Article

Acquisition of Intraverbal Repertoire via Equivalence-Based Instruction in Children with Autism Spectrum Disorder

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Abstract

The present study investigated the contribution of equivalence class formation to the emergence of intraverbal relations in two children with Autism Spectrum Disorder. Study 1 evaluated the emergence of intraverbal relations via equivalence-based instruction. After teaching listener relations (AB) and tacts (BC), the emergence of intraverbal relations (AC and CA) was verified. One participant presented the immediate emergence of AC relations, and the other participant presented a pattern of performance that was compatible with delayed emergence. Based on these data, Study 2 evaluated the effect of the presence of equivalence-based instruction on the acquisition of intraverbal relations. The children in Study 1 also participated in Study 2. After teaching listening (AB) and tact (BC) relations, consistent intraverbal relations (e.g., A1C1 and A2C2) and inconsistent intraverbal relations (e.g., A3C4 and A4C3) were trained. Lucia only acquired consistent intraverbal relations. Lucas presented no difference in the acquisition of either type of relation in AC training, and there was a slight difference in the acquisition of CA relations. Based on Lucia's data, it can be concluded that equivalence-based instruction favors the acquisition of new relations. These findings may encourage the application of equivalence formation to other issues with social relevance.

Keywords: Equivalence, verbal behavior, intraverbal.

Aquisição de Repertório Intraverbal via Instrução Baseada em Equivalência em Crianças com TEA

Resumo

Nos estudos aqui apresentados, investigou-se a contribuição da equivalência de estímulos para a emergência de relações intraverbais. O Estudo 1 avaliou a emergência de intraverbal via instrução baseada em equivalência (EBI) em duas crianças com autismo. Após o ensino de relações de ouvinte (AB) e tacto (BC), verificou-se a emergência de relações intraverbais (AC e CA). Um participante apresentou a emergência imediata das relações AC e o outro apresentou um padrão de desempenho compatível com emergência atrasada. Com base nestes dados, o Estudo 2 avaliou o efeito da presença de EBI na aquisição de relações intraverbais. As crianças do Estudo 1 participaram do Estudo 2. Após o ensino de relações de ouvinte (AB) e tacto (BC), foram treinadas relações intraverbais consistentes (A1C1, A2C2, por exemplo) e inconsistentes (A3C4, A4C3) com classes de equivalência. Para Lúcia houve a aquisição apenas das relações intraverbais consistentes. Para Lucas não houve diferença significativa na aquisição de ambos os tipos de relação no treino AC e houve uma ligeira diferença na aquisição das relações CA. A partir dos dados de Lúcia, principalmente, pode-se concluir que EBI favorece a aquisição de novas relações. Os dados dos estudos além comprovar, podem incentivar a aplicação de equivalência de estímulos.

Palavras-chave: Equivalência, comportamento verbal, intraverbal.

Adquisición de Repertorio Intraverbal mediante Instrucción Basada en Equivalencia en Niños con TEA

Resumen

El presente estudio investigó la contribución de la formación de clases de equivalencia para la emergencia de relaciones intraverbales en niños con trastorno del espectro autista. El Estudio 1 evaluó la emergencia de relaciones intraverbales vía instrucción basada en equivalencia (EBI). Después de enseñar relaciones de oyente (AB) y tacto (BC), se verificó la emergencia de relaciones intraverbales (AC y CA). Un participante presentó la emergencia inmediata de las relaciones AC y el otro presentó un patrón de desempeño compatible con la emergencia atrasada. El Estudio 2 evaluó el efecto de la presencia de EBI en la adquisición de relaciones intraverbales. Después de la enseñanza de relaciones de oyente (AB) y tacto (BC), se entrenaron relaciones intraverbales consistentes (A1C1, A2C2, por ejemplo) e inconsistentes (A3C4, A4C3) con clases de equivalencia. Lucia solo adquirió relaciones intraverbales consistentes. Lucas no presentó diferencias en la adquisición de ningún tipo de relación en el entrenamiento AC, y hubo una ligera diferencia en la adquisición de las relaciones CA. Con base en los datos de Lucia, se puede concluir que EBI favorece la adquisición de nuevas relaciones. Estos hallazgos pueden alentar la aplicación de la formación de clases de equivalencia a otros problemas con relevancia social.

Palabras clave: Equivalencia, comportamiento verbal, intraverbal.

Equivalence class formation has been studied mainly through the descriptive model that was proposed by Sidman and Tailby (1982). The standard procedure comprises the establishment of arbitrary conditional relations (AB and BC) and recombining tests (AA, BB, CC [reflexivity]; BA, CB [symmetry]; AC [transitivity]) of all positively related elements in reinforcing contingencies (Sidman, 2000).

The potential of applying knowledge that has been generated in the last 35 years of research in this field has been scarcely studied. Ex-

amples of a systematic effort in this direction are the studies by Souza and colleagues on teaching reading skills (Anastácio-Pessan, Almeida-Verdu, Bevilacqua, & de Souza, 2015; Gomes & de Souza, 2016; Melchiori, de Souza, & de Rose, 2000).

Considering the similarities between the behavior-analytic position of verbal behavior and the descriptive model of stimulus equivalence, Hall and Chase (1991) sought to explore the relationship between them. Among the objectives of their study, they sought to select examples of stimulus equivalence and describe them as instances of verbal behavior. To that end, the authors analyzed all of the properties of equivalence relations: reflexivity, symmetry, and transitivity. Concerning the property of transitivity, for example, they analyzed its emergence based on relations among auditory stimuli. Thus, once AB (where A is the spoken word "Cat," and B is the spoken word "Gato") and BC relations (where B is the spoken word "Gato," and C is the spoken word "Chat") are established, the AC relation (say "Chat" when presented with the word "Cat") can emerge without direct training. Considering the formal categories of verbal operants (Skinner, 1957), the AC relation, as well as the AB and BC relations, is considered an intraverbal relation.

