7-2021

Evaluating Matrix Training to Teach Children With Autism to Tact Private Events

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by
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A thesis submitted to the College of Psychology and Liberal Arts of
Florida Institute of Technology
in partial fulfillment of the requirements
for the degree of
Master of Science
in
Applied Behavior Analysis and Organizational Behavior Management

Melbourne, Florida
July, 2021

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Abstract

Title: Evaluating Matrix Training to Teach Children With Autism to Tact Private Events

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The research on teaching tacts has primarily focus on visual stimuli, with relatively little attention to teaching tacts of nonvisual stimuli. The present study extended the literature to different types of tactile stimulation by teaching 2-component tacts of body-part sensation combinations in the presence of tactile stimulation. Multiple objects were used to produce the sensations to encourage generalization. Two additional exemplars for each sensation were probed for generalization to novel objects. The experimenters used matrix training, in which target responses were arranged in such a way as to facilitate recombinative generalization to untrained combinations. We arranged 6 body part targets and 6 sensation targets along two axes of a matrix, resulting in 36 total target responses. Of those targets, we directly trained 6 body part-sensation combinations and probed for recombinative generalization to the remaining 30 untrained relations. A multiple-probe design across matrices (Axe & Sainato, 2010) evaluated the effects of the intervention procedures on the directly trained and untrained responses. Participants were two young children between the ages of 2 and 4 with ASD. The results of one participant demonstrated acquisition of body part-sensation tacts in response to tactile stimulation in the absence of the visual stimuli. The results support a matrix training approach to acquisition of private event tacts. Findings and implications in regard to teaching children with autism are discussed.

Keywords: tacting, private events, autism, matrix training, recombinative generalization

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Acknowledgement

I would like to acknowledge my advisor and my doc buddy, Dr. Nicholson and Sandhya Rajagopal. Thank you for your help, feedback, and support throughout this process.

I would like to acknowledge my committee, Dr. Follette and Dr. Sloman. Thank you for your patience and support.

I would like to acknowledge Stephanie and Madisyn. Thank you for your collaboration throughout the study.

Lastly, I would like to acknowledge my participants. I wouldn’t have been able to do it without you!

Dedication

This thesis is dedicated to my parents, Tic and Shawna, for their unwavering love and support. For the past 30 years you've been there to encourage me when I didn't think I was good enough, give me the strength when I didn't think I had any left, and help me get back on track when I lost my way. I wouldn't be where I am today without you. Thanks for never giving up on me. Cheers guys, I did it!

This thesis is also dedicated to my sister and nephews, Savannah, Jude, and Brooks. Thanks for always believing in me and putting a smile on my face.

Evaluating Matrix Training to Teach Children With Autism to Tact Private Events

Autism spectrum disorder (ASD) is a developmental disability affecting about 1 in 54 children that can cause significant social, communication, and behavioral challenges (Centers for Disease Control and Prevention; [CDC], 2020). Some individuals with ASD have unusual reactions to the way things smell, taste, look, feel, or sound, and they may also have trouble talking about their feelings (CDC, 2020). Children with ASD need to be able to report these types of events, such as the location of stimulation on their own body (e.g., "That is rough on my hand!", "That is yucky on my foot") for a variety of reasons, including increased independence and safety. This skill may also expedite the emergence of related skills, like communicating painful stimulation (Rajagopal et al., 2021). Children with ASD must talk about painful stimulation, such as belly pain, to prompt caregivers to provide the appropriate care.

Tacting Private Events

Labeling stimuli, internal or external, is called "tacting" in Skinner's analysis of verbal behavior. The definition of a tact is a verbal response under the control of a nonverbal stimulus that produces a generalized conditioned reinforcer (Skinner, 1957, p. 81). Children typically learn tacts when they hear a caretaker label a public stimulus, they both experience at the same time. For example, a child looks back and forth between a cat and her parent, and the parent, seeing what the child is looking at, says, “cat.” The child is then later able to say the word "cat" when she sees a cat.

Tact training is a common language intervention for children with ASD. Operant reinforcement is considered the primary source responsible for establishing stimulus control of a tact, according to Skinner (1957), and thus a primary vehicle through which practitioners teach this critical skill. While much of the literature focuses on teaching tacts of visual stimuli (McHugh et al., 2011; Majdalany et al., 2014), Sundberg and Partington (1998) recommend teaching tacts of other sensory modalities, which would include events that are unable to be directly observed by a second person, such as bodily sensations. In addition to the problem of caretakers being unable to observe such events simultaneously, teaching this skill to children with ASD can be challenging due to common barriers experienced by this population, such as defective social reinforcement, weak stimulus control, and lack of response generalization (Bak et al., 2021).

In Behavior Analysis, stimuli or responses that occur inside an individual's body and are not observable to others are referred to as “private events.” (Skinner, 1945). People are notoriously imprecise when talking about their private events because, when their language was developing as children, their caretakers could only infer that a private event was occurring by attending to other clues. Herein lies the reason why people have difficulty tacting private events (Skinner 1957).

Skinner described several ways we learn to tact private events, albeit imperfectly. Although private events are inaccessible to others, they are often accompanied by publicly observable stimuli (i.e., "public accompaniments," "common properties") or behaviors (i.e., "collateral behaviors;") that are typically correlated with specific kinds of private events (Skinner, 1957, p. 131). Public accompaniments to pain may include events such as banging a knee against a table or a bee landing on an arm. Collateral behaviors may include rubbing the knee, limping, wincing, or crying. These public events facilitate a child learning how to talk about private events because the caretaker can, upon observing them, infer that the child is experiencing some private sensation. The caretaker may then say something like, "You hurt your leg" when they see their child fall off a bike. From this brief interaction, the child is more likely to later emit the vocal verbal tact, "My arm hurts" when experiencing a similar sensation in the future.

Research on Private Events in Behavior Analysis

Due to their unobservable nature, private events are challenging to study, quantify, and verify. Nevertheless, a few researchers have attempted to study this topic. Stocco et al. (2014) developed an experimental analog of private stimulation to investigate the variables that influence accurate and inaccurate reports of private events across three experiments with undergraduate students. The researchers attempted to teach tacts of private events using Wingdings symbols that only the participants could see but correlated with public images while manipulating variables such as contingencies of reinforcement, audience, and complexity. The materials were cards with a symbol printed on one side (representing the private event) and an image printed on the other side (representing the public accompaniment), along with a list of nonsense syllables. At the start of each session, the experimenters assigned each symbol to a nonsense syllable (representing a tact for the private event symbol). The symbols printed on one side of the card were considered analogous with private events because only the participant could see the symbols. The images on the other side of the card were analogous with public accompaniments because both the researcher and participant could see them. The dependent variable was the percentage of correct tacts of the symbols. Correct responses were consequated with points that were exchangeable for cash earnings at the end of the study. At the start of each session, the experimenter told the participants they would learn to label the symbols printed on the cards with a corresponding nonsense syllable. The cards would be delivered to the participants symbol-side down, and the symbols were only to be seen by them. Each session consisted of presenting each symbol ten times, resulting in 30 trials. After the participant labeled the picture card/symbol with a syllable, the experimenter would deliver reinforcement.

In Experiment 1, the experimenters varied the public-private correspondence (strong vs. weak) between the symbols and the pictures. The strong deck of cards had images of Monet's Lilies on them (1/3rd of the painting on each of the three targets being trained), with correspondence to the assigned symbols in eight out of ten cards. In contrast, the weak deck had images of Van Gogh's Wheat Field Under Threatening Skies, with correspondence in four out of ten cards. Two conditions were alternated in a reversal design: in the Public-Accompaniment-Based Reinforcement condition, points were delivered after the participant emitted the correct tact of the private symbol when highly correlated with the public image. In the Form-Based Reinforcement condition, the researchers selected one tact each from the strong and weak decks, which, when emitted by the participant, would result in a point, irrespective of whether the tact corresponded to either the private symbol or public image. The researchers selected this evaluation because it is unlikely there will be a perfect correlation for all public accompaniment to private event tacts, and the strength of the correlation is likely to vary in natural situations (Stocco et al., 2014). For example, if every time an individual were to touch an object with uneven edges and experience a rough tactile sensation, there would be a high correspondence between the public stimulus (uneven edges) and the private sensation (feeling of roughness). If, on the other hand, only some objects with uneven edges produced a rough feeling, there would be a weak correlation between the public accompaniment and private sensation, resulting in less accurate tacting. Stocco et al. (2014) demonstrated that accurate reports of private events are more likely to occur when accompanied by a highly correlated public accompaniment. The private symbols were less likely to evoke correct responses in the Form-Based Reinforcement condition, lending support to Skinner's assertion that reinforcement in the presence of a public accompaniment leads to tacting private events. This finding has implications for practitioners: a teaching procedure has a greater likelihood of success if the clinician can arrange reinforcement of tacts of private events when there is a high correlation with a public accompaniment.

