulus equivalence. Stromer and Mackay (1990; also, Stromer & Stromer, 1990a, 1990b) devised a procedure that forces the learner to attend to two stimuli by presenting them together (e.g., A1 and B1) as a compound sample and presenting either A or B stimuli as comparisons in a zero-delay matching to sample.

Alternative procedures and equivalence with verbal stimuli. Stimulus equivalence among verbal stimuli can very likely be produced in several ways when intraverbals are taught. Specifically equivalence can result from procedures different from matching to sample. For example, by presenting together two stimuli (see *pairing naming in Section 5 below*).

Intermixing discriminations. Directly related to the acquisition of a discrimination is the effect of randomly presenting trials of all the stimuli to discriminate across a block of trials. Actually, teaching first a discrimination with two stimuli and then another one with two more stimuli does not imply the discrimination between all four stimuli. Evidence that the behavior of a given person is discriminated by the four stimuli comes from correct responding when they are presented quasi-randomly in a single phase (e.g., see Adams, Fields, & Verhave, 1993; Fields, Reeve, Adams, & Verhave, 1991, on the effectiveness of the *SampleToComplex protocol,* which includes a mixed phase, to produce emergence and Alonso-Álvarez & Pérez-González, 2006, and Pérez-González & Alonso-Álvarez, 2008, on the effects of mixing learned operants on more complex emergent responses). Therefore, adding a final phase to the teaching procedure in which all the taught verbal operants are intermixed very likely increases the likelihood of obtaining intraverbal emergence.

Intermixing discriminations in intraverbal emergence. When all the operants required for the emergence are taught in a single discrimination, in which all its critical elements should be discriminable, emergence is more likely. A procedure very likely involved in discrimination consists of intermixing all the required intraverbals in a block of trials. For example, Belloso-Díaz and Pérez-González's (2015b; Experiment 1) taught the P-A and P-B discriminations. In P-A, the picture of either a Pakistani (P1) or an Ethiopian woman (P2) was presented with the instruction, "Name the country," –the responses were the respective country (Pakistan or Ethiopia). In the P-B discrimination, the same pictures appeared and the instruction was, "Name the tribe" and the responses were their respective tribes ("The Kalash" or "The Surma"). Thus, the discriminations were presented in such a way that the response was under the control of *both* the picture and the instruction (see Figure 10). Finally, the intraverbals that relate the country and the tribe (e.g., "Name a tribe of Pakistan"-"The Kalash" and, "Name the country of The Kalash"-"Pakistan") were probed and emerged immediately. Lipkens, Hayes, and Hayes (1993), with one two-year-old child, and May, Hawkins, and Dymond (2013), with three adolescents with autism, presented identical relations with other stimuli and found the same effect. The results of these experiments indicate that when the verbal operants are taught in a way that guarantee control by all the relevant stimuli the intraverbals are very likely to emerge. Conversely, a procedure that does not warrant responding according to all the stimuli, because the responses could have been produced by only one stimulus, was used by Belloso-Díaz and Pérez-González (2015b -Condition 1; 2016) as shown in Figure 11. Unlike in other studies, three children failed to show emergence of the B-A Tribe-Country intraverbals (e.g., "Name the country of The Kalash"-"Pakistan").

