STUDENT PAPER WINNER: ABSTRACT

RESPONSE-CONSEQUENCE CONTINGENCY DISCRIMINABILITY WHEN POSITIVE AND NEGATIVE REINFORCEMENT COMPETE IN CONCURRENT SCHEDULES

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Three experiments were conducted to test the qualitative prediction of contingency discriminability theory that any difference in type between the consequences of concurrently available discriminated operants will heighten response-consequence contingency discriminability and increase behavioral sensitivity to those consequences. In each experiment, three human subjects working under two-ply concurrent schedules of variable-cycle money reinforcement completed four experimental conditions in each of two phases. The phases differed in terms of whether the two component schedules employed identical or different types of consequences. In Experiment 1, one phase consisted of concurrent schedules of positive versus positive reinforcement and the other consisted of concurrent schedules of positive versus negative reinforcement (avoidance). All subjects demonstrated steeper matching function slopes in the phase that arranged concurrently available different types of consequences. Experiments 2 and 3 were designed to test the necessity and/or sufficiency of two features that distinguished positive from negative reinforcement in Experiment 1: money gain versus money loss as the establishing operation for reinforcement; and the presentation of feedback after subjects met versus failed to meet the reinforcement contingency. Both features were sufficient, but neither was necessary, to produce a slope effect similar to that seen in Experiment 1. Overall, the results supported contingency discriminability theory. These results are discussed in terms of the potential utility of the present methods to advance further research into the effects of choice-controlling variables other than reinforcement frequency, and in terms of some issues that must be resolved prior to doing so.

STUDENT PAPER WINNER: ABSTRACT

AGING AND CATEGORIZATION: USING GENERALIZED EQUIVALENCE CLASSES AND THEIR CHARACTERISTICS TO COMPARE OLDER AND YOUNGER ADULTS

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The present study was an effort to bring together accounts of stimulus equivalence, the transfer of function among stimulus classes, and age-related changes associated with the creation of stimulus classes. This experiment explores these ideas using two participant groups, one consisting of younger adults and one consisting of adult volunteers over the age of 65. Participants were given training using nonsense syllables and eight sets of abstract stimuli. The stimuli differed on a number of features, four of which were class-consistent. Each stimulus contained a combination of one, two, three, or four of the class-consistent features, and the number of class-consistent features was used to identify the typicality of the stimulus within each class. Upon completion of the equivalence training and testing procedure, each participant was told that one of the stimuli from training carried a disease that infects 50% of the animals or plants with which it comes into contact. Participants were then shown a series of stimuli from the testing phase of the equivalence procedure and asked to rate how likely each of these stimuli were to also infect plants or animals. Ratings from this phase determined the transfer of function within the stimulus classes created during the equivalence training procedure. Results showed that older adults required more training trials to master baseline criterion levels than younger adults did, but both groups demonstrated the formation of equivalence classes and typicality effects within those classes. Further, both groups also demonstrated transfer of function within the equivalence classes that was related to the typicality rating of each stimulus within a class.

BRIEF REPORT

RELATIONAL LEARNING IN CHILDREN WITH COCHLEAR IMPLANTS

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A cochlear implant is a prosthesis that substitutes for Corti's organ and stimulates electrically the ganglion cells and nerve fibers of the auditory nerve, enabling auditory stimulation. External components of the device comprise a microphone (usually placed behind the ear) that receives external sounds and transmits them, via cable, to a speech processor (roughly the size of a cellular phone). The processor analyzes the sound and digitizes it into coded signals that are sent, through a transmitting coil, as radio-frequency signals (FM) to the cochlear implant receiver/stimulator under the skin. Surgically implanted electrodes placed along the cochlea are connected to the receiver/stimulator through a cable of platinum-iridium wires. The receiver/stimulator delivers the appropriate amount of electrical energy to the electrodes, stimulating the remaining auditory nerve fibers in the cochlea. This electrical sound information is sent from the auditory nerve fibers through the auditory system to the brain, resulting in auditory sensation (Clark, 1997, 2003; Waltzman & Cohen, 2000).

Several studies demonstrate that cochlear implant users show successful development of auditory comprehension and speech (e.g., Löhle et al., 1999; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000). Bevilacqua, Costa and Moret (2003) studied 63 deaf children with cochlear implants and found that 45% of individuals who became deaf prelingually (i.e., before acquiring language) achieved high auditory abilities; auditory abilities were rated as intermediate for 38% and low for 17%. Regarding oral language, 62% produced simple and complex phrases, whereas 38% produced only isolated words or no language at all. Longitudinal studies (e.g., Gstoettner, Hamzavi, Egelieder, & Baumgartner, 2000) showed increasing improvements in speech comprehension and speech intelligibility in prelingually deaf users of cochlear implant over the first 6 to 18 months after implant activation. However, their performances still lag behind the linguistic repertoire of typically developing children. Asymptotic performances have been observed around five years after implant activation (Hansel, Engelke, Otenjann, & Westhofen, 2005).

Bevilacqua et al. (2003) argue that critical factors for implant success, particularly with prelingually deaf children, are (a) early

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implantation, (b) precise speech processor adjustments, and (c) the quality of auditory habilitation (for the prelingually deaf) or rehabilitation (for the postlingually deaf).

A major component of (re)habilitation is training to establish symbolic functions for auditory stimuli. To monitor results of training, it is necessary to assess symbolic function of auditory stimuli received through the implant. However, as Sidman and Tailby (1982) pointed out, symbolic relations between stimuli are not overtly distinguishable from conditional relations of questionable symbolic status. They argued that symbolic relations are equivalence relations between stimuli, defined mathematically by the properties of reflexivity, symmetry, and transitivity. Sidman and Tailby (1982) established conditional relations involving auditory and visual stimuli and then tested for emergent relations that documented the defining properties of equivalence. These tests have become standard practice in the assessment of equivalence classes.