The emergence of intraverbal relations (AC and CA) can also be observed when auditory and visual stimuli are presented in baseline training (AB and BC). Thus, for the AB relation, A would be the spoken word "Animal," and B would be a picture of a cat that is to be selected among other pictures. Such a relation would be consistent with listening behavior. For the BC relation, B would be a picture of a cat, and C would be the word "cat" that is spoken by the participant. Such a relation would be characterized as the verbal operant tact. After establishing such relations, the emergence of AC relations (e.g., say "cat" when presented with the word "animal") and CA relations (e.g., say "animal" before the spoken word "cat") could be verified. These emergent transitive relations would be part of the set of tests that are required to confirm equivalence class formation, featuring within-

class interchangeability. From the perspective of verbal behavior analysis, such emergent relations would also be characterized as intraverbal behavior.

The inclusion of the response as a potential member of equivalence classes, provided they are specific to each class, was considered by Sidman (2000). In the current example, the response is not only class-specific because the response of saying "cat" (C) is under specific control of the stimulus "animal" (A) and not under the control of other stimuli, such as "plant" or "object." Additionally, the response is vocal (i.e., a response with stimulus properties). Therefore, when saying "cat" (C), a person would also listen to the auditory stimulus "cat." The same is true for CA relations (e.g., saying "animal" [A] when presented with the word "cat" [C]). This expands the number of derived relations.

Stimulus equivalence and verbal behavior are two concepts that have been differentially used to address issues that are related to what we commonly refer to as language. Carp and Petursdottir (2015) and Ma, Miguel, and Jennings (2016) sought an approximation between these two research traditions. They started with the hypothesis that intraverbal behavior can facilitate the emergence of stimulus relations that are compatible with equivalence class formation. Intraverbal behavior is characterized by thematic control (i.e., with no point-to-point correspondence between the response and the verbal stimulus that evokes it; Skinner, 1957).

Another relevant study was published by Carp and Petursdottir (2015). In its first stage, the authors performed pretraining of category naming with the purpose of ensuring control of the spoken category names "state," "bird," and "flower" over responses of selecting visual stimuli. The second stage consisted of training tact repertoires to establish discriminative control by the visual stimuli A1 to C3 over the vocal responses (A1', A2', A3', B1', B2', B3', C1', C2', and C3'). The third stage consisted of an intraverbal pretest that evaluated the relations between auditory stimuli and vocal responses (A'B', A'C', B'A', B'C', C'A', and C'B'). Matching-to-sample (MTS) AB/AC training (baseline) was then

performed with the visual stimuli. When the accuracy criterion was reached for such relations, symmetry (BA and CA) and transitivity (BC and CB) tests were conducted. At this point, if the accuracy criterion was reached at least for the baseline relations, then an intraverbal posttest was conducted using the same procedure that was performed in the pretest. Three participants passed both tests (equivalence and intraverbal), and the other three participants failed both tests, suggesting that performance in both the equivalence and intraverbal tests appeared to be correlated.

Ma et al. (2016) investigated whether intraverbal naming (Horne & Lowe, 1996) is sufficient to establish three-member equivalence classes. They also investigated whether intraverbal behavior can occur together with MTS performance that is consistent with symmetry and transitivity. The participants first underwent training of tact repertoires with the stimuli that were going to be used in the forthcoming class formation phase. After this training, the authors evaluated listening behavior that involved the same stimuli and then performed intraverbal training (A'B' and B'C', with A', B', and C' the auditory stimuli that were involved in the tact relations). After establishing intraverbal relations, all of the conditional relations were evaluated in an MTS format, including "baseline" relations (AB and BC with visual stimuli) and potentially emergent relations that were consistent with symmetry (BA and CB) and transitivity (AC and CA). They also tested symmetry-consistent intraverbal relations (B'A' and B'C') and transitivity-consistent relations (A'C' and C'A'). All of the participants in the three experiments presented the emergence of new stimulus relations (tests of equivalence class formation) and the emergence of new intraverbal relations after training tact and intraverbal relations.

In both studies described above, intraverbal behavior was considered a facilitator of equivalence class formation. We sought to determine whether we could observe this same verbal operant (i.e., intraverbal) as a dependent variable that is facilitated by reinforcement contingencies that typically develop equivalence relations (i.e.,

instruction based on equivalence). If so, then the emergence of intraverbal behavior would be an indication of equivalence class formation. The term "equivalence-based instruction" (EBI; Fienup, Covey, & Critchfield, 2010) has been used to refer to instances of using stimulus equivalence technology to develop a behavioral repertoire in an applied context. Studies of EBI have sought to evaluate the potential of equivalence class formation to aid the establishment of challenging stimulus relations in several populations, such as behavior-brain relations in undergraduate students (Fienup et al., 2010), relations between English and Spanish words in adolescents with head trauma (Joyce & Joyce, 1993), and relations between fractional and decimal numbers in normally developing adolescents (Lynch & Cuvo, 1995).

In a review, Gomes, Varella, and de Souza (2010) found out that only a few studies have related equivalence class formation and autism spectrum disorder (ASD). Considering the potential of equivalence class technology to promote behavioral generalization, the lack of applied studies that involve equivalence and autism is particularly intriguing. The purpose of the present study was to evaluate the contribution of the equivalence paradigm (i.e., EBI) to the establishment of intraverbal relations in children who were diagnosed with ASD.

Method

Participants

Two children participated in this study (one girl [Lucia] and one boy [Lucas]), both of whom were diagnosed with ASD. The names that are used herein are fictitious to avoid the identification of the participants. At the beginning of the study, Lucia was 9 years 2 months old, and Lucas was 4 years 3 months old. We used the Verbal Behavior Milestones Assessment (Sundberg, 2014) to verify whether both children had listening, tact, echoic, and intraverbal repertoires. They had not participated in any previous study of stimulus equivalence. They both spoke Portuguese as their first language. Their participation was conditional on the formal agreement

of their caregivers who were legally responsible for them and signed an Informed Consent Term. The present study was approved by the Research Ethics Committee of the Health Sciences Institute of Universidade Federal do Pará - UFPA (review no. 175.303 issued on December 14, 2012).

Environment, Instruments, and Materials

All of the experimental sessions were performed in a 5 m x 6 m room up to three times per week. Each session lasted 15-20 minutes. The room had a table and two chairs (one for the experimenter and one for the child), a box with toys (e.g., tablet, car, modeling mass, bubble soap, miniature dolls, puzzle, etc.), and food (e.g., cookies, grapes, clementines, cornflakes, popcorn, etc.), which were used as reinforcement for correct responses. A camcorder was also available to videotape the sessions for the subsequent evaluation of interobserver agreement and treatment integrity.