Experiment 2 was similar to Experiment 1, except the participants experienced a varied and constant reinforcement schedule with both experimenters in the opposite order to examine audience control. The results of this experiment demonstrated that it is less likely that reports of private events will be consistent if reinforcement delivery from the verbal community varies.

In Experiment 3, the experimenters investigated how increasing the complexity of public accompaniments can impact the accuracy of private event tacts. The results demonstrated that the more complex the public accompaniments were, the less accurate the reported tacts were. The experimenters concealed the cards under the table for one participant because responding came under the control of the public accompaniment. The concealment of the visual stimuli was necessary because it is likely that tacting will come under the control of the public accompaniment, not the private event.

For example, an individual is experiencing a stomachache. The public accompaniment related to the stomachache could be a friend seeing them consume raw chicken, or doing a belly flop into a swimming pool. Another way the friend may be aware the individual is experiencing a stomachache is that the individual has to give a speech, and due to the individuals learning history with their friend, the individual knows they dislike public speaking. This complex public accompaniment may be unique to the individual, making it difficult for others to know they have a stomachache. It is important to consider learning history and potentially complex public accompaniment because every individual has a unique history of public accompaniments to private event tacts.

Stocco et al. (2014) hypothesized that verbal reports would come under the control of public accompaniments, which can be a desired outcome in some situations but not all. Accurate reports of private stimuli were most likely to occur when a high correlation between public accompaniments and the given private event occurred. These findings could help educate clinicians and parents to teach children to talk about private events and sensations.

This study yields results that demonstrate that providing reinforcement often, contingent on public accompaniments highly correlated with the same private event, the more likely an individual's tact is to come under proper stimulus control (Stocco et al., 2014). A limitation to this study the experimenters only used a limited number of stimuli to teach private event tacts when multiple antecedents may evoke the same tact. Concealing the visual stimuli for one participant resulted in more accurate private event tacting, which may support teaching private event tacts in the absence of public accompaniments to produce more accurate reporting.

In another study that aimed to expand the research on private events, researchers used discrete trial instruction (Smith, 2001) to teach three children with ASD, ages 5 to 6, to tact olfactory stimuli and test for generalization to novel stimuli (Dass et al., 2018). Discrete trial instruction is a procedure that involves breaking skills down into smaller discrete responses, teaching those until mastered, and increasing the complexity of the responses over time based on client progress. During each trial, the therapist delivers a cue, or “discriminative stimulus,” prompts the desired responses, fades prompts over trials, and consequates responses with reinforcement or error correction.

The discrimination of olfactory stimuli is related to the sense of smell, which is essential for safety reasons such as evacuating when one smells smoke or refraining from eating food that smells rotten (Dass et al., 2018). In this study, researchers taught four categories of scents (i.e., fruity, yummy, stinky, citrus) using three exemplars per scent (e.g., strawberry, watermelon, coconut). One exemplar for each type of scent (e.g., cherry) was reserved to probe for generalization. The researchers taught the participants to tact 20 scents by name (e.g., strawberry) using direct training and category (e.g., strawberry smells fruity) using instructive feedback. During the teaching sessions, an experimenter held an opaque glass bottle that contained the scent under the participant's nose for 5 s. The glass bottle was opaque to conceal the visual stimuli to ensure the tact was under the stimulus control of only the nonvisual stimulus (i.e., olfactory sensation). By the end of the study, all participants could correctly tact the olfactory stimuli and corresponding categories, and two of the three participants generalized tacts to untrained stimuli. Dass et al. (2018) was the first study to evaluate the effectiveness of discrete trial instruction to teach children to tact olfactory stimuli and demonstrate that multiple exemplar training procedures (Stokes & Baer, 1977) result in generalization for this olfactory sensation. Social validity measures gathered from the caregivers reported that they were satisfied with the procedures and willing to implement the procedures at home or school. A limitation to this study was that the researchers did not fade the verbal instruction to account for proper stimulus control. Responding may have come under the control of the verbal instruction (i.e., "What does this smell like?"). Dass et al. (2018) recommended teaching tacts in the absence of the verbal antecedent to promote generalization of tacts. It is important for individuals to tact olfactory sense in the absence of someone asking, “What does this smell like?” because many antecedents could produce the same tact. For example, an individual independently tacting the smell of a grill and the smell of smoke could promote safety skills. Sundberg and Partington (1998) recommend fading supplemental prompts for tacts quickly, so the response is controlled only by the relevant stimuli, the nonverbal stimulus.

Studies on Tactile Stimulation

Another type of private event is tactile sensation. Tacts for tactile sensations can be taught by an observer who verbally emits the tact in the presence of a public accompaniment that stimulates the learner and provides reinforcement when the learner repeats the tact. Recent studies in behavior analysis have begun exploring procedures to teach individuals with intellectual disabilities to tact tactile properties. As in Dass et al. (2018), concealment of visual stimuli is a critical feature of procedures to teach children with ASD to tact tactile stimulation to ensure responding is under the control of the tactile sensation itself and not what the stimuli look like (Belisle et al., 2018; Mullen et al., 2017; Rajagopal et al., 2021).

Mullen et al. (2017) taught stimulus equivalence relations between arbitrary auditory, tactile, and visual stimuli to two children with ASD. Six relations tested throughout the study were between arbitrary spoken words (e.g., “KAS," "TEP," "BOP," "SAL"), tactile stimuli (e.g., a feather, cotton ball, wooden block, sandpaper), and arbitrary visual symbols (e.g., wavy lines, star, spiral, zigzags). The experimenters used a nonconcurrent multiple baseline design across participants (Watson & Workman, 1981) to evaluate the effects of the intervention. The percentage of correct responses within a 10-trial block was the primary dependent variable. Sessions were conducted in a special education classroom at a table. The study consisted of four phases: baseline, arbitrary spoken words to tactile stimuli relation training, baseline, tactile stimuli to arbitrary visual symbol relation training, and baseline. The stimuli used included arbitrary visual symbols printed on a 5 x 5 cm piece of paper. The words and symbols used were arbitrary to ensure the participants had no prior learning history. The researchers used a paper bag to conceal the tactile stimuli (i.e., a feather, cotton ball, wooden block, and sandpaper) from the participants' sight to ensure tacts were only under the tactile property's stimulus control.

During training sessions, the experimenters used least-to-most prompting (e.g., vocal prompt, gestural prompt, physical prompt) to teach correct responding. When the comparison stimuli were arbitrary spoken words (e.g., "KAS," "TEP," "BOP," "SAL"), the experimenter would present the arbitrary word first, and then the participant would feel the tactile stimuli (e.g., a feather, cotton ball, wooden block, sandpaper) for 10 s in the paper bag. The experimenter would then ask, “Was that the same?” The participants' correct response was either a “yes” or “no” for the related stimuli. When the comparison stimuli were tactile (i.e., a feather, cotton ball, wooden block, and sandpaper), the participants' correct response was the selecting the corresponding arbitrary visual symbols (e.g., wavy lines, star, spiral, zigzags) out of an array of four symbols. The experimenters tested for stimulus equivalence of untrained relations by probing tactile stimuli to arbitrary spoken words and comparing arbitrary visual symbols to tactile stimuli. The results demonstrated that both participants responded correctly to both training stimuli relations and the untrained relations using multiple exemplar training. The authors recommended using non-arbitrary stimuli in future studies, such as the tactile sensations “soft” and “rough.”

Belisle et al. (2018) evaluated the effectiveness of a procedure to teach tact extensions of abstract tactile stimuli. A “tact extension” occurs when a tact is emitted in the presence of an untaught stimulus for the first time (Skinner, 1957). For example, if a child learns to tact “rough” in response to the tactile sensation produced by rubbing one's finger on Velcro and then says, “rough” the first time he feels sandpaper, the latter would be considered a tact extension. In this study, two adolescent males who used the Picture Exchange Communication System (PECS; Bondy & Frost, 2002) participated (Belisle et al., 2018). Kevin was a 16 year old with ASD, and Jason was a 14 year old with Down Syndrome. Belisle et al. (2018)

used least-to-most prompting within a discrete trial instruction format and alternated teaching and test trials, delivering reinforcers only during training trials. The researchers trained "wet" and "dry" tacts using a washcloth and a sponge, and "hard" and "soft" tacts using a plastic bone, marbles, a plush bone, and foam balls. This study utilized multiple exemplar training (Stokes & Baer, 1977), which involved presenting several examples of each teaching target to promote generalization. Test stimuli included water cups, a plastic and plush snake, a wooden block, and a makeup sponge. The stimuli were presented in a felt-lined stimulus box on all trials to prevent the participants from seeing the stimuli. The participants put their hands into one side of the box, and the other side opened to the experimenter, who was able to verify that the participant contacted the stimuli.