4. Additional variables that can be involved in the emergence of intraverbals

Previous acquisition of the responses. Emergence of verbal operants is related to the prior acquisition of the verbal responses. For example, Pérez-González, García-Conde, and Carnerero (2011) found that if echoics are taught first, the emergence of tacts with the same response are more likely to emerge (see other studies on the effect of learning echoics on the emergence of tacts and selections in Hawkins, Kingsdorf, Charnock, Szabo, & Gautreaux, 2009; Longano & Greer, 2015; see also Eikeseth and Smith, 2013). Regarding the emergence of intraverbals, Belloso-Díaz and Pérez-González (2016) studied the effect on emergence of teaching operants with the same responses as the intraverbals that were probed for emergence: They taught intraverbals such as, "Name a tribe of Pakistan"-"The Kalash" and probed the emergence of the intraverbal with the elements in reverse stimulus-response functions – "Name the country of The Kalash"-"Pakistan." They found that these intraverbals did not emerge initially. Thereafter, they taught either tacts or additional intraverbals with the element "Pakistan" as response (such as tacting the picture of a Kalash woman with the verbal stimulus, "Name the country", or the intraverbal, "Name a country of Asia"-"Pakistan"). Learning any of these verbal operants resulted in the almost immediate emergence of intraverbals with identical responses. Similarly, Carnerero and Pérez-González (2015) and Carnerero, Pérez-González, and Osuna (2018) found a correlation between the emergence of tacts and the further emergence of intraverbals. Moreover, studies on intraverbal emergence with words in a native and a foreign language demonstrated (a) that the emergence of intraverbals in a native language is more likely than in a foreign language and (b) if tacts or mands with the response in the foreign language are taught, then intraverbals with words in a foreign language as responses easily emerge (Cortez, dos Santos, Quintal, Silveira, & de Rose, 2020; A. Dounavi, 2011, K. Dounavi, 2014; Matter, Wiskow, & Donaldson, 2020; May, Chick, Manuel, & Jones, 2019; Petursdottir & Haflidadóttir, 2009; Petursdottir, Ólafsdóttir, et al., 2008; Wu, Lechago, & Rettig, 2019). Moreover, when two contextually-controlled tacts are learned, the intraverbals with the responses used in the tacts easily emerge (e.g., Belloso-Díaz & Pérez-González, 2015; Lipkens et al., 1993; May et al., 2013).

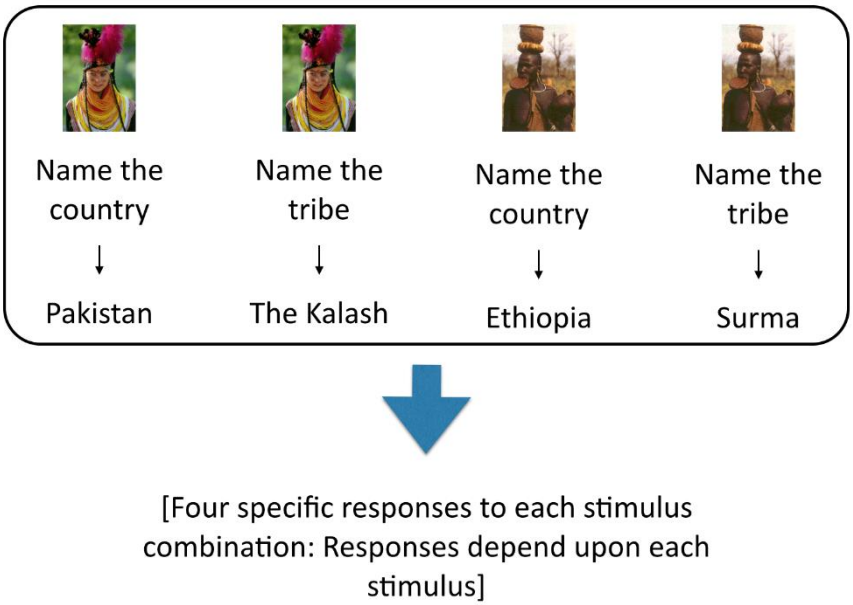

Figure 10. Discrimination taught in the procedure used in Experiment 1 in the study by Belloso-Díaz and Pérez-González (2015b) (top panel). The acquisition of the correct response that defines the discrimination is only possible by attending to every stimulus. Thus, when the discrimination is learned, the two stimuli present in each trial control the response (bottom).