The Verbal Behavior Milestones Assessment was used to evaluate the participants' behavioral repertoires. It is an evaluation tool that focuses on verbal skills and also provides curriculum guidance. The instrument is divided into five parts: milestones, barriers, transition, task analysis, and individualized teaching plan. Only the milestones (and more specifically concerning listening skills, tact, echoic, and intraverbal repertoire) were evaluated in this study.

Nine stimuli that were divided into three sets (A, B, and C) were used in this study. To facilitate the description of the study, alphanumeric codes were assigned to each stimulus. The participants did not contact such codes. The stimuli that belonged to Set A (A1, A2, and A3) and Set C (C1, C2, and C3) were auditory stimuli (words dictated by the experimenter). The stimuli that belonged to Set B (B1, B2, and B3) were visual (color-printed pictures with plastic covers, measuring 11 cm ´ 7 cm, obtained in Google©). B1 was a picture of the "Coliseum." B2 was a picture of the "Eiffel Tower." B3 was a picture of "Redeemer Christ."

Dependent Variable

The dependent variable was the percentage of correct vocal responses without prompts (i.e., independent correct responses) in intraverbal (AC and CA) relations that were consistent with previously trained relations. Each trial began with the presentation of an auditory stimulus by the experimenter (e.g., "It is in Brazil"; A3), and the participant had to say "Redeemer Christ" (C3).

Evaluation of Interobserver Agreement and Treatment Integrity

Thirty percent of the total number of sessions throughout all phases of the study were evaluated by a second trained observer whose data served to assess interobserver agreement and treatment integrity. Agreement was scored when both independent observers recorded a "correct response without prompt," "correct response with prompt," or "incorrect response" for a given response of the participant. The interobserver agreement score was obtained by dividing the number of agreements by the sum of agreements and disagreements, multiplied by 100. The average percentage of agreement was 93.6% for Lucia (AB: 100%; BC: 97.2%; AB and BC: 87%; AC: 84%; CA: 100%) and 94.7% for Lucas (AB: 100%; BC: 98%; AB and BC: 89%; AC: 93.9%; CA: 93%).

The evaluation of treatment integrity was based on a list of steps for the implementation of each trial. We evaluated whether, when implementing a trial, the experimenter (a) obtained the child's attention, (b) presented the antecedent stimulus, (c) provided a prompt or reinforced or corrected the participant's response, and (d) randomized stimulus locations and the trial sequence. Treatment integrity scores were calculated by dividing the sum of correctly implemented items throughout the trials by the total number of trials, multiplied by 100. The average percentage of integrity was 92.5% for Lucia (AB: 100%, BC: 89.1%, AB and BC: 97%; AC: 76.5%; AC: 100%) and 93.6% for Lucas (AB: 97.5%, BC: 95.5%; AB and BC: 100%; AC: 77%; CA: 98%).

Data collection procedures

This study was divided into four phases: listening training (AB), tact training (BC), mixed training (AB and BC), and intraverbal test/training (AC and CA).

Listening Training (AB). The purpose of this phase was to teach the participants to perform properly as a listener by selecting visual stimuli (Set B) conditionally to previously presented auditory stimuli (Set A) so that a set of AB relations would be established (A1B1, A2B2, and A3B3). Therefore, all of the trials comprised conditional auditory-visual discriminations. Each trial began with the experimenter setting up three comparison stimuli that were horizontally aligned on the table: B1, B2, and B3. The experimenter then presented an auditory stimulus (e.g., "It is in Brazil" [A3]). The participant then had to select the arbitrarily related comparison stimuli (in this case, B3). When the auditory stimulus was A1, the selection of B1 was reinforced. When the auditory stimulus was A2, the selection of B2 was reinforced. When the auditory stimulus was A3, the selection of B3 was reinforced. Each comparison stimulus appeared an equal number of times in each of three locations (left, center, and right) in the center area of the table.

At the beginning of training, when the participant still did not select the comparison stimulus under control of the auditory stimulus, a prompt (e.g., pointing to or guiding the child's hand to the correct figure) was provided. When independent correct selections were observed, the prompting procedure was discontinued. In case the independent selecting response was toward an incorrect comparison stimulus, help was provided to avoid subsequent errors. The presentation of preferred items (toys or food) was contingent on selecting the comparison stimulus that was defined by the experimenter as correct in a Variable-Ratio (VR 2) Schedule (ranging from 1 to 3 correct responses). A 30-second intertrial interval then started. Feedback with praise (e.g., "good job," "perfect," "that's right," "you got it right," etc.) was also provided contingently on correct responding, with or without a prompt.

From the second session onward, a 3-second delay was introduced before the prompt presentation to allow the correct response to occur without the prompt (i.e., independent response). When independent correct responses were observed, we changed the reinforcement criterion so that such independent correct responding was differentially reinforced. Incorrect responses were followed by the correction procedure, comprising the following steps: attention withdraw for 3 seconds, re-presentation of the discriminative stimulus, prompting procedure (experimenter pointed to or guided the child's hand to the correct comparison), praise contingent on correct responding with a prompt, the presentation of a low-cost and already mastered demand (e.g., ask the participant to clap hands), trial restart as an opportunity to obtain an independent correct response, and reinforcement contingent on a correct response. Correct responses during the correction procedure were not considered when calculating performance accuracy. Each session comprised 18 trials (six of each relation). No more than two consecutive trials of each type were presented, and a correct comparison never appeared in the same position twice in a row.

Tact Training (BC). The purpose of this phase was to teach the child to name the stimuli B1, B2, and B3. Each trial began with the presentation of one of the three visual stimuli (e.g., "Redeemer Christ" [B3]). One of the vocal responses, which were also the auditory stimuli of Set C, was then required (in this case, "Redeemer Christ" [C3]). At the beginning of training, after presentation of the visual stimulus, the experimenter also presented the auditory stimulus as a vocal prompt by saying the name of the stimulus so that the child could repeat it. During the first session, reinforcement (access to a preferred item in a Continuous Reinforcement or VR2 schedule) was provided contingent on repeating the vocal response of the experimenter, and a 30-second intertrial interval was started. From the middle of the first session onward, the vocal model prompt was faded-out (e.g., from "Coliseum" to "Coli" and then "Co") and then delayed (presented 3 seconds after presentation of the visual stimulus) to increase the probability of correct independent responses. Afterward, only correct tact responses were reinforced. When the child incorrectly named a stimulus

(e.g., by changing the name of the stimulus) or did not respond when independent responses were required, the same correction procedure that is described above was implemented (with the difference that the prompt was auditory). Each session comprised 18 trials (six of each relation), and the same type of trial never occurred twice in a row.