Belisle et al.'s (2018) procedures effectively brought tact extensions of abstract tactile properties under the proper stimulus control of the tactile sensations (i.e., abstraction; Skinner, 1957). Responding at mastery level to both training and test targets were maintained for two weeks after training. These results support the use of discrete trial training and multiple exemplar training to teach nonvocal individuals to emit tactile tacts under proper stimulus control. Both individuals demonstrated generalized responses to novel examples of wet, dry, hard, and soft stimuli. This study showed that the treatment procedures were effective; however, the authors only taught four sensations, and the stimulation only occurred to the participants' hands.

Rajagopal et al. (2021) extended the research on teaching tactile sensation tacting to other body parts using multiple-word utterances. Rajagopal et al. (2021) sought to teach three children with ASD to tact sensations (e.g., soft, prickly, rough, sticky) across their body parts (e.g., hand, elbow, leg, arm, back, knee, neck, tummy, head) in response to various objects producing the stimulation (e.g., feather boa, cotton ball, pinecone, spiky ball, fur, makeup brush). The targets were counter-balanced across participants. Generalization probes tested for the emergence of sensation tacts produced by novel objects, novel body parts, and novel sensations. A multiple baseline design across participants (Johnston & Pennypacker, 2009) was employed to evaluate the intervention package. The primary dependent variable was the percentage of correct independent sensation-body part tacts. Sessions took place in a private treatment room at a clinic specializing in behavioral services for children with ASD. During sessions, the participant was seated across from the experimenter at a table and in front of a research assistant. Two of the three participants put their heads through a foam board fixed to the top of a table, similar to Belisle et al. (2018) utilizing a felt-lined box to conceal stimuli from the participants' view. One participant closed his eyes because he told the experimenter he was afraid of the foam board. During each teaching session, the experimenter presented trials of nine sensation-body part tacts two times each, which resulted in 18 trials per session. The participants were seated across from the experimenter. A research assistant sat behind the participants to deliver the tactile stimulation. During each trial, the research assistant delivered 5 s of stimulation with the target object on the target body part, and the experimenter delivered vocal prompts, which were systematically faded using a constant time delay (Snell & Gast, 1981). Generalization probes to novel body parts, objects, and sensations were conducted during baseline and immediately after the participants' mastery of the teaching targets. All three participants demonstrated mastery of tactile tacts on multiple body parts in response to various stimuli used to produce the target sensation. All three participants responded to generalization probes to novel body parts and novel objects following teaching, demonstrating recombinative generalization. Presentation of novel objects that mimicked the sensation taught (i.e., multiple exemplar training) produced the highest levels of correct responding during generalization probes. However, none of the participants correctly responded to tactile stimulation from objects that produced novel sensations, consistent with a behavior analytic account of language acquisition. That is, if the participants never contacted a particular sensation during training, it is highly unlikely that they would be able to tact it.

The most common procedures used to teach tacts of private events are discrete trial instruction in combination with the concealment of the visual stimulus to account for accurate stimulus control (Belisle et al., 2018; Dass et al., 2018; Mullen et al., 2017; Rajagopal et al., 2021). Researchers have successfully used multiple exemplar training to teach individuals with ASD to tact olfactory and tactile stimuli. All researchers reported that using multiple exemplar training resulted in generalization to novel, untrained stimuli producing the same sensation (Belisle et al., 2018; Dass et al., 2018; Mullen et al., 2017; Rajagopal et al., 2021). Belisle et al. (2018) tested for generalization to five novel stimuli per participant, and Rajagopal et al. (2021) tested for generalization to six novel stimuli per participant. Rajagopal et al. (2021) recommended that future researchers can program for generalization to exponentially more targets by systematically arranging targets in such a way as to promote recombinative generalization to untaught stimuli, such as through the use of matrix training (Goldstein, 1980).

Matrix Training

One aspect of the literature on teaching others to tact private events is that all researchers included tests for generalization (Belisle et al., 2018; Dass et al., 2018; Rajagopal et al., 2021). Testing for generalization to novel environments, people, and stimuli is essential because it is a critical tenet of behavioral interventions that clinicians must produce outcomes that generalize to the natural environment and promote new skills without direct training (Baer et al., 1987).

Researchers have investigated procedures that specifically arrange for and induce recombinative generalization among learners outside of the private events literature, which produces exponential indirect learning.

“Recombinative generalization” refers to the phenomenon in which a learner can emit novel combinations of previously learned component behaviors (Goldstein, 1983, p. 280). For example, if a learner is taught to tact "Superman fly" and "Batman drive," they can tact "Superman drive" and "Batman flies" without any direct training. A commonly used procedure that promotes recombinative generalization is matrix training. Matrix training systematically arranges stimulus and response combinations to be presented during teaching to promote recombinative generalization. The target stimuli are arranged in a table (i.e., matrix) with the targets associated with one component of a response (e.g., “actors,” such as Superman and Batman) listed in the horizontal rows and the targets associated with the other component (e.g., “actions” such as fly and drive) listed in the vertical columns. One target is selected from each component to be taught as a combination (e.g., “Superman flies;” Kemmerer et al., 2021). Figure 1 displays an example of the matrix training arrangement.

Two standard training formats are diagonal training and overlap training (Curiel et al., 2020). Diagonal training consists of directly training the targets that intersect in the cells along the diagonal of the matrix and probing for recombinative generalization for the targets in all of the other cells. Overlap training consists of teaching two cells in each row along the diagonal in a "stairstep" configuration (Goldstein, 1983). Practitioners use evidence-based teaching strategies like most-to-least prompting or progressive time delay to teach directly trained cells (Curiel et al., 2020).

Three categories of skills that have been taught in the matrix training literature are language development, play skills, and sentence construction (e.g., spelling; Curiel et al., 2020). When embarking upon a matrix training intervention, practitioners should consider the learner’s skill level. Targeting skills already known to the client on both axes of the matrix (i.e., the rows and the columns) will likely produce quick acquisition, and diagonal training may be sufficient to produce longer utterances. Targeting unknown skills on both sides of the matrix may require overlap training (Curiel et al., 2016; Goldstein et al., 1987), at least for beginning learners.

Curiel et al. (2020) reviewed 12 studies published between 1999 and 2017 that evaluated matrix training with participants with ASD. Across all studies, the participants comprised two adults and one 2-year-old, but most were between the ages of 4 and 12-years-old. The authors found that matrix training is an effective instructional planning technique that has led to untrained response combinations in many studies, in areas such as tacting (Frampton et al., 2016), forming sentences (Kohler & Malott, 2014), and emitting multiword phrases (Pauwels et al., 2015).

More broadly, matrix training is effective in teaching skills such as play (Hatzenbuhler et al., 2019; MacManus et al., 2015; Wilson et al., 2017) and language (Frampton et al., 2016; Goldstein et al., 1987; Goldstein et al., 1989; Goldstein & Mousetis, 1989; Jimenez-Gomez et al., 2019; Karlan et al., 1982; Kohler et al., 2014; Mineo & Goldstein, 1990; Naoi et al., 2006; Neves et al., 2018), which are essential to young learners' development.

There are significant implications for practitioners in autism treatment because matrix training results in participants learning more than half of the targets in the matrix without direct teaching (Curiel et al., 2020). Matrix training can be used to arrange skills such as tacting and receptive identification that are recommended in commonly used curricula, such as the Verbal Behavior Milestones and Placement Program (VP-MAPP; Sundberg, 2008). For example, a practitioner can choose six verbs (e.g., jumping, flying, spinning) and six nouns (e.g., baby, cat, troll), resulting in 36 different target combinations. Using the matrix training organization, teaching six combinations (e.g., baby jumping, cat flying, troll spinning) appearing on the diagonal of the matrix can promote generalization to the other 30 untrained targets without direct teaching (Curiel et al., 2020). It is easy to incorporate these targets in tandem with programs already in place (e.g., social skills programs) and various environments (e.g., schools or clinics). Matrix training can be a practical approach to teaching tact or receptive identification target combinations for multiple concepts (e.g., shapes, nouns, verbs, prepositions) and novel-sense modalities, such as tactile or gustatory, in a highly efficient manner.