Extensive research with both normally capable individuals and individuals with various types of disabilities has documented the applicability of the method to virtually every conceivable type of symbolic relations. These include all-visual relations (e.g., Spradlin, Cotter & Baxley, 1973), all-auditory relations (Dube, Green & Serna, 1993), tactile-visual relations (Bush, 1993), gustatory-visual relations (Hayes, Tilley, & Hayes, 1998), proprioceptive-visual relations (DeGrandpre, Bickel, & Higgins, 1992), as well as (most pertinent to the present work), auditory-visual relations (e.g., de Rose, de Souza, & Hanna, 1996; Green, 1990; Sidman & Tailby, 1982).

Stimulus equivalence has been studied with deaf children and others with language impairments. Variable outcomes have been reported: negative results (Devany, Hayes, & Nelson, 1986), mixed results (Barnes, McCullag, & Keenan, 1990; Vause, Martin, Yu, Marion, & Sakko, 2005), or mostly positive results (Carr, Wilkinson, Blackman, & McIlvane, 2000). These results suggest that training procedures to establish stimulus relations with these populations may vary in their symbolic outcomes. The present study attempted to extend the stimulus equivalence methodology to study auditory-visual relations and assess their symbolic function in individuals with profound bilateral sensorineural hearing loss who had received cochlear implants.

METHOD

Participants

Participants were two children and two teenagers. Each had received a Nucleus 22® cochlear implant 2-4 years before. Table 1 presents their hearing loss etiology and other characteristics. The children were prelingually deaf and teenagers were postlingually deaf. At the beginning of the study the children could distinguish between words on the basis of their consonants and could produce two-word or three-word phrases, thus demonstrating that they could respond, to some degree, to stimuli delivered by the speech processor. Also, they were proficient at lip reading, but did not use sign language and were doing poorly at school, exhibiting very limited reading repertoires. The teenagers acquired language before becoming deaf and language functions completely recovered during the first six months after the implant's activation.

Setting, Stimuli, and Apparatus

Experimental sessions were conducted during a three-day hospital visit for implant maintenance. Sessions were scheduled at any available time during routines for implant fitting and conducted in a room (7 x 4 m) containing two workstations, located facing two adjacent walls of the room and separated visually by cabinets. The experimental session was conducted in one of the stations while the other could be in use for implant fitting with another patient. Participants had the speech processor turned off during sessions, eliminating competing auditory stimulation. Sessions were 20 to 30 minutes long. Two to four sessions could be conducted daily.

Three sets of visual stimuli and one set of auditory stimuli were presented in a matching-to-sample format. All sets contained three stimuli each. Visual stimuli were Greek letters (Set A = Λ, Ω, Γ; Set B = Ξ, Σ, Π; Set C = ω, λ, δ), approximately 3 cm high (font Arial 120). Visual stimuli were displayed on a 14-in computer monitor. The display consisted of white windows (4 x 4 cm) on a gray background. One window was located on the center and one in each of the four corners. The attached computer controlled all experimental operations, except for auditory stimulus generation. Auditory stimuli were presented by another computer, interfaced with the implant. The Nucleus 22® has 22 electrodes implanted along the cochlea. Auditory stimuli (Set

Table 1

Participants' characteristics.

Participants	Gender	Age (yrs)	Time since Implant (yrs)	Duration of auditory deprivation (yrs)	Type of deafness	Acquisition of deafness
RFL	M	16	2	1	Acquired	Postlingually
RNT	F	12	4	1	Acquired	Postlingually
SBL	F	8	3	5	Acquired	Prelingually
CML	F	8	4	4	Congenital	Prelingually

Note. All four participants had received Nucleus 22® cochlear implants.

D) were electrical signals (a sequence of five 1-s discrete pulses) delivered to single electrodes in three different cochlear positions: basal, medial, and apical. As a result of these placements, D1, D2, and D3 were heard as high-, medium-, and low-pitched tones, respectively. Table 2 shows locations and resulting frequencies.

Procedure

The experiment had two phases. In Phase I, visual-visual AB and AC arbitrary matching relations were taught directly, thus providing the logical basis for the emergence of BC and CB relations (i.e., combined tests for symmetry and transitivity [Sidman & Tailby, 1982]). Arbitrary stimulus relations were used to ensure that any emergent stimulus equivalence relations were due to the experimental procedures and not to prior learning. In Phase II, arbitrary auditory-visual matching relations (DC) were introduced. The goal was to determine (1) if such relations could be established and (2) if so, whether DA and DB relations would emerge, thus demonstrating the expansion of the equivalence classes. The experiment was presented as a game in which the participant was instructed to try to be correct as much as possible. Correct selections produced a picture of a hand making a "thumbs up" signal, displayed on the screen for approximately 2-s; a 2-s dark screen followed incorrect selections. The following trial began immediately after the confirming or disconfirming consequence.

Phase 1. The experimenter modeled responding (two modeling trials for the teenagers and five for children) and then passed the mouse button to the participant. All visual-visual matching-to-sample trials began with a Greek-letter sample stimulus presented in the center window. Participants were required to place the cursor within that square and then to depress the mouse button. If they did not press, the experimenter pointed to the picture and to the mouse button. Immediately after a response, comparison stimuli were displayed simultaneously in any three of the four squares located in the corners of the computer screen. Participants chose a comparison stimulus by placing the cursor within its square and depressing the button once again. If they showed any evidence of not knowing what to do the experimenter used manual guidance, placing his hand over the participant's hand and moving the cursor over the screen. Guidance was necessary only very rarely.

AB relations were trained first. Training was comprised of 16 consecutive blocks of trials. During all baseline training, each block repeated until the participant selected correctly on all trials of the block. Blocks 1 through 5 trained a conditional discrimination with samples A1 and A2, and comparisons B1 and B2. The two initial blocks presented only one sample (A1 in the first and A2 in the second) on all trials of the block, with both comparisons. These blocks had 8 trials each. Blocks 3 and 4 also alternated samples A1 and A2, now with 4 trials in each block. The fifth block, with 6 trials, presented samples A1 and A2 in a randomized sequence. Therefore, blocks 1 through 5 established a conditional discrimination with samples A1 and A2 and comparisons B1 and

Table 2

Electrode locations and frequency band (hertz) of tones used as D stimuli (D1, D2, and D3) for each participant.

