Establishing auditory-tactile-visual equivalence classes in children with autism and developmental delays

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Abstract The current study sought to evaluate the efficacy of a stimulus equivalence training procedure in establishing auditory–tactile–visual stimulus classes with 2 children with autism and developmental delays. Participants were exposed to vocal–tactile (A–B) and tactile–picture (B–C) conditional discrimination training and were tested for the emergence of vocal–picture (A–C) and picture–vocal (C–A) responses. The results demonstrated that, following training, both participants responded successfully on both the training stimulus arrangements and the test probes that were never trained, illustrating emergence of cross-modal transitive and equivalence relations.

Keywords Cross-modal equivalence · PEAK relational training · Stimulus equivalence · Tactile stimuli

First popularized by Murray Sidman (Sidman and Tailby 1982), stimulus equivalence procedures offer unique advantages over traditional approaches for skill acquisition. Specifically, when taught a few key relations using these procedures, other untrained relations often emerge. Because these procedures result in several stimulus relations that do not need direct training, stimulus equivalence procedures are often regarded as a more efficient method of teaching (Zinn et al. 2015) for many learners. Most of the literature on stimulus equivalence focuses on establishing visual–visual or visual–vocal stimulus classes. Relatively few studies have been conducted that incorporate other sense modalities (e.g., gustatory, olfactory, tactile) into stimulus equivalence training procedures (Rehfeldt 2011). Teaching only visual–visual and visual–vocal stimulus relations is problematic because it accounts for only a small portion of the

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totality of sense modalities experienced. Equivalence relations that incorporate tactile stimuli are one sensory modality often overlooked within the behavior-analytic literature.

Bush (1993) demonstrated that a transfer of stimulus function occurred among visual, auditory, and tactile stimuli when participants were taught a series of conditional discriminations containing the different sense modalities. Bush's study provided the first evidence of equivalence class formation that included tactile stimuli. Toussaint and Tiger (2010) used similar methodology to teach early literacy skills to individuals with degenerative visual impairments. The experimenters successfully used a match-to-sample format to assess and teach equivalence relations among Braille letters, printed letters, and spoken letter names to children with degenerative visual impairments. Although a few examples of cross-modal equivalence classes using tactile stimuli exist, none have been demonstrated in individuals with autism or developmental delays. Therefore, the purpose of the current study is to extend the previous literature on cross-modal equivalence classes by evaluating the effectiveness of stimulus equivalence training procedures in establishing visual–tactile–auditory stimulus classes in children with autism and developmental delays.

Method

Participants, setting, and materials

Two children participated in the study. Josh (4 years old) and Dustin (5 years old) had prior diagnoses of autism and developmental delay, respectively. The participants were selected for the study because they responded consistently to reflexive and symmetrical relations of sameness, and baseline levels of correct responding suggested that they lacked the skill targeted in this study. Both participants were vocal and had been observed emitting intraverbals, tacts, and mands and forming age-appropriate sentences.

All sessions took place in a Midwest American prekindergarten special education classroom. Sessions were conducted at a table away from other students to minimize distractions, lasted between 20 and 30 min in duration, and were conducted over the period of 1 month. Materials included the programs 9C—Symmetry: Tacting Tactile Stimuli and 9K—Symmetry Tactile to Arbitrary of the PEAK–E curriculum (Dixon 2015).¹ Both programs, which were designed to teach only symmetrical relations, were combined for the current study. Table 1 depicts the stimuli used. Picture stimuli were displayed on 5 × 5 cm pieces of paper. Arbitrary words and symbols were selected to ensure that the participants did not have a previous learning history with the stimuli. Paper bags were used to conceal tactile stimuli to ensure that responding was solely under the stimulus control of the tactile property and not under control of any visual properties of the stimulus.

¹ Although PEAK is a commercially available curriculum, the necessary details for procedural replication or clinical application of content found within this article are presented in their totality.