Curiel et al.'s (2020) systematic review was limited to matrix training research for individuals with ASD. It did not examine essential variables such as generalization outside of the matrix or the social validity of the procedures. Kemmerer et al. (2021) extended the previous systematic review to including those critical variables and outcomes for trained targets and maintenance. Their review analyzed 40 experiments published between 1987 and 2019 that included participants with no diagnosis, ASD, mental retardation, Down syndrome, cerebral palsy and deafness, attention-deficit/hyperactivity disorder, communication disorder, dyspraxia, Smith–Magenis syndrome, language delay, aphasia, and spastic quadriplegia. The participants were primarily early adolescents, then toddlers, late adolescents, adults, and teenagers. The most commonly used designs were multiple probe designs (Axe & Sainato, 2010; Curiel et al., 2016; Curiel et al., 2018; Dauphin et al., 2004; Frampton et al., 2016; Jimenez-Gomez et al., 2019; MacManus et al., 2015; Nigam et al., 2006; Pauwels et al., 2015; Remington et al., 1990) and multiple baseline designs (Curiel et al., 2020; Frampton et al., 2019; Goldstein et al., 1987; Goldstein & Mousetis, 1989; Hatzenbuhler et al., 2019; Mineo & Goldstein, 1990; Schneider et al., 1996). Kemmerer et al. (2021) reported that 30% of the experiments used all known stimuli for both vertical columns and horizontal rows (Frampton et al., 2019; Frampton et al., 2016; Kohler et al., 2014; Nigam et al., 2006; Remington et al., 1990; Schneider et al., 1996); 25% used all unknown stimuli (Axe & Sainato, 2010; Curiel et al., 2016; Goldstein et al., 1987; Pauwels et al., 2015); 25% did not specify, and 15% used a mix of both known and unknown stimuli. A majority of the experiments, 69%, used a combination of instructional methods to teach targets. The most common instructional methods were prompts (51%), error correction (36%), and reinforcement (33%).

The size of the matrices varied across experiments. There were a total of 18 different size combinations used; the most common arranged targets along the rows and columns in groups of three-by-three (18%), four-by-four (18%), and six-by-six (21%). More than half of the experiments used diagonal matrix training to teach the training targets (50%), and less than 35% used overlap training (Kemmerer et al., 2021). Only 10% of experiments reported an assessment of social validity, all resulting in positive outcomes, and over half of the experiments reviewed assessed maintenance, demonstrating positive outcomes (Kemmerer et al., 2021).

There were mainly positive outcomes reported by Kemmerer et al. (2021), in which all of the participants achieved mastery of the skills taught in the matrix and recombinative generalization targets. Frampton et al. (2016) used a three-by-three matrix to establish novel combination tacts of known nouns (e.g., duck, rabbit, pig) and known verbs (e.g., reading, painting, sitting) with five children with ASD. A multiple probe design across participants evaluated the effectiveness of the training. The researchers first trained three noun-verb combinations (e.g., "duck reading," "rabbit painting," "pig sitting") using diagonal training. The combination of nouns and verbs produced nine total targets ("duck painting," "duck sitting," "rabbit reading," "rabbit sitting," "pig reading," "pig painting." Four participants achieved mastery of 15 novel combinations by the end of the study. The fifth participant learned nine noun-verb combinations, which led to the emergence of 27 novel combinations.

Axe and Sainato (2010) demonstrated the effectiveness of matrix training by teaching four preschool children with ASD to follow instructions to perform an unknown action in response to an instruction involving an action toward a picture on a worksheet (e.g., "highlight the onion"). The six-by-six matrix consisted of six action targets along the vertical columns (e.g., underline, stamp, put an X on, highlight, put a triangle on, circle) and six object targets on the horizontal rows (e.g., pepper, deer, tape, onion, skateboard, stapler). The researchers conducted direct training of the combined target skills that appeared along the matrix's diagonal. Three of the four participants demonstrated proficient instruction-following and responded at 91% and above on untrained targets, demonstrating recombinative generalization by the end of the study.

Another study that evaluated the effects of matrix training with preschool children with ASD was Jimenez-Gomez et al. (2019). The researchers taught known noun-unknown verb combinations of play actions as both tacts and listener responses. A multiple-probe design across submatrices demonstrated the acquisition rate of targets directly taught and those not directly taught (i.e., recombinative generalization). The participants were required to perform play actions (e.g., when the researcher said, “Show me 'train crashing,'” the participant crashed a toy train into an object) or tact play actions performed by the researcher (e.g., when the researcher asked, “What is it doing?” the participant tacted, “train crashing") during teaching sessions. A six-by-six matrix with nouns down the rows and verbs along the columns determined teaching and generalization targets. Each matrix resulted in 36 noun-verb combinations. The researchers divided each matrix into two submatrices, each containing three diagonal targets, similar to other studies that successfully taught children with ASD using a matrix training approach (Axe & Sainato, 2010; Curiel et al., 2016). Each of the three participants learned two matrices, resulting in four submatrices per participant.

The Matrix 1 nouns were people, animals, and characters (e.g., baby, dog, Tigger), while the Matrix 2 nouns were vehicles (e.g., train, car, plane). Matrix 1 included the verb targets “walking,” “sleeping,” “sitting,” “jumping,” “waving,” “clapping,” and “dancing.” Matrix 2 included the verb targets “crashing," “falling,” “rolling,” “flying,” “spinning,” “hiding,” and “driving.” Only previously mastered target nouns were included in the study, and targeted verbs were all novel. Sessions consisted of five-trial blocks in which the diagonal targets were presented in varying orders. The experimenter conducted recombinative generalization probes (i.e., non-diagonal targets) once the participants mastered the trained targets. The researchers conducted probes for six novel targets in Submatrix A and 24 novel targets in Submatrix B. The results demonstrated that participants mastered new targets in fewer sessions in Matrix 2. Correct responses to the untrained targets varied across participants. The researchers provided additional training for the untrained targets that did not meet mastery criteria. Overall, following Submatrix A, correct responding increased across most subsequent submatrices for trained and untrained targets. The results from all three participants revealed matrix training to be effective and efficient at producing responses to untrained targets.

Further, the researchers reported that two participants spontaneously engaged in novel tact and listener responses in the natural environment. The successful outcomes of this study to produce spontaneous recombination of language, along with other matrix training studies that taught communication to children with ASD (Axe & Sainato, 2010; Curiel et al., 2016), demonstrate that matrix training arrangements are essential to providing more efficient, effective treatment. Further, matrix training should be applied across sense modalities, as previous studies have only included visual stimuli. The emergence of spontaneous tacts could lead to accurate self-reporting of private events, such as "scratchy foot," if the child were to step on something unpleasant.

Past research has laid the foundation for implementing successful matrix training procedures to produce generative outcomes in language and communication (Curiel et al., 2020; Kemmerer et al., 2021). Constructing a matrix that uses both unknown and known targets should be considered to improve acquisition and generalization (Kemmerer et al., 2021). The current research has not yet expanded to using matrix training to teach children with ASD to tact private events. The purpose of this study is to replicate and extend Rajagopal et al. (2021) to teach children with ASD to tact tactile sensations on various body parts, using matrix training to arrange the teaching and probe targets.

Methods

Participants

Two Caucasian children between the ages of 2 and 4 with an ASD diagnosis participated in the study. Participants were recruited from a local clinic in Florida that provides applied behavior analysis (ABA) services. The participants were required to demonstrate skills on a Level 2 for Linguistic behavior on the Verbal Behavior and Milestones and Placement Program (VB-MAPP; Sundberg, 2008). The participants were required to have a strong echoic repertoire and independently emit echoic responses to the experimenter's verbal prompts or an augmentative communication device. For the participants to meet inclusion criteria, they were required to emit a correct tact and listener response to six of their body parts.

At the start of the study, Wayne was 2 years and 6 months old. He communicated using one or two-word sentences when prompted. Wayne's' scores fell primarily in Level 2 of the VB-MAPP for the Mand, Tact, Listener, Match to Sample, Echoic, and Linguistic domains. Wayne's individualized treatment program goals included increasing independent tacts, imitating vocal words, responding to instructions, and play skills.

At the start of the study, Katie was 3 years and 11 months old. Katies' scores mainly fell in Level 2 of the VB-MAPP for the Mand, Tact, Match to Sample, Play, and Linguist domains. For the Listener and Echoic domains, Katie scored in Level 1. Katie communicated using one or two-word sentences. Her individualized treatment program goals included increasing independent tacts, imitating vocal sounds, responding to instructions, gross and fine motor skills.

We consulted with case managers to ensure potential participants fit the inclusion criteria for this study. Once potential participants were identified, the experimenter conducted an informed consent meeting with caregivers in vivo. The experimenter obtained informed consent from caregivers via written document.

Settings and Materials

All sessions took place in a private treatment room at a university-based clinic that provides ABA services in Florida. The environment was a quiet, distraction-free room where no other individuals entered during sessions (e.g., other children, caregivers). The room had a table, chairs, and materials box that included: : (a) a timer, (b) a binder containing data sheets (sample data sheets for Wayne see Appendix A), (c) a clipboard, (d) two pens, and (e) eye masks. The experimenters used a GoProHERO5 video camera to record sessions.

The stimuli associated with the target sensation tacts (e.g., stuffed animal, feathers, Velcro, nail file) was kept in an opaque box, out of sight from the participant. Each participant's caregiver had an opportunity to view every object used in the study and watch their child being stimulated. We allowed the caregivers to experience the same objects and sensations on their arms to feel what their child would experience. Caregivers approved all stimuli, sensations, and body parts taught during the study to avoid any potential that the stimulation would cause the participants any discomfort. The experimenters asked the participants to close their eyes or put on an eye mask during sessions. Identified stimuli used as reinforcers were also present.