	D1		D2		D3	
Participants	Electrode number (Basal)	Frequency Band (Hz)	Electrode number (Medial)	Frequency Band (Hz)	Electrode number (Apical)	Frequency Band (Hz)
RFL	5	4093-5744	14	1350-1550	20	150-350
RNT	5	4093-5744	14	1350-1550	20	150-350
SBL	5	5744-6730	14	1550-1768	19	550-750
CML	5	6730-7885	14	1768-2031	20	550-750

B2, in a minimum of 30 trials. Then, blocks 6 through 10 used a similar sequence to train a conditional discrimination with samples A1 and A3 and comparisons B1 and B3. A similar sequence was used in blocks 11 through 15 to train a conditional discrimination with samples A2 and A3 and comparisons B2 and B3. Finally, block 16 had 18 trials with samples A1, A2, and A3 in a randomized sequence; each trial presented comparisons B1, B2, and B3. Therefore, training the AB conditional discrimination required a minimum of 108 trials (30 for blocks 1 to 5, 30 for blocks 6 to 10, 30 for blocks 11 to 15, and 18 for block 16). After a similar sequence of blocks taught the AC conditional discrimination, participants were instructed that confirming consequences would appear only in some trials, and the next block presented 6 trials, intermixing AB and AC conditional discriminations, with confirming consequences on 50% of the trials.

The following sessions inserted probes for emergent relations BC, and CB. Probe blocks mixed, in a randomized order, 9 AB trials, 9 AC trials, and 9 BC or CB probe trials. Each block tested only one emergent relation and provided confirming consequences only on baseline trials (the overall probability was maintained at 0.5). The next block presented 6 trials reviewing AB baseline. The next probe block mixed 9 BA symmetry probes with 18 AB trials. A block reviewing AC baseline also preceded CA symmetry probes, conducted in a block mixing 9 CA trials with 18 AC trials.

Usually two blocks were conducted for BC and CB equivalence probes and one block for BA and CA symmetry probes. For CML, symmetry probes were omitted due to the limited time available for sessions. Participant RNT showed low scores in BC and CB probes together with a steady decrease in baseline scores (see Results, below). Equivalence probes were then discontinued for this participant and the next two blocks reviewed the AB baseline, with confirming consequences in 50% of the trials. Two blocks of BA symmetry probes followed. BC probes resumed, followed by CA symmetry probes and then CB probes.

Phase 2. DC relations were established between auditory samples (D1, D2, D3) and visual comparisons (C1, C2, C3), using a sequence of blocks similar to that used to train AB and AC (with a minimum of 108 trials). The participant was told that the speech processor would be disconnected, and that he or she should make a hand signal when an auditory stimulus was presented. Participants were familiar with this practice, often used during the clinical procedures. At the start of each trial, visual comparison stimuli were displayed simultaneously with the five-pulse sequence and the experimenter held the mouse until the participant indicated that he or she detected a sound. If no response occurred within 10 s, another sequence was presented, and this was repeated until the participant raised his or her hand. Then, he or she was given the mouse. Confirming or disconfirming consequences followed the selection of a comparison stimulus. Thereafter, AB and AC trial types were reintroduced and intermixed with DC trials. Training blocks had 9 trials, reinforcement probability was reduced to 0.5 and blocks repeated until 100% of selections were correct.

Phase 2 established the basis for the emergence of DA and DB auditory-visual conditional relations, thus serving as a combined test for symmetry and transitivity. Each of these relations was evaluated in a separate 36-trial test block (nine of each baseline relation, AB, AC, and DC, and nine probe trials: DA or DB). Reinforcement probability was 0.50 for baseline trials, and no confirming consequences followed probe trials.

RESULTS AND DISCUSSION

RFL completed Phase 1 with the minimum number of trials required: 216. RNT and CML needed 224 trials to complete this Phase, and SBL needed 236 trials. In Phase 2, participants RFL and RNT (postlingually deaf) required 112 and 148 trials to complete training, respectively. Participants CML and SBL (prelingually deaf) completed only the blocks of Phase 2 with one sample but never achieved criterion in the first block that presented two samples.

Figure 1 shows accuracy scores of all participants in equivalence tests in Phases 1 and 2. Each bar corresponds to one block of test trials. Connected squares represent scores on baseline trials in probe blocks. Participants' initials and ages are shown to the right of the data. All participants exhibited stimulus equivalence with visual stimuli A, B, and C. CML showed high scores in equivalence probes from the beginning and the other participants showed somewhat delayed emergence of equivalence. RNT, particularly, showed low scores in equivalence probes and also a decrease in baseline scores. Equivalence emerged only after retraining of AB baseline and BA symmetry tests. Deafness, therefore, did not interfere with development of symbolic relations per se.

In Phase 2, RFL, one of the two participants who learned the DC auditory-visual conditional discrimination, also showed auditory-visual equivalence classes. RNT, the other participant tested for auditory-visual classes, showed increasing scores in the two initial DA probe blocks, reaching about 75% of selections consistent with auditory-visual equivalences in the second block. She then showed 100% selections consistent with equivalence in the next probe block, which tested the DB relation. Subsequent probe blocks showed deterioration of the DB relation and of baseline performance as well. No consistent pattern was found in the inconsistent selections. It is possible that baseline retraining, followed by retesting of equivalence, could promote the emergence of the auditory-visual classes for RNT. No further time was available, however, to continue the study with this participant.