Mixed Training (AB and BC). In this phase, AB and BC relations were presented in the same session to maintain high accuracy for all relations before proceeding to the tests and training that were scheduled for the next phase. Each session comprised 18 trials that were divided into two blocks. The first block included only AB relations (nine trials, three of each type of relation), and the second block included only BC relations (nine trials, three of each type). In this phase, independent correct responses were reinforced with a preferred item in an FR3 schedule and praise in an FR2 schedule.

AC/CA Intraverbal Testing/Training. In this phase, we assessed performance accuracy first for AC and then CA relations (Table 1), both not directly trained. AC and CA relations were interspersed among AB and BC (baseline) relations. Each AC trial started with the presentation of an auditory stimulus from Set A (e.g., "It is

in Brazil" [A3]). A vocal response that corresponded to one of the stimuli from Set C (in this case, "Redeemer Christ" [C3]) was expected, characterizing intraverbal behavior. There was no programmed consequence (praise, food, correction, etc.) for the first trial (out of the three) for each AC and CA relation. From the second trial onward, if the child did not respond, then the experimenter would provide the auditory stimulus (vocal model; e.g., "Redeemer Christ" in an A3C3 test trial and "It is in Brazil" in a C3A3 test trial) so that the child could simply repeat it. This procedure was performed until independent correct responses were observed. Incorrect responses (e.g., saying "Coliseum" instead of "Redeemer Christ," saying "Brazil" instead of "It is in Brazil," or saying anything else) or the absence of vocal responses for 5 seconds were considered errors, followed by the correction procedure described above. Only after performance reached the accuracy criterion ($\geq 90\%$ independent correct responses in two consecutive sessions with not more than one error per relation type), the participant could be given the CA test/training. The same criterion was used to end this phase. The AC/CA test/training sessions comprised 21 trials: nine of AC or CA relations, six of AB relations, and six of BC relations.

Table 1
**Intraverbal Relations AC and CA from Study 1**

	Intraverbal AC		Intraverbal CA	
Class	Antecedent Stimuli Group [A]	Correct Response Group [C]	Antecedent Stimuli Group [C]	Correct Response Group [A]
1	"It is in Italy"	"Coliseum"	"Coliseum"	"It is in Italy"
2	"It is in France"	"Eiffel Tower"	"Eiffel Tower"	"It is in France"
3	"It is in Brazil"	"Redeemer Christ"	"Redeemer Christ"	"It is in Brazil"

Results

Regarding performance for the baseline relations (AB and BC), both participants had performance accuracy that was close to the chance level in the first training session (average accuracy of 39%). For tact training, both participants had 0% performance accuracy in the first training session. More sessions were required to teach tact relations (five for Lucia and 11 for Lucas) than listening behavior (two for Lucia and three for Lucas). In the mixed training phase (AB and BC relations), performance accuracy (94% overall accuracy with not more than one error per relation) was reached in three sessions.

Figure 1 shows performance accuracy (percentage of correct independent responses) for intraverbal (AC and CA) relations for both Lucia (upper portion of the figure) and Lucas (lower portion of the figure).
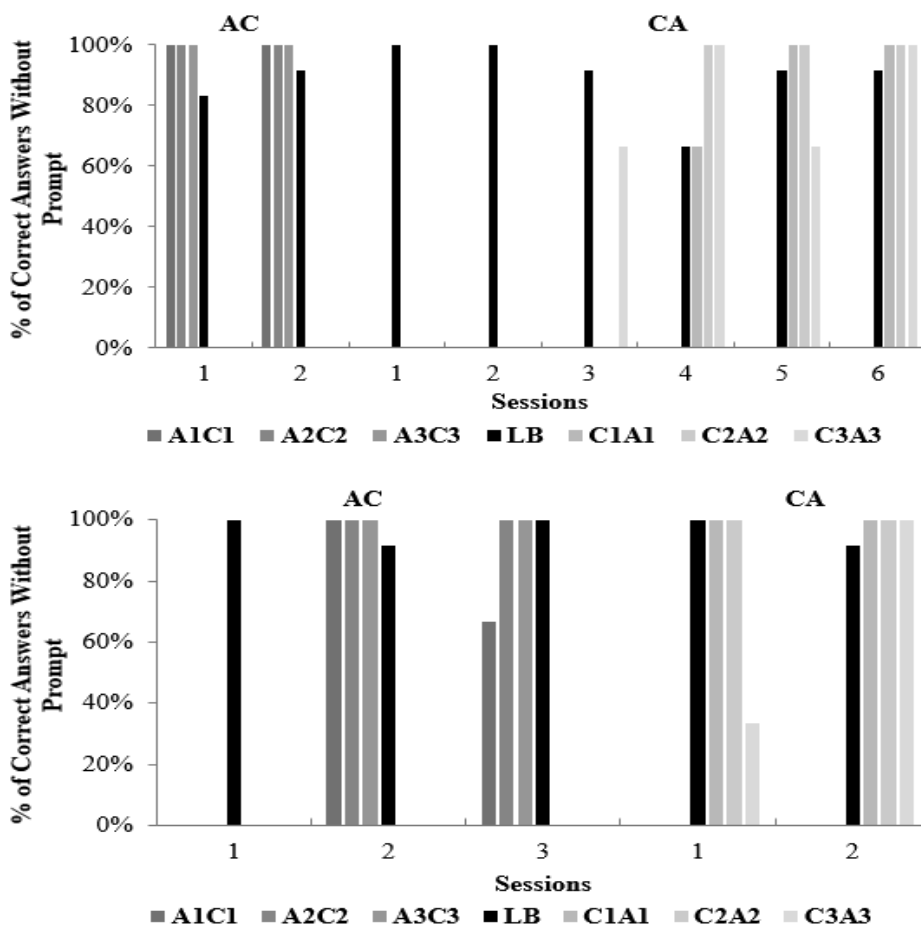
Figure 1. Percentage of correct responses without prompt in the intraverbal (AC and CA) relations and in baseline relations (AB and BC) for Lucia (upper portion) and Lucas (lower portion).