Dependent Variables and Measurement

The primary dependent variable was the percentage of correct, independent (i.e., unprompted) responses to the trained and untrained body part-sensation tacts in each twelve 1 trial block. *Trained* refers to the diagonal target responses directly taught (i.e., shaded boxes in Figure 2). *Untrained* refers to the non-diagonal target responses not taught (i.e., white boxes in Figure 2).

The experimenter scored a correct response if the participant stated the stimulated body part on that trial and the type of sensation within 5 s without a verbal prompt (e.g., "neck feels soft," following the presentation of a stuffed animal rubbed on the neck). We scored a prompted response if the participant emitted a vocal response with point-to-point correspondence to the experimenter's verbal prompt within 5 s (e.g., saying "knee feels sticky " following the presentation of tape on the knee and the experiment's verbal prompt, "knee feels sticky). We scored an incorrect response if that participant did not initiate a response within 5 s, responded with a different body part than the one that was being stimulated (e.g., says “knee,” when the elbow was stimulated), saying the name of a different sensation than the one being presented (e.g., says “soft,” when a nail file was being gently rubbed on the skin), only emitted one component of the tact (e.g., says “foot” instead of “foot feels sticky”), or emitted any other non-target response (e.g., “I do not know”). The mastery criteria to move on to the next phase was 90% correct responding across three consecutive sessions.

The participants only were only required to say the name of the body part and sensation to be scored as correct (e.g., head soft), but we prompted an entire phrase or sentence that is grammatically correct (e.g., head feels soft). For Katie, the experimenters we added criteria for correct response articulation and vocal approximations. The operational definitions for the articulation of each target response was recorded by the experiment and only successful approximations were scored as correct. For example, when she would emit the word “foot” it often sounded like “oot”, or “smooth” sounded like “smoo”.

Interobserver Agreement and Treatment Integrity

All research assistants were trained and required to demonstrate procedures at 100% accuracy across two mock sessions before conducting sessions or collecting data with actual participants. The research assistants were graduate or undergraduate students working toward a degree in Behavior Analysis and required a minimum of a Registered Behavior Technician credential.

A second observer independently collected data for a minimum of 33% of sessions for each condition, in each tier. The data was scored from a video recording of the sessions. The primary experimenter compared the data obtained by both observers and scored an agreement or disagreement for each trial, using the trial-by-trial method (Cooper et al., 2020). The percentage of agreement between observers was calculated by dividing the number of trials in agreement by the total numbers of trials, then multiplied by 100.

In Tier 1, the mean agreement in baseline resulted in 100% for Wayne, and 100% for Katie. Mean agreement for recombinative generalization probes was 100% for Wayne, and 100% for Katie. Mean agreement for novel object stimuli probes was 100% for Wayne, and 100% for Katie. Mean agreement during the teaching phase was 100% for Wayne, and 91.66% (range; 91.66% to 100%) for Katie.

In Tier 2, the mean agreement in baseline resulted in 100% for Wayne, and 100% for Katie. Mean agreement for recombinative generalization probes was 100% for Wayne, and 100% for Katie. Mean agreement for novel object stimuli probes was 100% for Wayne, and 100% for Katie. Mean agreement during the teaching phase was 100% for Wayne, and 91.66% (range; 91.66% to 100%) for Katie.

In Tier 3, the mean agreement in baseline resulted in 100% for Wayne, and 91.66% (range; 91.66% to 100%) for Katie. Mean agreement for recombinative generalization probes were 100% for Wayne, and 100% for Katie. Mean agreement for novel object stimuli probes were 100% for Wayne, and 100% for Katie. Mean agreement during the teaching phase was 91.66% (range; 91.66% to 100%) for Katie.

The degree to which researchers implemented the intervention as planned resulted in the treatment integrity data measures (Gresham et al., 1993). A trained observer collected treatment integrity data on the experimenter's implementation of the steps involved in the procedures. We calculated the treatment integrity score by dividing the number of steps implemented correctly by the total number of steps on the checklist (Appendix B) and multiplied by 100.

In Tier 1, the treatment integrity scores for baseline sessions conducted with Wayne was 100%, and 100% for Katie. The treatment integrity scores for recombinative generalization probes conducted with Wayne was 100%, and 100% for Katie. The treatment integrity scores for novel object stimuli probes was 100% for Wayne, and 100% for Katie. The treatment integrity scores for the teaching sessions was 100% for Wayne, and 100% for Katie.

In Tier 2, the treatment integrity scores for baseline sessions conducted with Wayne was 100%, and 100% for Katie. The treatment integrity scores for recombinative generalization probes conducted with Wayne was 100%, and 100% for Katie. The treatment integrity scores for novel object stimuli probes was 100% for Wayne, and 100% for Katie. The treatment integrity scores for the teaching sessions was 100% for Wayne, and 100% for Katie.

In Tier 3, the treatment integrity scores for baseline sessions conducted with Wayne was 100%, and 100% for Katie. The treatment integrity scores for recombinative generalization probes conducted with Wayne was 100%, and 100%

for Katie. The treatment integrity scores for novel object stimuli probes was 100% for Wayne, and 100% for Katie. The treatment integrity scores for the teaching sessions for Katie was 100%.

Experimental Design

A multiple-probe design across submatrices (Axe & Sainato, 2010) evaluated the effectiveness of matrix training on tacts of the known body part and unknown sensation combinations among children with ASD. The multiple-probe design is a variation of the multiple baseline design, which demonstrated experimental control by behavior changing when, and only when, the independent variable was applied (Horner & Baer, 1978). Each tier had to meet the mastery criterion before the intervention began in the next tier; the experimenters introduced the teaching procedures in a staggered fashion according to this design. All initial baseline sessions occurred simultaneously, and additional baseline sessions before and after intervention began on other tiers.

This study consisted of a baseline phase, a teaching phase, and pre-and post-training generalization probes. Probes (white boxes in Figure 2) occurred during the baseline phase and after the participants met the mastery criterion for two sensation-body part tacts in each of the three submatrices (i.e., six body part-sensation tacts) to assess the participants' ability to tact untrained body part-sensation combinations.

Pre-Experimental Procedures

Body Part Probe

The experimenters delivered the verbal stimulus, "Show me your [body part]," or "What is that?" while pointing to the participant's body part. During the tact probes, the experimenters did not touch the participant's body part to avoid producing a sensation. During probe trials, the experimenters delivered praise for correct responses and ignored incorrect responses.

Wayne responded correctly to seven out of the 12 probes, and six body parts were selected for target assignments. Katie responded correctly to five probes as a listener and could tact two body parts. Since she could only identify and tact two of the same body parts, training was provided prior to the start of the study.

Target Assignment

Following probe trials, each participant's case manager and caregiver approved the selected six body parts and six sensation targets. Table 1 depicts the tactile stimuli used to produce stimulation for both participants. For Wayne, the body part targets included the neck, knee, tummy, foot, elbow, and back. For Katie, the body part targets included the head, hand, arm, foot, knee, and tummy. The targets and objects were counter-balanced across participants. Assigned on the horizontal rows in the matrix are the body part targets, and on the vertical columns are the sensations targets. Figure 2 depicts the matrix arrangement for Wayne, and Figure 3 depicts the matrix arrangement for Katie, each display which body part and sensation targets were trained (shaded cells along the diagonal of the matrix) versus those probed for the emergence of untrained relations (white cells).

The experimenters derived three submatrices from the main matrix. The bold lines in the matrix in Figure 2 and Figure 3 denote the submatrices. We directly taught two targets from each submatrix, one set at a time. In other words, the first two combinations taught in Tier 1 of the multiple probe design occurred first. The second two combinations taught in Tier 2 occurred next, and the last two combinations taught in Tier 3 occurred last. For example, for Wayne Submatrix 1 included two trained targets (i.e., neck feels soft, knee feels sticky) and two untrained targets (i.e., neck feels sticky, knee feels soft). Submatrix 2 included two trained targets (i.e., tummy feels smooth, foot feels rough) and 10 untrained targets (i.e., tummy feels soft, foot feels soft, tummy feels sticky, foot feel sticky, neck feels smooth, knee feels smooth, foot feels smooth, neck feels rough, knee feels rough, tummy feels rough). Submatrix 3 included two trained targets (i.e., elbow feels dry, back feel wet) and 18 untrained targets (i.e., neck feels dry, knee fees dry, tummy feels dry, foot feels dry, back feels dry, neck feels wet, knee feels wet, tummy feels wet, foot feels wet, elbow feels wet, elbow feels soft, back feels soft, elbow feels sticky, back feels sticky, elbow feels smooth, back feels smooth, elbow feels rough, back feels rough).