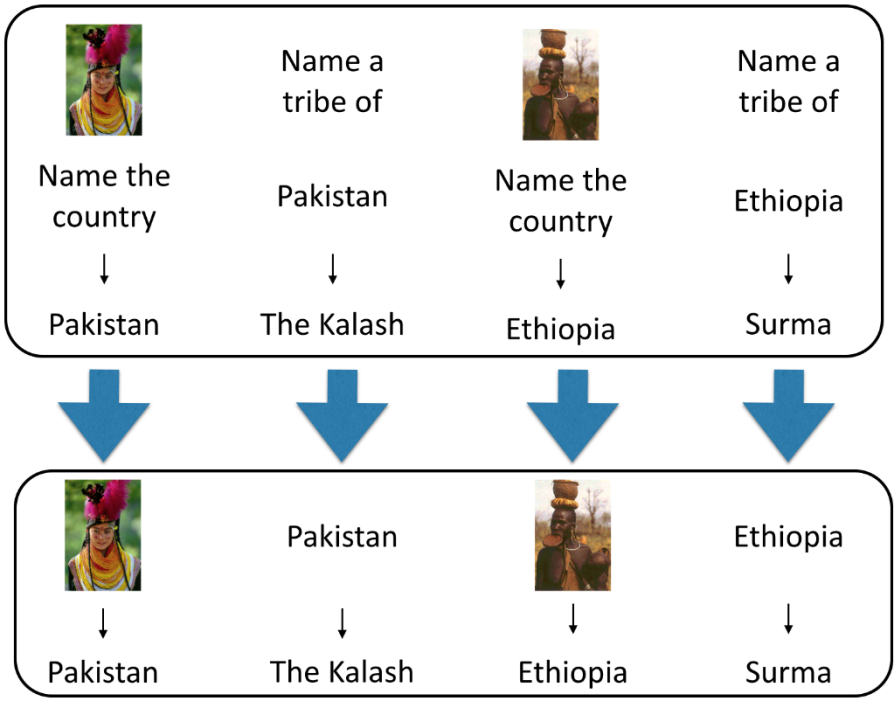

Figure 11. Discrimination taught in the procedure used in Condition 1 of Experiment 2 in the study by Belloso-Díaz and Pérez-González (2015b) (top panel). The discrimination can be acquired by attending to only one stimulus in each trial. Thus, even after the discrimination is learned, only one stimulus can control the response (bottom panel). The verbal stimuli, "Name the country" and, "Name a tribe of" cannot control specific responses. This procedure does not guarantee the control of more stimulus than the indicated below, even though many experienced learners can learn to produce the response under the control of the two stimuli presented in each trial.

Previous history with stimuli of the sort of the involved stimuli. If the stimuli involved have been conditioned as reinforcers by pairing them with known reinforcers by mean of classical conditioning procedures, then operants with these stimuli are easier to acquire and more likely to emerge: Longano and Greer (2015) and Maffei-Lewis (2011) demonstrated that initially neutral stimuli could be conditioned as reinforcers. Greer, Pistoljevic, Cahill, and Du (2011) and Cao (2016) demonstrated that this conditioning affects learning. Arntzen and Lian (2010) and Nartey, Arntzen, and Fields (2014) documented the effect of using familiar (i.e., conditioned) stimulus on equivalence formation. Moreover, Tonneau and González (2004) demonstrated the involvement of classical conditioning in the acquisition of conditional discriminations (see also a theoretical analysis by Tonneau, 2001). Pilot studies on intraverbal emergence conducted in my lab indicate that teaching intraverbals with non-words is extremely difficult, even for adults. The effects founds so far may be due to the effects conditioning the stimuli (similar to the effects of "familiarity" found in studies conducted with a cognitivist approach and methodology). It is likely than the effect found with words in the native language on the responses described in the previous paragraph also affect emergence when the words are presented as stimuli, in the sense that familiar words, instead of foreign words, presented as stimuli facilitate intraverbal emergence.

Repeating probes. Intraverbals often emerge gradually across probes (e.g., Belloso-Díaz & Pérez-González, 2015a; Pérez-González, Belloso-Díaz, Caramés-Méndez, & Alonso-Álvarez, 2014).