According to the data that are presented in Figure 1, Lucia (upper portion of the figure) presented 100% accuracy, and Lucas (lower portion of the figure) presented 0% accuracy for AC relations in the first session. Nevertheless, Lucas had 100% accuracy in the second session. For CA relations, Lucia had 0% performance accuracy, and Lucas had 33% performance accuracy for C3A3 relations and 100% performance accuracy for C1A1 and C2A2 relations. Lucia's performance reached 100% accuracy after seven sessions. The same happened for Lucas in the second session. For both participants, performance accuracy for baseline relations was always high (performance accuracy > 88% for Lucia in six of eight sessions and > 94% for Lucas in all sessions).

Discussion

Study 1 evaluated the adequacy of the equivalence paradigm, namely EBI, to establish intraverbal relations in children who were diagnosed with ASD. According to Sidman (2000), all the elements positively related in reinforcement contingencies may become interchangeable (i.e., may become part of equivalence classes). Lucia's performance in AC relations strongly support this assumption. Lucia presented intraverbal behavior (AC) after the direct training of AB (listening) and BC (tact) relations. The descriptive model of equivalence relations proved to be adequate to deal with the acquisition of a verbal repertoire, more specifically intraverbal relations.

With regard to Lucia's performance in CA relations, one issue is that in the three initial test trials (one of each relation: C1A1, C2A2, and C3A3), although she did not present the targeted responses (e.g., "It is in Brazil" [A3]) when she was presented with the auditory stimulus (e.g., "Redeemer Christ" [C3]), she said "Brazil" in the presence of "Redeemer Christ" (C3), "Italy" in the presence of "Coliseum" (C1), and "France" in the presence of "Eiffel Tower" (C2). Such partially correct responses were categorized as errors. Because our procedure included programmed reinforcement during the test trials (except for the very first test trial of each relation), correct responding in the first test trial is required to infer emergence. The aforementioned "errors" led to prompting procedures in subsequent trials (standard procedure in the case of errors). However, Lucia's behavior (saying "Brazil" when listening to "Redeemer Christ") can be considered intraverbal behavior (Skinner, 1957). Our topography-guided reinforcement criterion may have prevented us from seeing the partial correctness of Lucia's behavior.

Although the immediate emergence of AC relations was not observed in Lucas, his data suggested the acquisition of such relations after two training sessions (i.e., after being given six training trials of each relation). Lucas' performance pattern is compatible with the delayed emergence hypothesis. A relatively small number of trials was required to reach high accuracy for AC relations compared with the number of sessions or trials to establish AB relations (three sessions or 18 trials) and BC relations (nine sessions or 54 trials). Considering this, the occurrence of intraverbal AC relations is consistent with the concept of EBI (Fienup et al., 2010). However, one possibility is that the repertoire in question was simply learned during the retest sessions as a result of the prompt (embedded in the correction procedure). If so, then Lucas should present similar acquisition patterns for intraverbal relations that involve new stimuli (i.e., stimuli that were not potential members of the equivalence classes).

However, based on the data reported herein and regardless of whether the obtained performance reflected immediate or delayed emergence, we can conclude that intraverbal relations can be facilitated (dependent variable) by a contingence arrangement that is compatible with equivalence class formation. Such relations can be considered part of the emergent relations that have equivalence relation properties (Hall & Chase, 1991) rather than simply repertoires that facilitate or are behavioral requirements (independent variable) for equivalence class formation (Carp & Petursdottir, 2015; Ma et al., 2016).

Considering the aforementioned results, Study 2 investigated the hypothesis of immediate or delayed emergence by evaluating the emergence of intraverbal relations by comparing the acquisition of transitivity-consistent *vs.* transitivity-inconsistent conditional relations in the context of equivalence class formation. Significantly higher scores for consistent relations compared with inconsistent relations may indicate that the trained relations have properties of equivalence relations. If the acquisition of both consistent and inconsistent relations follows the same pattern, then this would support the hypothesis that learning during test/retest trials is the critical variable to explain the data.

Study 2

Lucas' performance pattern in Study 1 (i.e., low performance accuracy in the first test session

and high accuracy in the retest sessions) does not reveal whether it is attributable to delayed emergence (and thus some evidence that such relations have properties of equivalence relations) or whether the participant directly learned the relations during the retests. Study 2 explored this issue by comparing the acquisition of relations that were consistent *vs*. inconsistent with class formation.

Such methodological alternatives to examine defining properties of stimulus equivalence relations (Sidman, 2000) have been explored in several previous studies (e.g., D'Amato, Salmon, Loukas, & Tomie, 1985; Lionello-Denolf & Urcuioli, 2002; Picanço & Barros, 2015; Soares, Silva, Velasco, Barros, & Tomanari, 2016; Velasco, Huziwara, Machado, & Tomanari, 2010). In Picanço and Barros (2015) and Soares et al. (2016), the subjects (capuchin monkeys) were given symmetry-consistent training (e.g., A1B1, A2B2, and the symmetry-consistent relations B1A1 and B2A2) and symmetry-inconsistent training (e.g., A3B3, A4B4, and the symmetry-inconsistent relations B3A4 and B4A3) to determine whether the acquisition of conditional relations is facilitated when they are consistent with equivalence class formation.

Therefore, the purpose of Study 2 was to evaluate the influence of the presence (class formation-consistent relations) and absence (class formation-inconsistent relations) of EBI on the acquisition of intraverbal relations. If EBI influences the acquisition of intraverbal relations, then transitivity-consistent intraverbal relations would be mastered after fewer training trials than transitivity-inconsistent relations. Conversely, if no influence of EBI occurs, then there should be no significant difference in the acquisition of transitivity-consistent and -inconsistent intraverbal relations.

Method

Participants, Environment, Instruments, and Materials

The participants, environment, instruments, and materials were the same as in Study 1. Twelve stimuli were used in Study 2, divided into three sets (A, B, and C). Stimulus Set A (A1, A2, A3, and A4) and stimulus Set C (C1, C2, C3, and C4) were auditory (words dictated by the experimenter). The stimuli that belonged to Set B (B1, B2, B3, and B4) were visual (colored-printed pictures that had plastic covers, measuring 11 cm ´ 6 cm, obtained from Google©). B1 was a picture of the city of "Aveiro." B2 was a picture of "Berlin." B3 was a picture of "Tokyo." B4 was a picture of "Amsterdam."