Successful matching to sample requires a simultaneous discrimination between the comparison stimuli and a successive discrimination between the samples. Participants had already proved capable of acquiring the simultaneous and successive discriminations between the visual stimuli in Phase 1. The Phase-2 auditory samples, however, were pure tones. These stimuli were detected by all participants, but CML and SBL did not achieve criterion when discriminations between them were required. Perhaps these difficulties were due to the nature of the stimuli. Discrimination of pure tones in isolation may be an unusually challenging auditory task – perhaps even for people whose hearing is unimpaired. Notably, all participants could discriminate certain more complex auditory stimuli (dictated words) presented via the speech processor after 2-4 years of post-implant training.

A question for future research is whether the learning failures exhibited by some participants in this study can be overcome by using different auditory stimuli. Training in this study was constrained by practical realities of the hospital situation (only a 3-day stay, competition from clinical appointments, etc.). It seems reasonable to suppose that more familiar auditory stimulus types (e.g., dictated words rather than pure tones) would speed acquisition – although this is by no means certain. Also better programming of procedures for teaching auditory-visual matching might have facilitated learning the equivalence relations.

Certain limitations notwithstanding, this study does point to a population that may be of great interest within the experimental analysis of human behavior. In contrast with the other participants, RFL successfully acquired auditory-visual matching and also showed class expansion with inclusion of the auditory stimuli. Thus, studying auditory-visual stimulus equivalence in users of cochlear implants is feasible. For those concerned with foundations of relational learning (e.g., Hayes, 1991; McIlvane, Serna, Dube, & Stromer, 2000), the deaf population – especially the young, prelingually deaf – stands out as

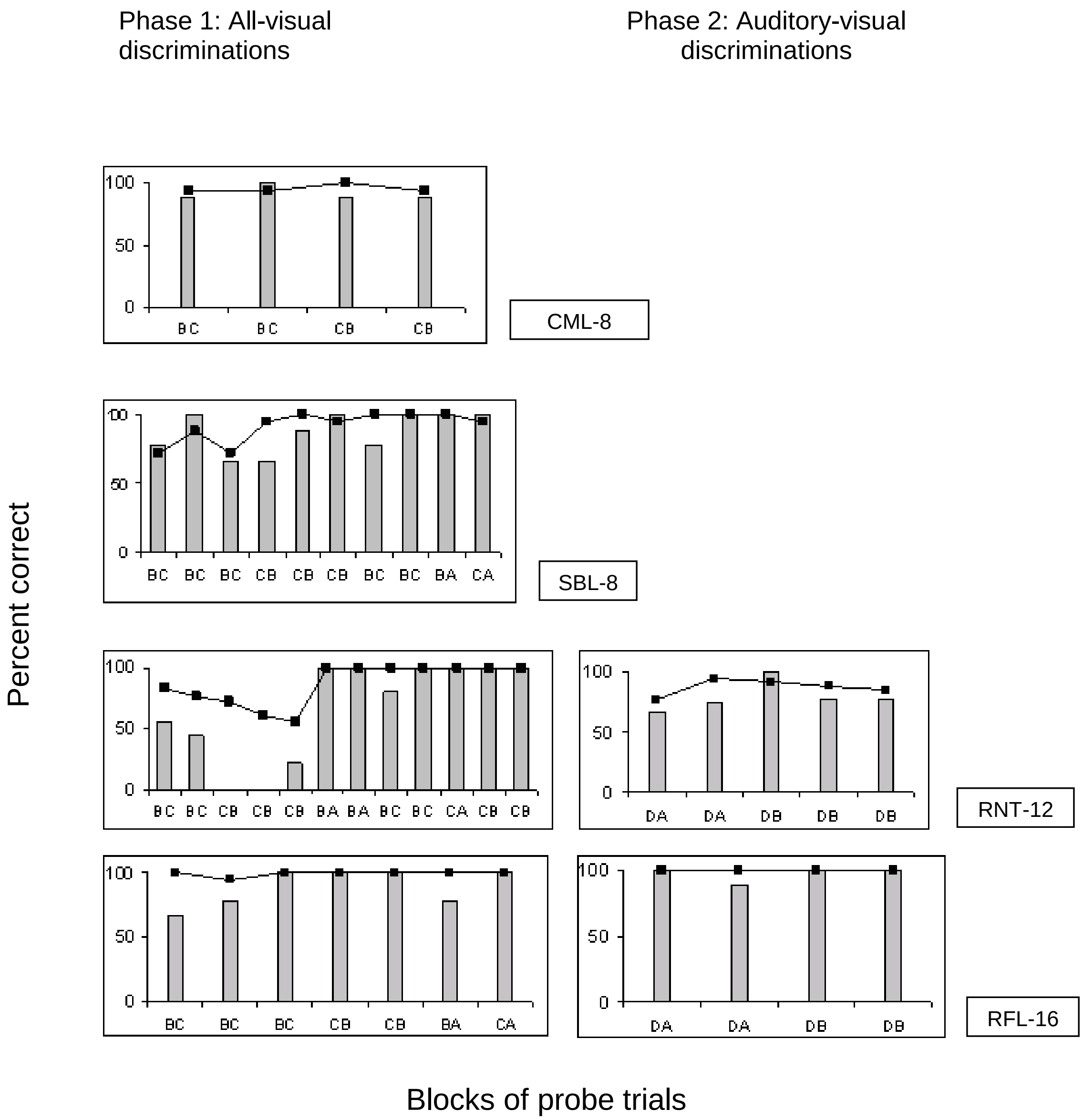

Figure 1

potentially attractive test case. Most such children may be presumed to have little or no central neurological damage/dysfunction. Their sensory limitations are often due to peripheral impairments (e.g., those resulting from infections) and, more importantly, these limitations may be partially or fully correctable via increasingly capable cochlear implants. It might be possible, therefore, to study the conditions under which the newly received auditory stimuli are related to stimuli from other modalities. One might, for example, assess the degree to which multiple exemplar training is necessary to establish relational learning performances involving auditory stimuli.