Optimal sequences. When a number of intraverbals are probed at the same time, an optimal sequence may exist. For example, Pérez-González et al. (2008; see also Belloso-Díaz & Pérez-González,

2015a; Pérez-González, Belloso-Díaz et al., 2014) taught the AB and BC intraverbals (such as, "Name a city of Argentina"-"Buenos Aires", etc.) and observed that the BC and AC intraverbals emerge first, the BA intraverbals emerge thereafter, and the CA intraverbals emerge last. It is very likely that probing in the order on which these discriminations usually emerge results in a faster demonstration of emergence than if the order is different. Another sequence effect analysis reveals that teaching the operants initially results in more likelihood of getting emergence. For example, Belloso-Díaz and Pérez-González (2015b, Experiment 2; 2016, Experiment 1) observed that probed intraverbals emerged within fewer probes when requisite tacts were taught initially then when they were taught after several baseline probes. In the same line, Belloso-Díaz and Pérez-González (2015a) taught two intraverbals AB and BC together with simpler intraverbals denominated *Exemplars* and *Categories* and observed emergence of the remaining ABC intraverbals in 4 out of 5 children when the *Exemplars* and *Categories* were taught initially but only in 1 out of 5 children when these intraverbals were taught after long baseline probes.

Negative transfer. Studies on paired associates showed that learning to produce a response to a stimulus is more difficult if the person has learned to respond with a different response to that stimulus (negative transfer –cfr., Catania, 2007). If these results are extrapolated to the emergence of intraverbals, learning to produce a verbal response B in the presence of a verbal stimulus A would make more difficult the production of a different response C in the presence of the same stimulus A (e.g., the emergence of the A-C intraverbal); for instance, when the task requires the child to name the exemplar and also the category (e.g., saying "this is a cow and an animal"). The solution here consists of teaching conditional discriminations (as explained above).

Symmetry. Emergence with the ABC structure of stimulus equivalence and deductive reasoning have demonstrated that the emergence is quite more likely when simpler operants are previously learned. These intraverbals were denominated *Exemplars*, which are intraverbals composed by antecedent stimuli that include the name of a category and the response consists of saying an exemplar of that category (e.g., "Name a city"-"Buenos Aires"), and *Categories*, intraverbals which are composed by antecedent stimuli that include the name of an exemplar and the response consists of saying the name of the category that exemplar belongs to (e.g., "What is Buenos Aires?"-"A city." One of the most interesting findings of these studies is that learning both Exemplars and Categories has a strong effect (Belloso-Díaz & Pérez-González, 2015a; Pérez-González, Belloso-Díaz, et al, 2014; Pérez-González, Herszlikowicz et al., 2008; Pérez-González & Oltra, 2020, in press). The effects of learning the Exemplars should be easy to understand given the effect of teaching the response, as explained above. What is surprising is the effect of teaching the Categories, which consists of operants in which the responses of the intraverbals probed for emergence in the ABC emergence probes appear as stimuli. This finding strongly suggests that we are in the presence of a new process that affects the emergence of intraverbals. This process is similar to that of the effect of presenting symmetry probes on the emergence of more complex relations with selection-based responses (e.g., Pérez-González, 1994, and its replications).

Relational frames. The processes described before are not enough for the acquisition of some types of intraverbal emergence. For example, it seems clear that a verbally sophisticated person can learn to say the verbal response B in the presence of a contextual cue X and the verbal stimulus A and thereafter he can learn to say the verbal response A in the presence of contextual cue Y and B. If the operation is repeated with stimuli C and D, E and F, and so forth under the same contextual cues X and Y, it is very likely that if that person learns to say T in the presence of X and U, he will respond T to the presentation of contextual cue Y and U (the reader can test that immediately). The latter would be an