Dependent Variable

The dependent variable was the percentage of correct independent vocal responses in intraverbal relations (AC and CA). The procedure to assess interobserver agreement and treatment integrity was the same as in Study 1. The average percentage of interobserver agreement was 96.5% for Lucia (AB: 96%; BC: 98%; AB and BC: 92%; AC: 100%) and 98.6% for Lucas (AB: 100%; BC: 98%; AB and BC: 100%; AC: 100%; CA: 98%; 96% for the additional training for A3C3, A4C4, C3A3, and C4A4 relations). The average percentage of treatment integrity was 98.1% for Lucia (AB: 97%; BC: 97.5%; AB and BC: 98%; AC: 100%) and 99.5% for Lucas (AB: 100%; BC: 99%; AB and BC: 99%; AC: 100%; CA: 100%; 99% for the additional training for A3C3, A4C4, C3A3, and C4A4 relations).

Data Collection Procedure

Study 2 was also divided into four phases: listening training (AB), tact training (BC), mixed training (AB and BC), and intraverbal training (AC and CA). The procedure that was performed in the first three phases was similar to the procedure that is described in Study 1, with the exception of the following: (a) in the first session of each type of training, a prompt was provided immediately after presentation of the antecedent stimulus to prevent errors, (b) one more relation was added to AB and BC training (A4B4 and B4C4, respectively) so that the full baseline comprised a set of eight relations (A1B1, A2B2, A3B3, A4B4, B1C1, B2C2, B3C3, and B4C4), (c) as a result of the greater number of relations, the number of trials per session also increased from 18 to 24 trials throughout the three training

phases, and (d) the performance accuracy criterion to advance to the next phase was at least 90% correct independent responses in two consecutive sessions with not more than one error per relation (e.g., A1B1, A2B2, etc.).

Assessment of AC and CA Relations (intraverbal) under Training Conditions. This phase was intended to teach intraverbal AC and CA relations. The training procedure included transitivity-consistent (e.g., A1C1 and A2C2) and transitivity-inconsistent (e.g. A3C4 and A4C3) relations according to the equivalence class paradigm. The same is true for CA relations (see Table 2). AC and CA relations were interspersed among AB and BC (baseline) relations. There was no programmed consequence (e.g., praise, food, correction, etc.) for the first trial of each AC and CA relation. Beginning in the second trial, a vocal prompt (e.g., "Aveiro" for A1C1

relations and "It is in Portugal" for C1A1) was provided immediately after presenting the antecedent stimulus. From the second session onward, the prompt was delayed in the first trial for each relation. If an independent correct response was observed, then a prompt procedure was performed only when errors were observed. The absence of a response or the occurrence of incorrect responses was followed by the same correction procedure that is described in Study 1. When the performance accuracy criterion (at least 90% correct independent responses in two consecutive sessions with not more than one error per type of relation) was reached, the participant was given CA training sessions. This criterion was also used to complete this training phase. Experimental sessions in this phase comprised 28 trials: 12 AC or CA trials, eight AB trials, and eight BC trials.

Table 2
Intraverbal Relations AC and CA from Study 2

Type of Relation	Intraverbal AC		Intraverbal CA	
	Antecedent Stimuli Group [A]	Correct Response Group [C]	Antecedent Stimuli Group [C]	Correct Response Group [A]
Consistent	"It is in Portugal"	"Aveiro"	"Aveiro"	"It is in Portugal"
	"It is in Germany"	"Berlin"	"Berlin"	"It is in Germany"
Inconsistent	"It is in Japan"	"Amsterdam"	"Amsterdam"	"It is in Japan"
	"It is in Holland"	"Tokyo"	"Tokyo"	"It is in Holland"

Because we reinforced transitivity-inconsistent relations (e.g., "It is in Japan" – "Amsterdam"), at some level our procedure may have established conditional relations that were different from those that are reinforced by our verbal community. For ethical reasons, to address this, the last phase of the present study consisted of additional training of intraverbal

A3C3, A4C4, C3A3, and C4A4 relations, which are consistent with what is selected in our verbal community (e.g., "It is in the Netherlands" – "Amsterdam"). The sessions comprised 24 trials, 16 for intraverbal relations (four for each relation) and eight baseline AB and BC trials (one for each relation).

Results

All of the baseline conditional relations that involved listening (AB), tact (BC), and mixed (AB and BC) relations were learned by both participants, and their acquisition patterns were similar to those that were observed in Study 1.

Therefore, we focused on comparing the acquisition of transitivity-consistent *vs.* transitivity-inconsistent intraverbal relations.