For scientists and clinicians interested in assessing and/or remediating sensory disorders (e.g., audiology, speech pathology, etc.), the equivalence paradigm offers easily implemented methodology for assessing symbolic functions. The equivalence tests are well-operationalized and have substantial face validity (Wilkinson & McIlvane, 2001). If children can acquire the requisite matching-to-sample baselines, the consequence is highly likely to be emergent behavior that confirms symbolic status (McIlvane et al., 2000; Sidman, 1994). Such circumstances thus provide a secure basis for comparison when exploring largely uncharted territories such as the nature and quality of relations involving cochlear-implant delivered auditory stimuli.

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BRIEF REPORT

DELAYED MATCHING-TO-SAMPLE TRAINING FACILITATES DERIVED RELATIONAL RESPONDING

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Non-behavioral psychologists interested in the dynamics of learning make a distinction between procedures that enhance the acquisition of a set of skills and procedures that enhance the retention or transfer of that set of skills (Schmidt & Bjork, 1992; Schroth, 1995; 1997). The distinction is partly based on the observation that, under certain conditions, procedures that retard the acquisition of some performance during training can actually serve to enhance performance during transfer or retention tests (e.g., Schmidt, Young, Swinnen, & Shapiro, 1989; Shea & Morgan, 1979; see also Magill & Hall, 1990, for a review). For example, increasing the amount of task variability during training of a motor skill (patterned finger tapping) can retard acquisition but facilitate retention and transfer during tests (Hall & Magill, 1995). Likewise, decreasing the frequency of performance feedback during acquisition of a ballistic timing task impeded acquisition, but enhanced retention (Schmidt, et al., 1989). In general, this literature suggests that introducing certain task-relevant difficulties during the acquisition of a set of skills can serve to increase the likelihood of retention and effective transfer of those skills.

Research in stimulus equivalence provides a well-established preparation to study the dynamics reported above. First, the train and test preparation characteristic of research in stimulus equivalence provides the procedural context necessary to ask questions about the effects of learning conditions on the likelihood of transfer. Second, the definition of stimulus equivalence (Sidman & Tailby, 1982) provides a well-defined matrix of tasks which can be used to assess the extent and robustness of transfer and retention effects with less ambiguity relative to other procedures.

Arntzen (2006) investigated the effects of a set of imposed delays between the offset of sample stimuli and the onset of an array of comparison stimuli (hereafter, the retention interval) during training of baseline conditional relations on the likelihood of derived equivalence class formation with adult humans. Consistent with the literature cited above, Arntzen (2006) found a greater likelihood of equivalence-consistent responding as the duration of the retention interval was increased during training.

There were several features of Arntzen's (2006) procedure, however, that limit the conclusions that can be drawn from the results. For example, each participant was exposed to several conditions during which conditional relations were trained and emergent conditional relations assayed. Participants were exposed to either an ascending or descending series, in which the retention interval either increased or decreased, respectively, across conditions. Although the participants' performance in the ascending series improved with each increase in the retention interval value, the performance of participants' in the descending series was not similarly degraded as retention interval values were reduced. Arntzen suggests that the improvements seen in the ascending series may have been due, at least partially, to the increased exposure to training and testing circumstances rather than the imposed delays alone.

In the current study, we sought to minimize repeated training and testing opportunities by exposing an individual participant to only one

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delay and making the comparisons across groups of participants rather than within individual participants. In addition, we used common English and unfamiliar Portuguese and Czechoslovakian words as stimuli and tested only for the reversibility (symmetry) of trained conditional relations. To summarize, we asked whether introducing a delay between sample offset and comparison onset during the training of baseline conditional relations (e.g., given A1 pick B1, not B2, B3, or B4) would influence the likelihood of emergent symmetric relations (e.g., given B1 picking A1, not A2, A3, or A4).

METHOD

Participants

Twenty-six college students (10 male and 16 female) were recruited via publicly posted flyers and newspaper advertisements and were screened to ensure availability and a lack of familiarity with Behavior Analysis, and common words in Portuguese and Czechoslovakian because words from these languages comprised part of the set of experimental stimuli. Participants were randomly assigned to one of three groups (described below). Regardless of group membership, all participants earned $0.05 for every correct response during training and $1.00 for each completed session. The amounts earned were supplemented (at the end of the experiment when necessary) to maintain a minimum wage rate of $6.00 per hour.

Setting and Apparatus

Sessions were conducted in a 2 m by 3 m room equipped with a chair and a small table. The apparatus consisted of a Macintosh Power Book (G3) enclosed in a touch screen adapter (Troll Touch, Inc.). A custom-written program (MTS v. 11.6.7, see also Dube & Hirris, 1997) was used to present stimuli, manage all contingencies and collect data.

Procedure

The general plan of the experiment involved training a total of eight conditional relations – four with English words as sample stimuli and non-English words as comparison stimuli and the other four with non-English words as samples and English word comparisons – and testing for emergent reversibility of the trained conditional relations (see Table 1). The primary independent variable involved an experimenter-imposed delay between the offset of the sample stimulus and the onset of the comparison array during training and testing trials. Participants were divided into three groups: For Group 0 (n=8), Group 2 (n=8), and Group 8 (n = 10), there was a 0, 2 or 8 s delay, respectively, between the offset of the sample stimulus and the onset of the comparison array. The screen was white during the delay. All other contingencies were identical across groups and participants. All participants were instructed to respond by touching the screen. No other task-relevant instructions were presented.

Phase 1 (Baseline). Participants were exposed to one 8-trial block in which each conditional relation to be tested was presented once without programmed feedback. Trials began with the presentation of a stimulus in the vertical and horizontal center of the screen. Touching the sample stimulus removed it from the screen and, after passage of the programmed amount of time, produced an array of four comparison stimuli. During this phase, touching a comparison stimulus cleared the display and initiated a 1.5 s inter-trial interval (ITI). No other feedback was programmed.