Procedures

Reinforcer Identification

The experimenters identified reinforcers for each participant using a free-operant (Roane et al., 1998), or a three-session multiple-stimulus-without-replacement (MSWO; Conine et al., 2021) preference assessment. The free-operant preference assessment occurred at the beginning of each day sessions were conducted to evaluate frequently changing preferences and to identify a variety of reinforcers. The free-operant preference assessment occurred with both participants to avoid the potential of problem behavior associated with the removal or withdrawal of preferred stimuli. Additionally, the three-session MSWO was conducted to identify the single highest-preferred stimulus, using edibles primarily, that may be used as a reinforcer for discrete trial instruction (Conine et al., 2021). The experimenters identified items for the preference assessment by asking caregivers for suggestions for preferred items.

When conducting a free-operant preference assessment, the experimenters allowed the participant noncontingent access to a random array of stimuli (e.g., building blocks, dolls) they could interact with for a 5-min period. During this time, the stimuli were not withdrawn or withheld. The experimenters recorded the duration the participant interacted with each item and the frequency of approaches or interactions to stimuli. The items selected for use in the subsequent experimental sessions for that appointment were those with the longest duration of interaction or most frequent approaches.

When conducting a three-session MSWO preference assessment, the experimenters arranged items in a semi-circle, equal distance from each other in front of the participant. The experimenters instructed the participant to choose one item and allowed the participant to interact with the item for 30 s. The experimenters rearranged the remaining items without replacing the previously chosen item and repeated the procedure until all items were selected. The MSWO consisted of three sessions. The participant’s top two items were delivered contingent on correct responses during teaching sessions or appropriate attending behaviors during probe sessions.

Preferred items were available during 1 min breaks. For Wayne, preferred items usually included iPad games or songs, toys such as dinosaurs, or edibles such as popsicles, goldfish, and radians. For Katie, preferred items included play-doh, stickers, and edibles such as mini M&M's and goldfish.

Session Description

Three to nine 12 trial session blocks were conducted per day, three to five days per week. Discrete trials instruction was the primary teaching method.

At the start of each session, the experimenter delivered the instruction, “You are going to feel something somewhere on your body. When you do, tell me what you feel." In order to prevent the verbal instruction from establishing antecedent control over the response, delivery of the instruction occurred only at the onset of each session rather than before each trial. The goal was for the participant to spontaneously tact the body part-sensation in the absence of someone asking them a question, such as "What do you feel?" The sensation itself should become the discriminative stimulus for responding so that the participant will then be more likely to tact these sensations in the future spontaneously.

Throughout all conditions, the experimenters sat at the table either beside or behind the participant. The participant either closed their eyes or placed an eye mask over their eyes to obstruct their own view of the stimulus producing the sensation. At the onset of each trial, the experimenter provided 5 s of stimulation with the predetermined item by lightly rubbing it on the designated body part of that trial. The stimulus was applied to the participants' skin lightly to avoid any discomfort. If the participant exhibited any signs of distress (e.g., crying, whining) or mands to stop, the experimenter immediately discontinued the session and consulted the caregiver.

Baseline

During baseline sessions, the experimenters did not provide prompts or deliver consequences for responses, correct or incorrect. The experimenters delivered praise or tangibles an average of every three trials for appropriate attending behaviors.

The experimenters presented trials of two body-part sensation combination tacts six times each, resulting in 12 trials per session during teaching sessions. Stimuli were presented two times each, with three exemplars (e.g., stuffed animal, feathers, faux fur) used to produce each sensation (e.g., soft). The stimuli used to produce the tactile sensation alternated each trial. For example, one trial consisted of the experimenters brushing the participants' neck with a stuffed animal for the "neck feels soft" target; the subsequent trial then included a piece of tape placed on the knee for the "knee feels sticky" target; the subsequent trial then required the experimenter to rub feathers on the participants neck for the "neck feels soft" target and so on until all 12 trials were conducted. The opportunity to tact "neck feels soft" was presented six times in a session with a stuffed animal producing the soft sensation two; feathers producing the soft sensation twice, and a faux fur producing the soft sensation twice. The opportunity to tact "knee feels sticky" was presented six times using the tape to produce the sensation twice, a post-it note to produce the sensation twice, and the lint roller to produce the sensation twice. The order of the targets was predetermined and randomly distributed across the session.

Teaching

Upon the presentation of the tactile stimulation on the participant's skin (e.g., feather on the arm), the experimenters immediately (0-s delay) provided an echoic prompt for the tact (e.g., "arm feels soft"). When the participant echoed the response, the experimenters delivered praise and a reinforcer (e.g., high five, edible). If the participant emitted an incorrect response, the experimenters removed and represented the tactile stimulation for 5 s. Re-presentation of the echoic prompt occurred every 2 s until the child remitted a correct response. Upon emitting a correct response during error correction, the experimenters delivered a neutral consequence (e.g., "That is right.")

Prompts were faded using a constant time delay procedure (Snell & Gast, 1981). After the first teaching session, the echoic prompt was delayed 5 s. When the child emitted an independent response, the experimenters delivered a reinforcer and high-quality praise. When the child emitted a correct, prompted response, the experimenters provided neutral praise (e.g., "Good job"). When the child emitted an incorrect response or did not respond, the experimenters represented the tactile sensation for 5s and provided the echoic prompt every 2 s until the child emitted a correct response, followed by a neutral consequence.

Both Wayne and Katie required modification during the teaching phase. In Tier 2, Wayne was consistently erring on trials involving rough stimuli. We decreased the prompt delay to 0 s for one session. During the subsequent four sessions, he consistently erred on trials involving rough stimuli; accordingly, we provided a 0 s prompt for rough stimuli. For Katie, a 3-s prompt was provided after two sessions at a 0 s prompt. The mastery criteria to move on to a 5-s prompt was 80% correct responding for one session.

Recombinative Generalization Probes

The experimenters probed for recombinative generalization through probes of untrained relations from the matrix during the initial baseline phase and following mastery of each submatrix's trained targets. The generalization procedures were identical to those in baseline. For example, if "head feels soft" was directly taught with a stuffed animal, feathers, and faux fur, then "soft" was tested on the hand for "hand feels soft" with a stuffed animal, feathers, and faux fur. Each body part-sensation target was presented once for each stimulus per session. Thus, Tier 1 contained six trials, Tier 2 contained 30 trials, and Tier 3 contained 54 trials.

Novel Stimuli Probes

The experimenters tested for generalization to novel objects (i.e., paintbrush, blanket, lollipop, sticky hand, moisturizer applicator, Lego, dish sponge, sandpaper, paper towel, makeup brush, wet paper towel, wet makeup brush) using two additional stimuli for each trained sensation. Probes were conducted before baseline and following mastery of the directly taught targets used the same procedures described in baseline. If the child learned "sticky" in response to tape, a post-it note, and a lint roller, two novel exemplars to test for generalization were a lollipop and sticky hand. Each target was presented two times per session, with two exposures to each novel stimuli. Each novel object probe consisted of eight trials.

Maintenance

The experimenters will probe for maintenance of the trained and untrained responses (i.e., 36 targets) two-four weeks following the study's conclusion. The maintenance probe procedures will be identical to those in baseline.

Social Validity

After the study concludes, the experimenters will collect social validity measures from the participants' caregivers and the participants themselves. The experimenters will explain the procedures and general outcomes of the study in a debrief meeting. The participants' caregivers will be asked to complete a questionnaire and rate several statements regarding the study's procedures using a 7-point Likert scale (Appendix C). The experimenters will ask the participants additional questions (Appendix D) to assess social validity (Rajagopal, 2021) (e.g., Did you like this research? Was research fun? Will you do research with us again?).

COVID-19 Safety Precautions

We took the necessary precautions recommended by the Centers for Disease Control and Prevention for protection against COVID-19 (CDC, 2020). The experimenters and research assistances who were not vaccinated were required to wear a mask throughout the study. The room and any used toys were thoroughly cleaned with disinfectant before and after each session to reduce the risk of spreading the disease. Before each session, the experimenters, research assistants, and the participants' caregivers took their temperatures to ensure they were not running a fever and filled out a questionnaire to report any symptoms. If unexplained symptoms or fever over 100.4 were present, the experimenters postponed the session until all individuals were symptom-free.

Results

Data have not yet been complete due to the COVID-19 pandemic. Data collection is ongoing. The following reports the results obtained thus far.

Wayne

Figure 4 depicts the percentage of correct body part-sensation tacts for Wayne. Maintenance probes for correct responding to body part-sensation tacts will be conducted two-four weeks following the conclusion of the study.

Submatrix 1

The two trained targets in Tier 1 were “neck feels soft” and “knee feels sticky”. Wayne did not emit any correct responses to the trained body part-sensation tacts during baseline. Wayne did not emit any correct responses during the untrained, recombinative generalization probes or novel object probes. During the teaching phase, Wayne reached mastery criteria for body part-sensation tacts in six sessions. Wayne emitted correct responses to novel object probes during 100% of trials. Wayne emitted correct responses to untrained, recombinative generalization probes during 100% of trials.