Figure 2 shows performance acquisition curves for transitivity-consistent and transitivity-inconsistent intraverbal AC relations for Lucia. Figure 3 shows similar data for AC and CA relations for Lucas.
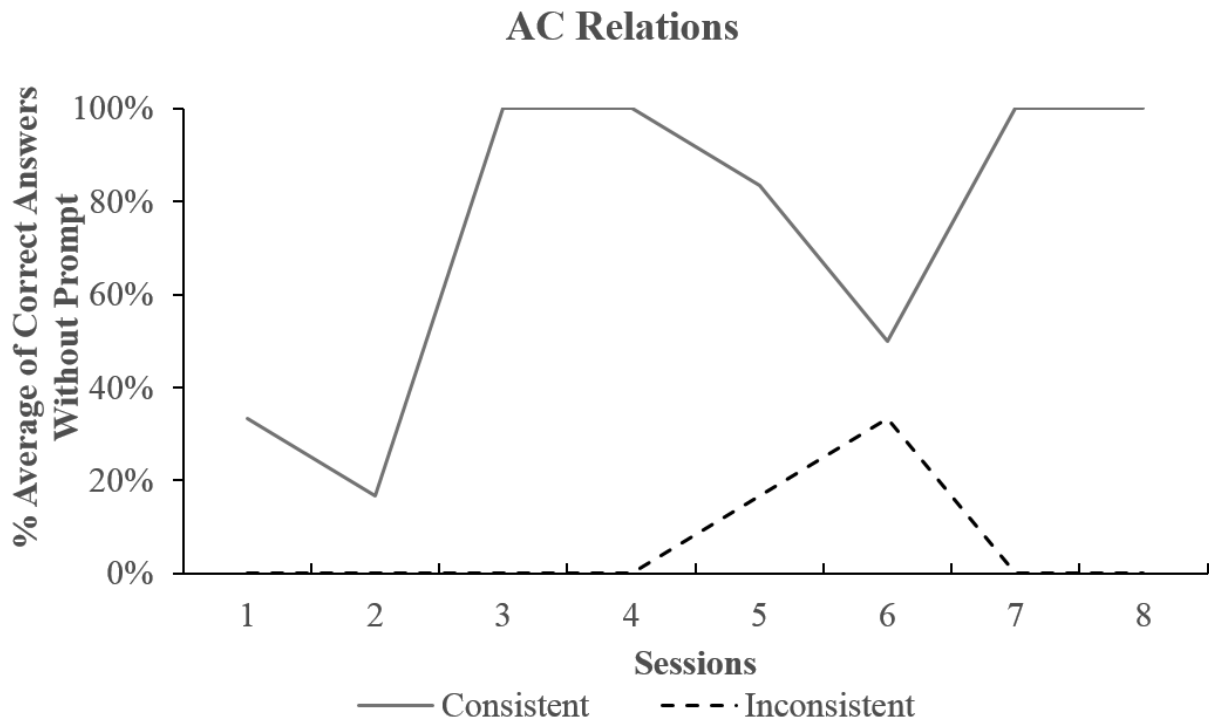
Figure 2. Comparison of performance acquisition curves between consistent (continuous line) and inconsistent (dashed line) AC intraverbal relations with equivalence class formation, for Lucia.

Figure 2 shows that Lucia's performance accuracy in transitivity-consistent intraverbal AC relations started at a high level and reached the acquisition criterion in the third session (after 18 trials). Even after eight sessions (48 trials), Lucia's performance in transitivity-inconsistent AC relations did not present an increasing tendency.

Figure 3 (upper portion) shows that Lucas' performance accuracy in AC relations (both transitivity-consistent and transitivity-inconsistent) evolved similarly, reaching the accuracy criterion in the third session. No significant difference in the acquisition of either type of relation was observed.

Figure 3 (lower portion) also shows that performance accuracy in transitivity-consistent intraverbal CA relations was 0% in the first session and 100% in the second session. Such a high level of performance accuracy was maintained in subsequent sessions. With regard to transitivity-inconsistent CA relations, performance accuracy was 0% in the first session, gradually increasing throughout training until it reached 100% in the fourth session after 24 training trials.

The last phase of the study was implemented to establish intraverbal A3C3, A4C4, C3A3, and C4A4 relations (consistent with our verbal community). Lucas' performance reached the accuracy criterion after four training sessions.
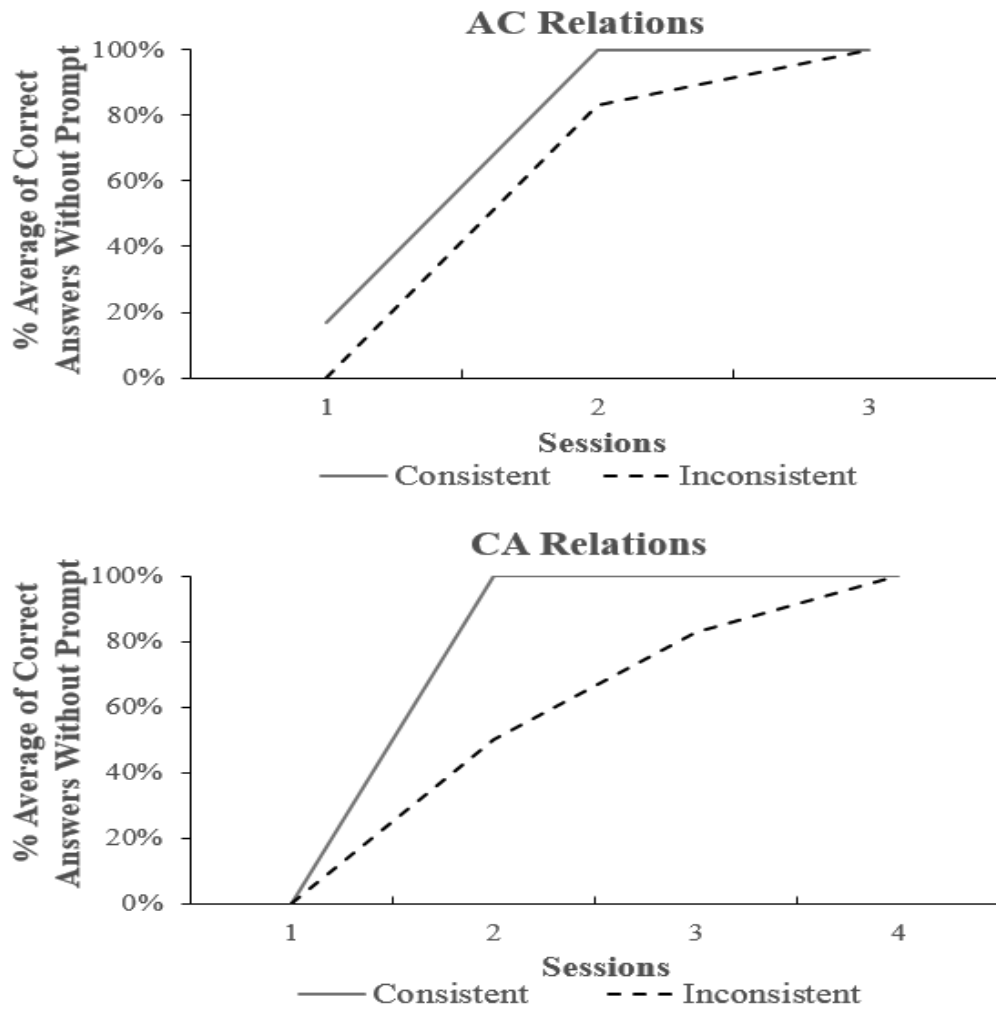
Acquisition of Intraverbal Repertoire via Equivalence-Based Instruction in Children with Autism Spectrum Disorder.

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Figure 3. Comparison of performance acquisition curves between AC and CA intraverbal relations consistent (solid line) and inconsistent (dashed line) with formation of equivalence classes, for Lucas.