Phase 2 (Training). Trials were identical to those presented in the baseline phase with the exception that choice of the experimenter-designated correct comparison stimuli resulted in the word "CORRECT" being displayed on the screen for 1 s accompanied by a tone and choice of any other comparison stimuli resulted in a 3 s time out during which the screen was white. Each of the eight conditional relations was randomly selected without replacement in a block of trials. Training trials were presented until the participant responded correctly on 24 consecutive trials or 384 training trials had been presented. In the latter case, the participant was invited to return for a second session which was identical to the first session.

Phase 3 (Testing). Participants who met the acquisition criterion were immediately exposed to testing trials in which stimuli previously functioning as comparison stimuli were presented as sample stimuli and vice versa. The delays between sample stimulus offset and comparison array onset remained at 0, 2, or 8 s depending upon group membership. The testing condition consisted of four exposures to 40-trial blocks (5 presentations of each of the 8 derived conditional relations). S1 was inadvertently exposed to only

Table 1.
The composition of training (left column) and testing (right column) trials during the experiment.

Training		Testing	
Sample	Comparison	Sample	Comparison
Food	Potrava	Potrava	Food
Bathroom	Koupelna	Koupelna	Bathroom
Ball	Esfera	Esfera	Ball
Farm	Fazenda	Fazenda	Farm
Postel	Bed	Bed	Postel
Duum	House	House	Duum
Comboio	Train	Train	Comboio
Margem	Bank	Bank	Margem

half of the testing trials relative to the remaining participants. Test trials were selected randomly (without replacement) such that each of the 8 test trial-types was presented once before any were repeated. Participation was considered complete after 160 testing trials or 2 hours, whichever came first.

Debriefing. Debriefing occurred in a separate session. Each participant completed a questionnaire regarding their use of verbal strategies as well an interview designed to get clarifications or follow-up answers. Upon completion, the participants were fully debriefed about the nature of the study.

RESULTS

Baseline. As a group, performance during the baseline block confirmed that participants were largely naïve with respect to the meaning of the Portuguese and Czechoslovakian words that served as experimental stimuli. The exceptions were S20 and S23 who selected the correct non-English words (presented as comparisons) on 3 of 4 baseline trials. Their performance on trials in which English words served as comparisons, however, was around chance levels of accuracy.

Acquisition. Participants in Groups 0, 2 and 8 met the training criterion of 24 consecutive correct responses in an average of 11.9 blocks (range = 5 to 24 blocks), 19.4 blocks (range = 9 to 61 blocks, and 11.4 blocks (range = 7 to 20 blocks), respectively. Participant 16 from Group 2 and Participants 24 and 25 from Group 8 failed to meet the training criterion by the end of their first 2 hour session and were invited back for a second session. Participants 24 and 25 from Group 8 failed to meet the training criterion during the second session as well and were paid and debriefed.

There was no difference in the rates at which conditional relations with English or non-English word samples were acquired within any of the three groups. There was also no significant difference in the speed of acquisition across groups (the average number of blocks to criterion in Group 2 are inflated due to one participant [S16] requiring 61 blocks to meet the acquisition criterion).