Submatrix 2

The two trained targets in Tier 2 were “tummy feels smooth” and “foot feels rough”. Wayne did not emit any correct responses to the trained body part-sensation tacts during baseline. Wayne did not emit any correct responses during the untrained, recombinative generalization probes or novel object probes.

Following the initial 0-s prompt, correct responding remained at 33.3% for three sessions. Accordingly, we decreased to a 0-s prompt for one session. Once the 5-s prompt was re-introduced, correct responding remained low and at a decreasing trend. A 0-s prompt was implemented for "rough" targets for three sessions.

Submatrix 3

The two trained targets in Tier 3 were “elbow feels dry” and “back feels wet”. Wayne did not emit any correct responses to the trained body part-sensation tacts during baseline. Wayne did not emit any correct responses during the untrained, recombinative generalization probes or novel object probes.

Katie

Figure 5 depicts the percentage of correct body part-sensation tacts for Katie. Maintenance probes for correct responding to body part-sensation tacts will be conducted two-four weeks following the conclusion of the study

Submatrix 1

The two trained targets in Tier 1 were “head feels soft” and “hand feels sticky”. Katie did not emit any correct responses to the trained body part-sensation tacts during baseline. Katie did not emit any correct responses during the untrained, recombinative generalization probes or novel object probes. During the teaching phase, Katie reached mastery criteria for body part-sensation tacts in 10 sessions. Correct responding was low when the 5 s prompt delay was implemented following one sessions with a 0 s prompt delay; accordingly, we implemented a 3 s prompt delay. During the 3-s prompt delay, correct responding increased to meet mastery criteria in four sessions. Katie emitted correct responses to novel object probes (eight trials total) during 87.5% of trials. Katie emitted correct responses to untrained, recombinative generalization probes (six trials total) during 89.3% of trials.

Submatrix 2

The two trained targets in Tier 2 were “arm fees smooth” and “foot feels rough”. Katie did not emit any correct responses to the trained body part-sensation tacts during baseline. Katie did not emit any correct responses during the untrained, recombinative generalization probes or novel object probes. During the teaching phase, Katie reached mastery criteria for body part-sensation tacts in nine sessions. Katie emitted correct responses to novel object probes during 87.5% of trials. Katie emitted correct responses to untrained, recombinative generalization probes (30 trials total) during 46.66% of trials.

Submatrix 3

The two trained targets in Tier 3 were “knee feels dry” and “tummy feels wet”. Katie did not emit any correct responses to the trained body part-sensation tacts during baseline. Katie did not emit any correct responses during the untrained, recombinative generalization probes or novel object probes. Following two sessions with a 0-s prompt, correct responding was at 41.67% followed by two sessions where correct responding remained at 75% of trials. Correct responding in the next session dropped to 66.67%, followed by two sessions at 91.67%. Katies correct responding in the subsequent session was at 100% for trained targets. Katie emitted correct responses to novel object probes during 75% of trials.

Discussion

The prior research on teaching tacts has primarily focused on visual stimuli. This study aimed to extend the literature on teaching tacts of nonvisual stimuli to children with ASD. Two children were taught two-component tacts of body-part sensation combinations in the presence of tactile stimulation. Various objects were used to produce each sensation to encourage generalization. Two additional objects were used to probe for generalization to novel stimuli. As recommended by previous researchers (Belisle et al., 2019), we used multiple exemplar target arrangements during teaching, which may positively affect the generalization probes in this study once further data are collected. Although we have not finished data collection for all participants, Katie's results suggest that the procedures effectively taught two-component tacts under the correct stimulus control: tactile sensation rather than visual aspects of the stimuli.

We arranged six body part targets and six sensation targets along two axes of a matrix, resulting in 36 total target responses. Six targets were directly trained, and 30 targets were probed for recombinative generalization to untrained target responses. Katie's results demonstrated quick acquisition of tacts, sustained learning, and generalization to novel objects and untrained body-part tact combinations. This study aims to extend the literature on the matrix training approach to producing recombinative generalization of tacting (Frampton et al., 2016; Jimenez-Gomez et al., 2019; Karlan et al., 1982; Kohler et al., 2014; Langton et al., 2020; Light et al., 1990; Nigam et al., 2006; Pauwels et al., 2015; Remington et al., 1990). This study extended the prior research on matrix training by replicating and extending Rajagopal et al. (2021) by evaluating whether children with ASD can learn to tact private events related to body part sensations.

Rajagopal et al. (2021) provided sensation training during the pre-experimental procedures to determine whether their participants were able to discriminate if a tactile sensation was present versus absent. Furthermore, the sensation training evaluated whether the stimulation was unpleasant or aversive for any participants. We did not find it necessary to conduct these preassessment steps through consultation with the caregivers and case managers. Both caregivers and case managers approved all stimuli that were used throughout the study and sensation targets. During the initial baseline sessions, the participants were exposed to all body part-sensation targets and stimuli. If the participants displayed any discomfort or asked to stop at any time throughout the study, we immediately terminated sessions.

During baseline sessions, the participants were introduced to the eye masks and stimuli used to produce sensations. The experimenter modeled how to correctly wear the eye mask over their eyes and cover their eyes with their hands. Wayne typically put his hands over his eyes or put his head down on the table when he was asked to close his eyes. Katie chose to wear the eye masks or cover her eyes with her hands. Both participants would sometimes open or uncover their eyes when stimulation began orienting their hands and gaze to the stimulated area. Katie would often engage in "peek-a-boo," where she would put her hands over her eyes, quickly put her hands down, and say "peek-a-boo." When the participants failed to keep their eyes closed, the experimenter would then gently hold an eye mask in front of their eyes to block their view. Throughout the session, the experimenter delivered praise for appropriately covering or shutting their eyes.

In the past, the use of facial screens and blindfolds have been used as a punisher to reduce self-injurious behaviors (Winton et al., 1984), mouthing (Horton, 1987), and stereotypic screaming (Dick & Jackson, 1983) in children with autism. We took precautions to ensure the eye masks or visual blocking was not aversive to the participants. During the baseline session, the participants were allowed to interact with the eye masks to get familiar with them. At the beginning of sessions, we would ask if they wanted to wear an eye mask or close their eyes. If they refused, pushed the eye masks away, or engaged in problem behavior, we would terminate the session. The participants were not required to keep their eyes closed or wear the eye mask for the entire duration of the session. We only required the eye mask to cover their eyes or for them to cover their own eyes during the 5 s of stimulation or until a response was emitted upon stimulation during sessions.

Both participants would often shake (e.g., shake arm), touch, or orient their gaze at the stimulated body part immediately upon stimulation and after the stimulation had ceased. The experimenter ensured they could not see the stimuli producing the stimulation to account for accurate stimulus control. Following the initial 0-s prompts for each of the trained targets, the experimenter noted their vocal approximations for the target responses. For example, Katie would emit "ead sopt" in response to the echoic "head feels soft" when a stuffed animal was rubbed on her head. Operational definitions of vocal approximations of target responses were added for Katie to ensure the experimenters were consistently consequating the same responses appropriately.

We used a constant time delay procedure for fade prompts for target responses during teaching but needed to make modifications for both participants. For Katie, we initially prompted one session with a 0-s prompt delay. Correct responding was low following the single session; we then implemented a 3-s prompt delay followed by a 5-s prompt delay. The criteria to move to the subsequent prompt delay were one session at 80% or higher correct responding. The prompt delay modification produced correct responding in all subsequent sessions.

In Tier 1 for Wayne, we implemented a 0-s prompt delay for one session, then faded to a 5-s prompt delay which produced increasingly more frequent correct responses in the subsequent sessions. In Tier 2, we implemented a 0-s prompt for one session; when we attempted to fade to a 5-s prompt delay, correct responding stayed consistent for three sessions. After analyzing the raw data, no specific targets were identified as problematic. Accordingly, we implemented a 0-s prompt for all targets. In the next session, Wayne correctly responded to 58.33% of targets, followed by two sessions of correct responding for 50% of trials. In the following session, Wayne's correct responding decreased to 25% of trials. We identified that Wayne was consistently erring on the target body part "foot" and sensation "rough." We implemented a 0 s prompt for the "foot feels rough" targets and 5 s prompt for the "tummy feels smooth" targets for one session. Correct responding did not increase in the following session. We reimplemented the 0 s prompt for the next two sessions for the "foot feels rough" targets and 5 s prompt for "tummy feels smooth" targets. We then faded to a 5 s prompt for all targets in the following session, which corrected 50% of trials. Wayne would emit the verbal response "foot feels rough" before any stimulation had occurred during this session. This could be due to thinning the schedule of reinforcement too quickly, whereas he is emitting the last reinforced response, or responding may have come under the wrong stimulus control, like closing his eyes. Wayne may find simulation on his foot aversive which is producing incorrect responding and evoking escape behavior. A possible solution may be to stimulate a different part of the foot, like the top of the foot or the ankle. If correct responding does not increase, the experiments will look to targeting a different body part altogether.