Discussion

Study 2 evaluated the acquisition of intraverbal relations through EBI based on comparing the acquisition of transitivity-consistent *vs.* transitivity-inconsistent intraverbal relations to evaluate the potential contribution of equivalence-like relations. Lucia presented intraverbal relations that had properties of equivalence relations, since she learned only transitivity-consistent AC relations. Such data corroborate previous studies (Picanço & Barros, 2015; Soares et al., 2016) with regard to the faster acquisition of consistent relations with class formation. Lucas' data showed that his intraverbal relations did not have properties of equivalence relations because there was no clear distinction between

the acquisition of transitivity-consistent and transitivity-inconsistent relations. Such data suggest that both consistent and inconsistent relations were learned over the course of the tests, as opposed to emerging from AB and BC training. This confirms the possibility that Lucas' data in Study 1 may not be indicative of delayed emergence (e.g., Aggio & Domeniconi, 2011) but rather may be attributable to the acquisition of intraverbal relations throughout the retest sessions.

Notable is the pattern of errors that were made by Lucia in baseline relations (e.g., AB) during AC training. From the third session onward, errors were observed mostly in listening A3B3 and A4B4 relations. For example, when an A3B3 trial was implemented after a transi-

tivity-inconsistent intraverbal A3C4 relation, the presentation of A3 (e.g., "It is in Japan") controlled the response of saying "Amsterdam" and selecting B4. Although selecting B4 contingent on the presentation of A3 was considered an error, it is consistent with the reorganization of equivalence classes (e.g., Pilgrim & Galizio, 1990, 1995) that could occur because of transitivity-inconsistent training. It is also consistent with the hypothesis that the intraverbal operant may mediate stimulus selection (Carp & Petursdottir, 2015; Ma et al., 2016).

When considering the application of such observations, Lucia's data suggest that it might be easier to teach intraverbal relations between stimuli and responses that are members of a potential equivalence class (e.g., "It is in Portugal" - "Aveiro"). Conversely, it is more difficult to teach intraverbal relations between stimuli and responses that belong to different equivalence classes (e.g., "It is in Japan" - "Amsterdam") because it required more sessions or trials to be established (Picanço & Barros, 2015; Soares et al., 2016). This assertion is compatible with EBI (Fienup et al., 2010). We refer to equivalence classes as a direct product of reinforcement contingencies (Sidman, 2000), which should be considered when working with event/stimulus substitutability.

The present study considered the comparison of acquisition curves as a methodological alternative to evaluate class formation, and this is also a useful tool to demonstrate differences in the acquisition of relations between events when they are consistent or inconsistent with equivalence class formation.

A common limitation of both Studies 1 and 2 is the absence of a pretest as a first phase of the study, which would involve all of the relations that were subsequently trained or tested. The inclusion of a pretest would have strengthened internal validity of the conclusions with regard to the effects of the interventions in both studies. However, the performance accuracy data in the first sessions of baseline relations (0% accuracy or chance level) indicate that the behavioral relations were not exhibited by the participants

prior to their participation in the study. Although they may have been in contact with such stimuli, they had not previously learned to respond to them as listeners (selection) or speakers (tact).

Another limitation involves some failures to enforce the acquisition criteria to progress to the next phase. Therefore, on some occasions, one or two additional training sessions were necessary, even after reaching the accuracy criterion (mainly in Study 1).

Future studies should seek to provide evidence that EBI has a positive impact on establishing verbal relations, such as the ones that were established herein. An interesting line of investigation would be to compare the acquisition of equivalence-consistent relations (e.g., AC after AB and BC training) to the acquisition of completely new relations (e.g., DF). This would avoid the necessity of teaching discriminations that are inconsistent with verbal relations that are exhibited by our verbal community.

Authors' Contributions

Substantial contribution in the concept and design of the study: Álvaro Júnior Melo e Silva e Romariz da Silva Barros)

Contribution to data collection: Álvaro Júnior Melo e Silva, Sara Ingrid Cruz Keuffer e Juliana Sequeira Cesar de Oliveira.

Contribution to data analysis and interpretation: Álvaro Júnior Melo e Silva, Sara Ingrid Cruz Keuffer, Juliana Sequeira Cesar de Oliveira e Romariz da Silva Barros.

Contribution to manuscript preparation: Álvaro Júnior Melo e Silva, Sara Ingrid Cruz Keuffer, Juliana Sequeira Cesar de Oliveira e Romariz da Silva Barros.

Contribution to critical revision, adding intelectual content: Álvaro Júnior Melo e Silva e Romariz da Silva Barros.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

General Discussion

Both Studies 1 and 2 addressed two areas of study: equivalence class formation and verbal behavior. These two areas differentially address a phenomenon that is commonly referred to as simply "language." We successfully explored the potential contributions of the present equivalence paradigm to teaching intraverbal relations in children who are diagnosed with ASD.

Future studies should evaluate participants who initially present listening behavior and tact but do not present an intraverbal repertoire. Such studies may reveal whether the implementation of a training procedure such as the one used herein (coherent with EBI) would later produce the emergence of intraverbal repertoires.

Study 1 demonstrated the possible usefulness of equivalence class formation for interventions that are geared toward socially relevant issues, such as developing verbal repertoires in children with ASD. Our findings may be beneficial in conjunction with other studies in the literature that had the same goal (Fienup et al., 2010; Joyce & Joyce, 1993; Lynch & Cuvo, 1995). The practice of applying the same instruments (i.e., EBI) to different social problems makes the scientific concepts that underlie such instruments even more robust and their results and assertions more reliable (Munafò et al., 2017).

Study 2 further demonstrated that the methodology of comparing the acquisition of equivalence-consistent and -inconsistent relations efficiently clarified an important aspect of the construction of intraverbal repertoires, namely the potential contribution of equivalence class formation to the final repertoire that was observed. This type of methodology appears to be a useful alternative when working under conditions of a low incidence of errors, such as interventions in children who are diagnosed with ASD.

In the present study, evidence of the participation of class formation in Lucia's intraverbal repertoire shows that EBI can increase the efficiency of teaching procedures in children who are diagnosed with ASD, in which intra-verbal relations that were consistent with class formation were readily obtained. The present findings will likely encourage further exploration of the application potential of equivalence class formation.

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