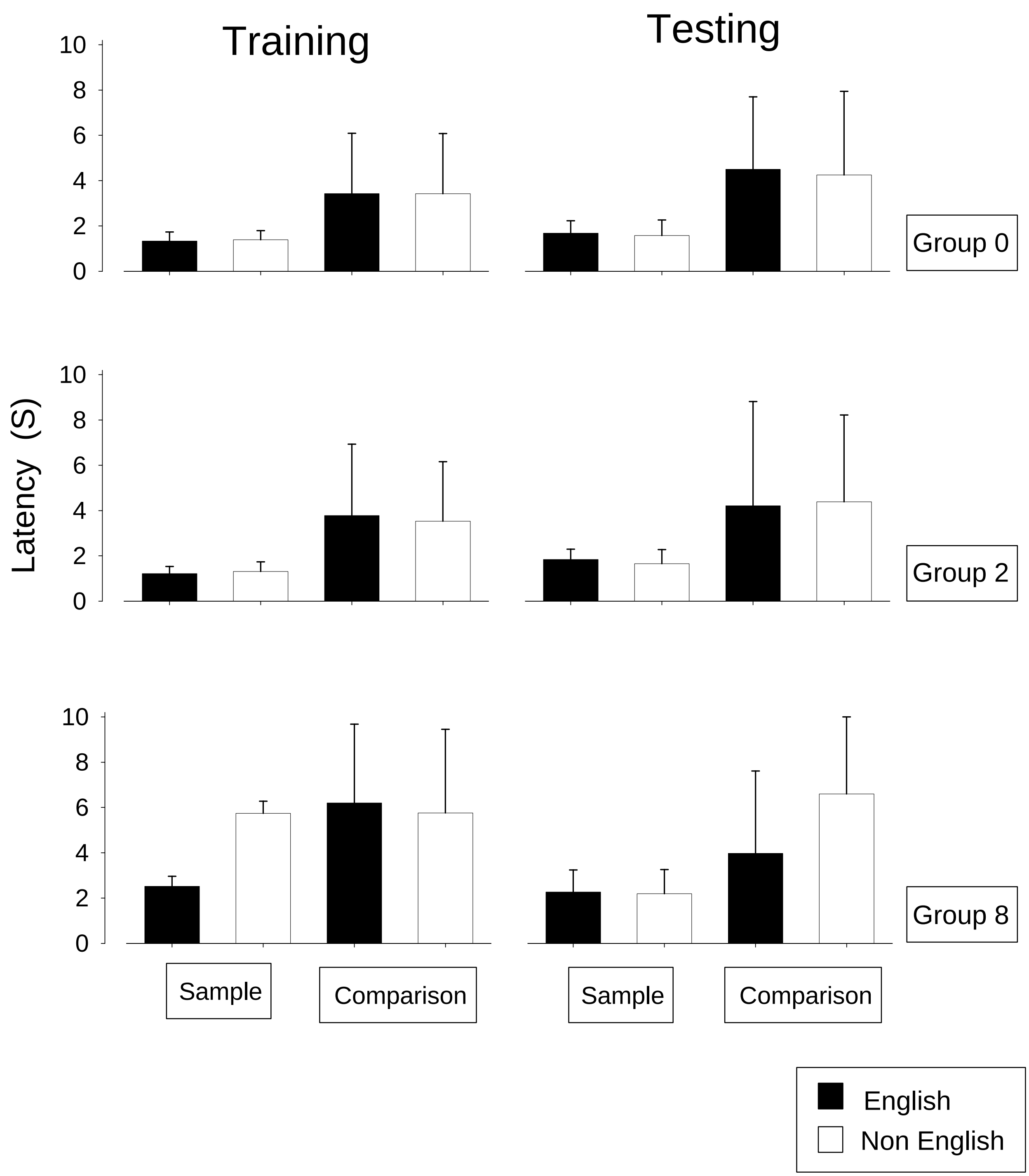

Figure 1

The left column in Figure 1 presents average observing-response and comparison–selection latencies during training separately for trials with English or non-English words serving as sample or comparison stimuli. Latencies for Groups 0, 2, and 8 are presented in the top, middle and bottom panels, respectively. The figure shows that, for Group 0 and Group 2, latencies to observe the sample stimulus or select a comparison stimulus were similar regardless of whether English or non-English words served as samples or comparisons. These data suggest that familiarity with the stimuli did not play a significant role in the organization of response latencies for participants in Group 0 and Group 2. The data from Group 8 differed, however. Participants in this group generally took longer to observe the sample stimulus and longer to make comparison selections. In addition, participants spent more time looking at non-English words (appearing as samples or comparisons) relative to participants in the other groups.

Figure 2 presents the percentage of correct trials across test blocks for each individual participant in Group 0 (left column), Group 2 (middle column), and Group 8 (right column). The participants' performances were deemed to show emergent symmetry if accuracy exceeded 80% (indicated by the solid horizontal reference line on each panel). The left column shows that accuracy on the test trials improved over the course of testing for three out of the eight participants (S3, S6, and S8) in Group 0. For four of the five remaining participants (S1, S2, S4, and S5), accuracy on the testing trials generally fluctuated around chance levels with no systematic difference in accuracy between trials involving English or foreign words as samples. S7's performance during tests was highly accurate in Block 2 but returned to chance levels of accuracy during Blocks 3 and 4.

The middle column shows that accuracy on the test trials improved over the course of testing for two participants (S10 and S13) and was highly accurate from the onset of testing for one participant (S16) in Group 2. The remaining five participants' performances (S9, S11, S12, S14, and S15) are more difficult to characterize briefly. S9 was highly accurate on trials with English word samples but not with non-English word samples. S11, S12 and S14's accuracy fluctuated around chance levels throughout the testing condition. S15's performance was moderately accurate (approximately 75% correct) during block 2 before returning to chance levels of accuracy.

The right column shows that performance on the test trials was highly accurate for five of the eight participants (S17, S18, S20, S22, and S23) in Group 8. In addition, S21's accuracy exceeded the established criterion for non-English samples during the final test block. Only two participants in this group (S19 and S26) failed to develop even one instance of symmetric relations among the stimuli. (An analysis of variance across groups, however, showed that the effect of delay was not significant, $F(2, 21) = 2.01$, $p > .05$). Interestingly, for all participants in this group, accuracy on trials involving non-English word samples was greater than accuracy on trials involving English word samples. In addition, for four of the eight participants (S17, S18, S20, and S22), performance on trials involving non-English word samples (and English word comparisons) was at or near 100% accurate from the beginning and throughout the testing condition. This may have been due to participants' familiarity with the commonly used English words comprising the comparison array. Alternatively, this performance may reflect differences in learning during the training condition when English words served as sample stimuli and the non-English words served as comparisons.

The right column of Figure 1 presents average latencies to respond to the sample stimulus and to select comparison stimuli for each of the three groups during testing. Mean latencies for Group 0, Group 2, and Group 8 are presented in the top, middle, and bottom panels, respectively. The data presented in the top and middle panels show that, for participants in Group 0 and Group 2, there was no systematic difference in the latencies to respond to English or non-English words presented as sample or comparison stimuli. The participants in Group 8, however, generally took longer to respond to all stimuli. In particular, participants in this group took longer to respond to non-English word comparisons relative to English word comparisons during testing.

A large majority of the participants reported the use of verbal devices during the training condition. These included memorization or rehearsal (13 participants) and intraverbal naming (7 participants). Examples of intraverbal naming included phrases such as "merging banks" or "pots cook food". There was, however, no obvious relation between the kind of naming strategy employed and the likelihood of emergent symmetrical relations. For example, of the seven participants that reported some intraverbal naming, three showed emergent symmetry (S8, S18, and S20) and four did not (S1, S4, S5, S11).

DISCUSSION

The purpose of the present study was to evaluate the effects of delays between sample offset and comparison array onset on the acquisition of conditional discriminations and the