emergent operant. Pérez-González et al. (2007) observed that children with autism can demonstrate that type of emergence under the contextual cue "Name the opposite of": They taught intraverbals like, "Name the opposite of black"-"White" and probed the related intraverbals, such as, "Name the opposite of white"-"Black," with two children with autism. Initially, the targeted intraverbals did not emerge and they were taught (thus, the AB and BA relations were taught). The procedure were repeated with several stimulus sets. Eventually, the two children demonstrated the emergence of the targeted intraverbals after learning the related intraverbals. Studies with Multiple Exemplar Instruction (MEI) broadly used by Greer and colleagues showed how to induce capabilities that result in that children demonstrate types of emergence that did not demonstrate before (e.g., Carnerero & Pérez-González, 2014; Fiorile & Greer, 2007; Gilic, 2005; Gilic & Greer, 2011; Greer, Stolfi, Chavez-Brown, & Rivera-Valdez, 2005; Greer, Stolfi, & Pistoljevic, 2007; Hawkins et al., 2009; Longano & Greer, 2015). Moreover, many MEI procedures are very likely successful when the more basic principles described above are also taken into account.

The relational frame concept goes beyond traditional explanations of MEI because it incorporates emergence and suggests a way of acquiring capabilities that allow a person to demonstrate emergence. Relational frames are sets of relations that involve several related skills in such a way that learning one or several relations derives in the emergence of the remaining relations of the frame[4]. For example, in its simplest form, a *frame of coordination* relates the AB and BA conditional discrimination under some contextual cue. The two related AB and BA intraverbals in the Pérez-González et al.'s study form a relational frame. By extension, any collection of related relations in which some skills or relations may emerge after learning one or several relations form a relational frame. Therefore, every type of intraverbal emergence may be considered as a relational frame. For example, the photo-name and photo-sound relations, and the name-sound and sound-name intraverbals (as in Lipkens et al., 1993) make a relational frame. Studies on intraverbal emergence indicate that teaching related verbal skills of a frame with one or several stimulus sets results in the eventual emergence of intraverbals. Moreover, when a procedure is repeated with several sets, emergence is observed more and more quickly (e.g., Pérez-González et al., 2008; Shillingsburg et al., 2018). Therefore, these procedures serve for inducing a type of intraverbal emergence, which can be conceptualized as a capability or a relational frame that enables the learner to demonstrate intraverbal emergence.

The processes observed after implementing teaching-probing-teaching cycles with several stimulus sets may explain why some participants respond with fewer requirements than their peers, in particular, adults: It is possible that before the experiment they had learned the relational frames used in the study, or related frames, with different stimuli. Notice, however, that relational frames are not needed for facilitating intraverbal emergence: Most processes explained above indicate that intraverbal emergence is possible when the relevant factors are considered in the teaching procedures, with no need of teaching relational frames. Moreover, relational frames do not explain why within the same frame, some emergences are more likely than others. For example, Lipkens et al. (1993) observed that after teaching Picture-A and Picture-B the A-B and B-A intraverbals easily emerged; if, instead, the Picture-A and the B-A intraverbals are taught, the A-B intraverbals are not so likely to emerge (as suggested by Belloso-Díaz &

[4] Relational frame has been defined by the advocates of the Relational Frame Theory (e.g., Hayes, Barnes, & Roche, 2001). In the present paper, a simple description of relational frame is presented. I do not share some assumptions of RFT, such as that all cases of emergence should derive from frames with non-verbal relations or that MEI procedures are the only ones to acquire a relational frame (e.g., Alonso-Álvarez & Pérez-González, 2017, 2018).

Pérez-González, 2016, and explained above –i.e., operants with the B elements as responses and its specific stimuli are not taught).