Table 1 List of stimuli used in the present study

Arbitrary words (A stimuli)	Tactile stimuli (B stimuli)	Arbitrary symbols (C stimuli)
KAS	Feather
TEP	Cotton ball
BOP	Wooden block
SAL	Sandpaper

Dependent variable, interobserver agreement, and procedural fidelity

The dependent variable was the percentage of correct responses within a 10-trial block. The percentage of correct responses was calculated by dividing the number of correct responses by the total number of responses in a trial block and then multiplying by 100. Interobserver agreement (IOA) was assessed for at least 40% of the sessions. An agreement was defined as both observers obtaining the same score for each trial within a block. IOA was calculated by dividing the total number of agreements within a block by the number of agreements and disagreements and then converting the ratio to a percentage. IOA was 94%.

Procedural fidelity was assessed for at least 10% of the sessions. A trained observer collected fidelity data by reviewing recordings of the sessions and using the PEAK implementation checklist (Belisle et al. 2016) to assess fidelity. Fidelity was calculated by dividing the total number of correct steps by the total number of incorrect and correct steps and converting the ratio to a percentage. Procedural fidelity was 97%.

Experimental design and procedures

A nonconcurrent multiple-baseline design across participants was used to evaluate the effects of training on emergence. Six relations were tested throughout the study (i.e., A–B, B–A, B–C, C–B, A–C, and C–A), where A stimuli were vocal words (auditory), B stimuli were tactile stimuli, and C stimuli were visual symbols. Four stimulus classes were taught. The study consisted of the following phases: (a) baseline, (b) A–B training, (c) baseline, (d) B–C training, and (e) baseline. Additionally, within each of the training phases, probes were conducted to test for the symmetrical relation being trained in that phase (i.e., B–A test probes in the A–B training and C–B test probes in the B–C training). Social praise and preferred edibles were identified by teachers as preferred stimuli for each of the participants prior to the beginning of the study and were used as consequences for correct responses during training.

Baseline and test probes During baseline, test probes were conducted for each of the six relations within a trial block throughout the study. Probes were conducted with each of the participants, and no prompts, feedback, or reinforcement were provided during this phase. For the A–B relation, the experimenter presented an arbitrary word (A), presented the tactile stimulus (B), and presented the instruction “Feel what is in the bag.” If the participant did not respond within 10 s, the experimenter prompted the participant using a least-to-most prompting procedure. Once the participant placed his hand inside the bag and felt the stimulus, the experimenter asked, “Was that the same?” while simultaneously pointing to the arbitrary word. The participant responded vocally with either “yes” or “no.” A correct response was recorded if the participant responded with “yes” if the sample word corresponded with the tactile stimulus or “no” if the stimuli did not correspond to each other. Any other response was marked as incorrect. Stimulus presentation was randomized, in which the vocal word corresponded to the tactile stimuli for five trials within the block (i.e., required a “yes” response as a correct response). For the B–A symmetry probe, the experimenter presented a tactile stimulus (B) and presented the instruction “Feel what is in the bag.” Again, the participant was prompted to feel the item if he did not respond within 10 s. While the participant felt the stimulus, the experimenter asked, “What is this called?” A correct response was recorded if the participant responded with the corresponding spoken word, and an incorrect response was recorded if the participant responded with any other vocal response or failed to respond.

For the B–C relation, the participant was provided with a sample tactile stimulus (B) and an array of the four arbitrary symbols (C). The experimenter then presented the instruction “Find the same.” If the participant selected the arbitrary symbol that corresponded to the sample tactile stimulus, a correct response was recorded. If the participant did not select the corresponding symbol or failed to respond, an incorrect response was recorded. For the C–B test probe, the experimenter presented a sample arbitrary symbol (C) and provided a tactile stimulus (B) for the participant to feel. The participant was prompted to feel the item, after which the experimenter pointed to the symbol and asked, “Was that the same?” The participant vocally responded with either “yes” or “no.” Stimulus presentation was randomized; five trials within each block required a “yes” response, and five required a “no” response. If the participant responded “yes” when the stimuli corresponded with each other and “no” when the stimuli did not correspond, then a correct response was recorded. Any other response was considered incorrect.