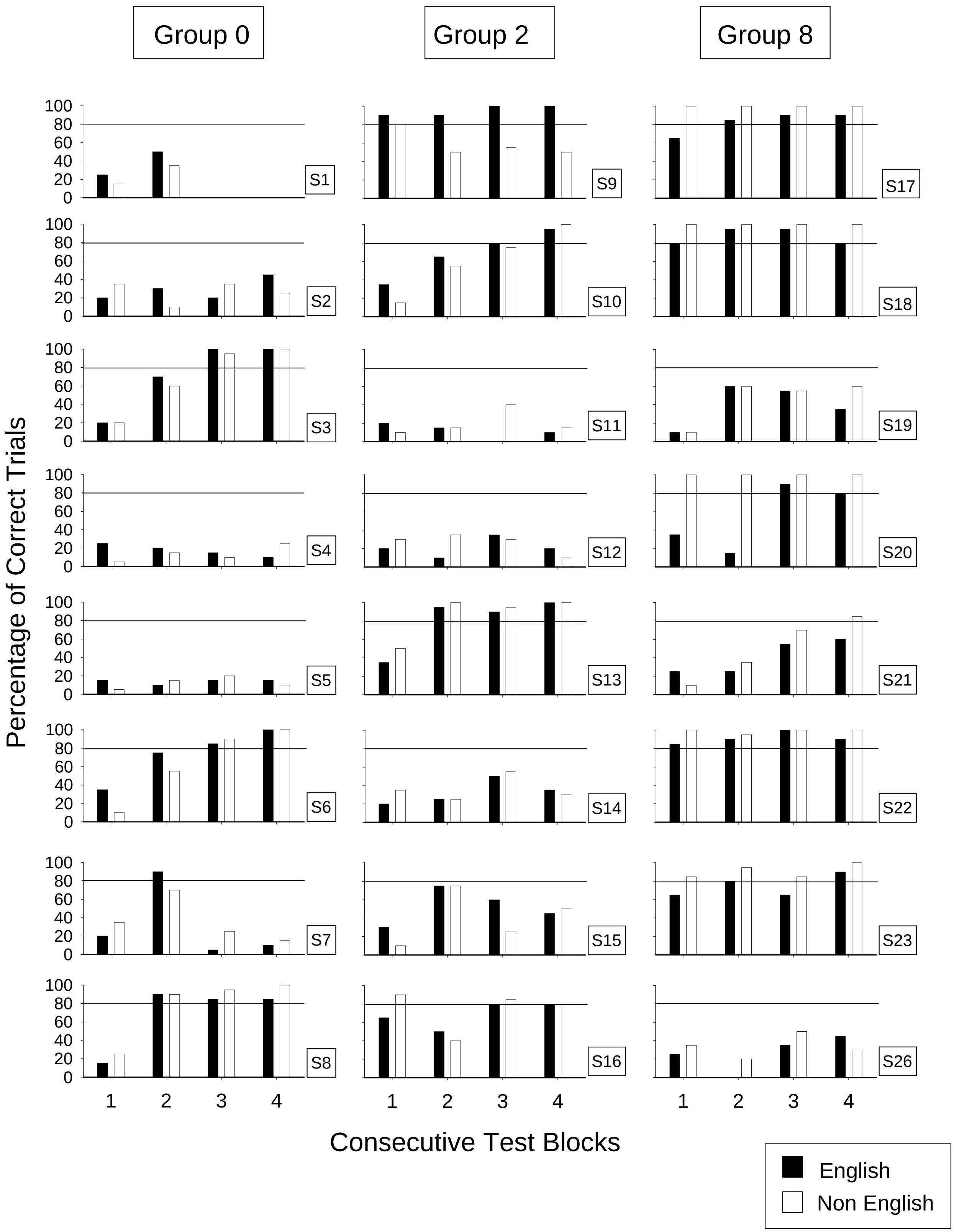
Group 0
Group 2
Group 8
Percentage of Correct Trials
0
20
40
60
80
100
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
S17
S18
S19
S20
S21
S22
S23
S26
1
2
3
4
Consecutive Test Blocks
English
Non English

Figure 2

development of their symmetrical counterparts. The data show some retardation in acquisition – participants either required more training (S16 in Group 2) or failed to acquire the conditional relations entirely (S24 and S25 in Group 8) as the delay between sample offset and comparison onset was increased. For the most part, however, there was no difference in the number of trials required to meet criterion across groups. These data are inconsistent with the behavioral literature on delay matching-to-sample (Sagrisson & White, 2001) as well as the non-behavioral literature cited above and may provide an interesting follow-up question for future research. Perhaps the delays imposed between sample offset and comparison array onset were too short to produce a decrement in learning rates.

The data also show that participants exposed to longer delays between sample offset and comparison onset during training are more likely to make symmetry-consistent choices on test trials. These data provide a systematic replication of the results reported by Arntzen (2006) and are also consistent with other data suggesting that the introduction of task-relevant difficulties during training can facilitate retention and transfer of learned skills (Magill & Hall, 1990).

One possible factor that may have influenced the differential development of emergent relations is the duration of contact with the experimental stimuli. The data show that participants in Group 8 spent nearly twice as long in the presence of the sample and comparison stimuli relative to participants in Groups 0 and 2. The extended exposure to sample and comparison stimuli may have served to eliminate irrelevant sources of control and increased control by experimenter-designated features such that symmetrical relations became more likely. This interpretation is consistent with the predictions of Stimulus Control Topography Coherence (hereafter, SCTC) theory (McIlvane & Dube, 2003). According to SCTC theory, emergent conditional relations require coherence of experimenter-defined and obtained stimulus control topographies. With respect to the current data set, long delays between sample offset and comparison onset during training may have served to increase the time participants spent observing stimuli prior to a sample-observing or comparison-selection response. The additional interaction with the stimuli may have facilitated the development of stimulus control topography coherence and led to an increased likelihood of emergent symmetry-consistent choices on the test trials.

An alternative or complementary mechanism may have been the development of other pre-current or supplemental behavior (such as naming) which facilitated the emergence of symmetrical relations (cf. Horne & Lowe, 1996). The role of naming in the current data set remains unclear, however. Although 33% of the participants reported some intraverbal naming during the training conditions, only three of those seven participants made symmetry-consistent choices on the test trials. Future research should attempt to manipulate the likelihood of naming directly to elucidate its role in the organization of conditional discrimination performances.

In conclusion, the methodology of equivalence research appears to provide a sensitive preparation to investigate the relation between training and transfer reported by researchers outside the behavioral tradition. These procedures also have the potential to more broadly inform our understanding of the derivation of relational responding. A systematic database relating the circumstances of training to the likelihood of derived relational responding may help to identify the conditions that are necessary and sufficient for such responding to emerge. In addition to the important theoretical benefits, such work may also contribute to the development of technologies designed to facilitate derived relational responding – an important outcome in a large variety of clinical and educational settings.

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