5. Discriminative processes and developmental processes

Developmental variables affect the emergence of verbal operants. For instance, the emergence of selections after learning tacts and the emergence of tacts after learning selections (which together define the *naming* capability –e.g., Greer & Ross, 2008; see also the original definition by Horne & Lowe, 1996) increases with some age-related variable: Below the age of two, few children demonstrate the emergence of these relations; later, they demonstrate the emergence of selections after learning the tacts; finally, around the age of three, children typically demonstrate the emergence of the tacts after learning the selections. Moreover, children who initially do not show these two types of emergence demonstrate it after receiving specific types of experiences that involve learning and being probed with multiple exemplars (e.g., Fiorile & Greer 2007; Gilic 2005; Gilic & Greer 2011; Greer et al., 2005; Greer et al., 2007; Hawkins et al., 2009; Longano & Greer, 2015). Although initially a person may require learning discriminations in which the stimuli are appropriately correlated with the reinforcer, these correlations may later not be required anymore. This phenomenon has been broadly described: First, equivalence relations can be acquired after exposure to pairs of stimuli. Leader and Barnes-Holmes (2001) and Leader, Barnes, and Smeets (1996) presented adults with pairs of stimuli such as A1B1, A2B2, B1C1, and B2C2, in a programmed sequence. Subsequent probes demonstrated the emergence of conditional discriminations AB, BC, BA, CB, AC, and CA. Thus, pairing is produced without correlations between stimuli or even between stimuli and the reinforcer and no response other than observing is required. Second, both selections and tacts emerge after children were presented with objects and their names (Cahill & Greer, 2014; Carnerero & Pérez-González, 2014; Longano & Greer, 2015; Omori & Yamamoto, 2013; Pérez-González, Cereijo-Blanco, & Carnerero, 2014; Pérez-González et al., 2011; Ramirez & Rehfeldt, 2009; Rosales, Rehfeldt, & Huffman, 2012; Takahashi, Yamamoto, & Noro, 2011), a process dubbed *pairing naming* (Carnerero & Pérez-González, 2014, 2015). It is very likely that some types of capacities are acquired along development that allow people to acquire control by two or more stimuli in the intraverbals even when a correlation between the two stimuli does not exist. Carnerero and Pérez-González (2015) and Carnerero et al., (2018) found emergence of intraverbals after exposing adults to musical sounds paired with the name (or the country) of an instrument.

Studies on intraverbal emergence have shown that the likelihood of demonstrating emergence increases with age, which suggests that some age-related variables influence emergence. Sometimes, that effect is shown as that fewer pre-requisites are apparently needed as age increases. For example, the number of participants that demonstrated the emergence of AC intraverbals after learning AB and BC intraverbals with no extra requirements increases from 6-7 years of age to adults: if Exemplars are learned before the probes, then the number increases and all the adults demonstrate emergence; if Categories are also learned (i.e., with the Exemplars) the percentage of children who show emergence also increases (see an analysis in Belloso-Díaz & Pérez-González, 2015a). Notice that the referred studies have found that even a portion of children demonstrate emergence with no extra requirements. This fact suggests that some skills or capabilities that facilitate intraverbal emergence are acquired across development. The acquisition of relational frames with operants of the same type of those used in a study, or the acquisition of similar relational frame may also produce this outcome. These phenomena may result in an experimental ceiling effect when some variables are studied and make more difficult to study developmental variables, and group designs may be necessary.

6. Summary of findings and applications

Most results of the studies on emergence are explained by the variables described above. Factors that very likely facilitate emergence of the intraverbals are summarized next, in the order in which presumably, and arguably, are typically acquired along development: First, the stimuli should be somehow conditioned, as a result of some kind of previous experience with the stimuli (as explained in *Previous history with stimuli of the sort of the involved stimuli* in section 4). Second, the learner should already had produced the responses in operants taught before the emergence probes, either as echoics, tacts, intraverbals, or mands (as explained in *Previous acquisition of the responses* in section 4). Third, all the operants required for emergence should be taught in discriminations, in which all its critical elements should be discriminable; hence, all required operants should be intermixed in a block of trials (as explained in *Intermixing discriminations in intraverbal emergence* in section 3). Fourth, the elements that need to be linked to one another must be correlated, and taught and probed with their specific stimuli. (as explained in *Intermixing discriminations in intraverbal emergence* in section 3). Fifth, sometimes, the correlation is not enough and the stimuli to be correlated should be presented in a discrimination as well as its symmetrical relation, such as when learning Exemplars and Categories are required for the emergence of CA after learning the AB and BC intraverbals (as explained in *Symmetry* in section 4). Sixth, all the operants required for emergence should be taught before the first probe (as explained in *Optimal sequences* in section 4). Seventh, it may exist an optimal sequence for teaching and, maybe, probing for obtaining emergence (as explained in *Optimal sequences* in section 4).