For the A–C transitive relation, the experimenter provided a sample vocal stimulus (A) and an array of the four arbitrary symbols (C). The experimenter said the word corresponding to one of the vocal stimuli, waited 3 s, and said, “Find the same.” If the participant pointed to the arbitrary symbol corresponding to the sample word, it was considered correct. If he selected a symbol that did not correspond or failed to respond, it was considered incorrect. For the C–A equivalence relation, the experimenter provided an arbitrary symbol (C) and then asked, “What is this called?” If the participant tacted the symbol with the corresponding word, then a correct response was recorded. If the participant failed to respond or emitted a tact that did not correspond to the word, it was marked incorrect.

Training Training phases were conducted identical to baseline, except that praise and preferred edibles were provided for correct responses and prompts were provided for incorrect responses. A least-to-most prompting procedure was used during training, which consisted of representation of the instruction followed by a vocal prompt or gestural prompt and then a physical prompt. During A–B training, once scores reached 80% correct responding or above for three consecutive blocks, the experimenters probed for the symmetrical B–A relation. If the participant emitted 100% correct responding for the B–A probe, test probes for the B–C and C–B relations were conducted and the participant was advanced to the next phase. However, if he did not achieve 100% correct responding for the B–A symmetry probe, another trial block of A–B training followed by another B–A probe was conducted. This continued until the B–A relation reached 100% correct. The B–C phase was conducted in a similar fashion, with the C–B probe tested once correct responding reached 80% or above for three consecutive blocks. If the participant demonstrated 100% correct responding for the C–B probe, A–B and B–A test probes were conducted, and the final phase was implemented. If responding was not 100% correct for the B–C probe, another trial block of training was conducted. This continued until the C–B relation reached 100% correct.

Results and discussion

Figure 1 displays the results. Neither participant demonstrated mastery of any relations during baseline. During baseline, Josh demonstrated low levels of correct responding,

Fig. 1 Results of stimulus equivalence training across participants. Closed symbols represent trained relations. Open symbols represent test relations

with scores of 20%, 0%, 10%, 20%, 40%, and 40% for the A–B, B–A, B–C, C–B, A–C, and C–A relations, respectively. During A–B training, Josh reached 100% correct responding within three trial blocks. The B–A symmetry probe for Josh was at 100% correct within this phase. For the probes following A–B training, he demonstrated 100% correct responding for A–B and B–A probes and responded at baseline levels for all other probes. In B–C training, Josh reached mastery criteria within six trial blocks. Josh responded at 80% correct for the first C–B probe within this phase, so an additional B–C training block was conducted, after which all probes were at 100%. For the final set of probes, Josh responded at 100% correct for all relations, except the C–B and C–A relations, which were at 90% and 80%, respectively. Dustin's baseline scores averaged 10%, 5%, 30%, 20%, 30%, and 10% for the A–B, B–A, B–C, C–B, A–C, and C–A relations, respectively. Dustin reached mastery criteria within five trial blocks during A–B training. The B–A test probe occurred at 70% but reached 100% following four additional A–B training blocks. Probes conducted after A–B training were 100% correct for A–B and B–A probes, and responding occurred at baseline levels for all other probes. Dustin achieved mastery criteria for B–C training within seven trial blocks. The C–B test probe for Dustin in B–C training was at 100%. Dustin responded at 100%, 80%, 80%, and 100% for the A–B, B–A, B–C, and C–B relations, respectively. Responding for the A–C and C–A relations was lower, with scores of 80% and 70%, respectively.

The present study supports and extends previous findings by Bush (1993) and Toussaint and Tiger (2010) by teaching equivalence relations that incorporate tactile stimuli to children with autism and developmental delays. A potential limitation is that procedural fidelity was assessed for only a small percentage of sessions. Additionally, because arbitrary stimuli were used, the utility of targeted skills by the participants may be limited. Future research should replicate the study using nonarbitrary tactile stimuli, such as establishing equivalence classes of hard, soft, rough, smooth, and so on. Future research can also evaluate procedures to promote the emergence of the transitive and equivalence relations, should the participant not demonstrate mastery of emergent relations following training. The current study adds to a growing body of stimulus equivalence literature by demonstrating that equivalence-based procedures can promote emergent stimulus relations incorporating tactile stimuli with children with neurodevelopmental disorders.

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Compliance with ethical standards

Disclosure Second author receives small royalties from sales of the PEAK curriculum.

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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

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