These variables explain successes and failures in obtaining emergence in the existing literature. They also explain that studies with different goals actually share processes. For example, the studies on equivalence in two languages, categorization, and transitive relations (categories b, c, and d in Table 1 and Figures 2, 3 and 4) analyzed emergence of intraverbals when relations between 3 stimuli were taught. The procedures of the studies on equivalence in two languages and those in the studies on categorization differ in that a word in a foreign language was used in the first and a second word in the native language was used in the second. According to the results of the existing literature, the probability of obtaining intraverbal emergence is similar when all variables are taken into account. For example, intraverbal emergence with two words in different languages of an object and with one name and the category of an object has similar probability if a person has already learned to emit operants with the responses of the targeted intraverbals and the verbal operants required for emergence are taught in discriminations. Moreover, the verbal or non-verbal type of the third stimulus (either an object in the studies on equivalence in two languages and in studies on categorization, or a word, in the studies on transitive relations with all verbal stimuli) has little effect on the likelihood of obtaining intraverbal emergence –this variable was studied by Belloso-Díaz and Pérez-González (2015b) and the results demonstrated just that null effect.

When observing the effects of all variables, developmental factors should be taken into account. Thus, as the participants are older, fewer requisites are required for obtaining emergence. This empirical result is very likely due to the quantity and quality of the experiences acquired, which correlate with age.

Applications. In applied settings, obtaining emergence of intraverbals and other verbal operants is critical because expand what was taught to an exponentially huge amount of novel operants. For obtaining emergence, the procedures that take into account the variables involved in emergence are quite more likely to result in emergence. In other words, when the procedures are careful enough, the targeted

intraverbals emerge and, conversely, when some required components are not taught or probed intraverbals may not emerge.

A critical area in which a number of studies have shown very little effects on emergence is that of categorization, which appears to be a key milestone in development. On the positive side, when the learners have acquired the responses probed for emergence, the stimuli have been conditioned, and the taught operants required discrimination of all their relevant elements (and the discriminations are intermixed), then intraverbal emergence was very likely to occur. Conversely, when the taught discriminations have not assured control of the responses by the appropriate relevant verbal stimuli, it resulted in few instances of emergence. For example, teaching a child to say, "this is an apple and it is a fruit" as a response in the presence of an apple would very unlikely result in intraverbal emergence of the sort, "What's an apple?"-"A fruit" or, "Name a fruit"-"Apple," because a complex response involving two elements (i.e., apple and fruit) does not bring about the emission of the two responses separately. Moreover, teaching the child to say "apple" sometimes and "fruit" some other times does not result in saying one in the presence of the other (even more, this is a case of negative transfer). The way to solve these problems include teaching to say the two words under separate contextual stimulus, like "Name this" + apple, and, "What kind of thing is this" + apple. Then, the child could very likely demonstrate the emergence of the intraverbals that relate the apple and its category (i.e., "What kind of thing is an apple"—"Fruit"). Notice that the procedure would be very similar to that used by Belloso-Díaz and Pérez-González (2015), Lipkens et al. (1993), and May et al. (2013), which easily demonstrated emergence.

Final remark. The present article described variables that account for the vast majority of the results of the studies published so far. Developmental variables should be taken into account as age-related variables (i.e., learning experiences) make possible to find emergence even when the requisite skills are taught in "non-perfect" ways, as fewer requirements are necessary along these learning experiences. The findings explained in the present revision have a huge potential of applications. Many procedures for teaching people with learning disabilities (i.e., autism) fail or result in partial emergence. The present paper explain why some of the used procedures failed and describes procedures that result in more cases of emergence. Discriminative processes are at the core of all processes. The status of the basic science of learning conducted with the methodology of behavior analysis provides useful tools for effective and efficient teaching of verbal behavior and derived, more complex, skills and capabilities.

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