The experimenters conducted sessions with both participants in the morning and afternoons during their scheduled therapy. We further analyzed the problem behavior data by tiers and time of day. In Tier 1, when sessions were conducted in the morning, no problem behavior occurred in any session; when sessions were conducted in the afternoon, problem behavior occurred during 5 sessions. In Tier 2, when sessions were conducted in the morning, problem behavior occurred during one session, and when sessions occurred in the afternoon, problem behavior occurred during seven sessions. In Tier 3 so far, when sessions were conducted in the morning, no problem behavior occurred, and in the afternoon, problem behavior occurred during three sessions. For Wayne, the experimenters saw an increase in problem behavior during the teaching phase in Tier 2, where we had to terminate several sessions. Wayne's problem behavior includes negative vocalizations, aggression, noncompliance, flopping, and elopement from the table.

When we saw an increase in problem behavior and incorrect responding, we took steps to ensure the produces were not aversive and that we were providing enough reinforcement. We may not have identified Wayne's highest reinforcers and problem behavior may have been maintained by escape from the table, resulting in more frequent elopement and noncompliance. In addition to conducting preference assessments before sessions, we consulted with the case manager to ensure we were identifying effective reinforcers. In the afternoons after Wayne has been outside, we would use popsicles during sessions. We identified iPad games and songs that increased appropriate sitting and responding.

Katie did not engage in any whining, crying, or negative vocalizations in response to any tactile stimulation. Katie engaged in a few instances of escape behaviors, such as going under the table or manding "no". The experimenter would then terminate sessions. Katie often worked for play-doh, stickers, and edibles.

The participants will be provided a social validity survey (Rajagopal, 2021) to assess the acceptability of the procedures in this study. Specifically, questions like, "Did you like research?" and "Did anything in this research hurt?" could provide information about the participants' perception of the research. Throughout the study, the experimenter ended sessions by saying, "Thank you for being a part of this research!" After the study, the experimenter will read the questions to the participants since the participants are unable to read. The survey results may provide insight into whether children with ASD and limited communication can respond to questions about research and their perception of enjoyment or pain.

Limitations

The primary limitation of this study is the incomplete data sets. The COVID-19 pandemic was a barrier for completing data collection. Additional limitations may become apparent as more data are collected. Wayne's data is for Tier 2, Tier 3, and maintenance probes for all tiers are incomplete and does not demonstrate experimental control. The conclusions derived from Wayne's data are tentative and hypothetical. While we did see changes in Tier 1, we have not replicated our data to support the notion that we will see the same changes in Tier 2 and Tier 3. Katie's data for baseline and teaching phases in all tiers are complete. Novel object probes and untrained probes have been conducted in Tier 1 and Tier

2. Novel object probes have been conducted in Tier 3. Maintenance probes have yet to be conducted in all tiers and the untrained, recombinative generalization probe in Tier 3.

This study was designed and implemented during the primary experimenters' graduate thesis course. Due to the time constraints of the program, data collection had not been completed in its entirety. We intend to finish data collection with both participants with the integrity with which it began, and maintenance probes of trained and untrained targets will be conducted following the study's conclusion.

A possible limitation of the current study was that the environment in which the sessions were conducted and the experimental procedures that were used were highly contrived. The environment was a very quiet, sterile treatment room, which is not consistent with a more natural environment, like a classroom or playground. The participants were instructed to close their eyes or wear an eye mask to obstruct their view. These antecedent stimuli could come to control the private event tact. For example, the instruction to close eyes or the experimenter put the eye mask on the participant could come to multiply control the tact, whereas the tact will not generalize elsewhere. It is essential to establish proper stimulus control of the private event tact (i.e., the sensation) to increase the likelihood that the participant will emit the sensation tact in the future.

Another possible limitation to the study was using the eye mask and relying on the participants to close their eyes. To ensure body part-sensation tacts were under the tactile property's stimulus control, the participants' view of their body and the stimulus had to be blocked. It was challenging for the experimenter during some sessions to ensure the target body part was being stimulated, the target stimulus was being used, and the participant could not see. If the participant was able to see the stimulus, it is likely that the tact will come under the control of the public accompaniment, not the private event. This could be a threat to internal validity.

Before the study began, a preassessment for responding to tactile stimuli was not conducted. This might be a limitation to this study. Individuals perceive tactile stimulation and sensations in varying degrees. In Tier 2 for Wayne, he erred following immediate 0-s prompt delays and required multiple teaching sessions for the "foot feels rough" target. Wayne would repeat the previously prompted response or emit some other vocalizations simultaneously with the verbal prompt. Wayne would emit some vocalization during some trials before the stimulation on his foot would occur. The lack of attending to the sensations on his foot could be due to a lack of sensation in the foot or other possible confounds. A possible confound may be that the stimuli used to produce the sensation were not salient. Since the sensation is a private event, we must confirm that the participant perceives the stimuli we are using. In addition, we must continually evaluate the stimulation is not producing an aversive.

Goldstein (1983a) recommended training on more than the diagonal targets when the individual components are unknown; this could be a possible confound to the study because one side of the matrix must be unknown by the participants (i.e., sensation component). The participants in this study were young, their language skills were limited, and their articulation was difficult to understand at times during the acquisition of new words. Targeting language that is already in their repertoire could produce faster acquisition of the target responses.

Future Research

Future research should teach individuals with ASD to tact other private events, such as painful stimulation. One way to teach tacts of pain without actually exposing an individual to a painful stimulation would be to incorporate MET when teaching sensations such as prickly or hot. Using prickly objects such as pinecones and spikey balls to produce a prickly sensation, or a heating pad and a warm thermos to produce a hot sensation resemble sensations one might experience if they have a sore throat, rash, or fever. The generality of the procedures to other settings, such as a medical office, and populations, such as children that speak other languages.

While current research on teaching private event tacts have been successful in using concealment of visual stimuli to ensure accurate stimulus control (Belisle et al., 2018; Dass et al., 2018; Mullen et al., 2017; Rajagopal et al., 2021), the procedures are often unnatural (e.g., a paper bag, opaque bottle). Future research should explore teaching sensation tacts in a more naturalist environment while still maintaining the privacy of the public event. A possible solution may be to provide caregiver training on teaching tacts of sense modalities such as auditory, gustatory, and olfactory that occur in the individuals' regular schedule and environment (e.g., hearing an alarm clock, stomachache after eating ice cream, or the smell of smoke). Future researchers should also continue to explore ways to concealing visual stimuli when teaching private event tacts.

This study used eye masks or having the participants cover their eyes to conceal the visual stimuli to teach private event tacts. Rajagopal et al. (2021) used a large foam board attached to a table with an opening for the participants to put their heads through, and Dass et al. (2018) used opaque bottles that contained scents which did not require eye coverings for their participants. Other studies used paper bags (Mullen et al., 2017) and stimulus boxes (Belisle et al., 2018) as alternatives to eye coverings. Future researchers should explore alternatives that may be less intrusive than eye coverings.

The use of matrix training has been successfully implemented to produce generative outcomes in language and communication in prior research (Axe & Sainato, 2010; Curiel et al., 2020; Kemmerer et al., 2021). The two standard training formats are diagonal training and overlap training using progressive time delay to teach trained cells (Curiel et al., 2020). While we did see the acquisition of new two-component responses utilizing this method, we recommend that future researchers evaluate which teaching method would be most beneficial to the participant, keeping their current skill level in mind.

Implications

Children with ASD often have difficulties communicating, especially about private events. Teaching young children to tact tactile stimulation when they experience it in the absence of a public accompaniment or collateral behaviors can improve verbal behavior. This study describes procedures that promote generative learning. This study also supports Skinner's (1957) claim that individuals can learn to tact private events through public accompaniments and the verbal community modeling the tact simultaneously.

The current study has clinical implications for arranging targets and designing instruction for language skills. If an individual demonstrated recombinative generalization after diagonal training with both known horizontal and vertical components, more complex targets could be introduced. If an individual cannot demonstrate recombinative generalization following diagonal training, remedial training sessions or modifications to the procedure may be required (Kemmerer et al., 2021). Manipulation to strategies within matrix training can be individualized to produce the most effective treatment. A manipulation might be the training layout. Diagonal training only directly trains the cells along the diagonal of the matrix. In a 6 x 6 matrix, only six cells are trained, and 30 cells are probed for recombinative generalization. Using an overlap training approach, two cells in each row are directly trained, so the learner comes into contact with 11 cells that are directly trained and 25 cells that are probed for recombinative generalization (Goldstein, 1983). Selecting targets for tacting or receptive identification using known stimuli, unknown stimuli, or a combination of both can be arranged to teach combinations of concepts, such as colors, shapes, animals, nouns, verbs, prepositions (Frampton et al., 2016; Curiel et al., 2020; Jimenez-Gomez et al., 2019).

Using matrix training to systematically arrange target stimuli and response combinations, in conjunction with MET, discrete trial instruction, and concealment of visual stimuli, produced successful outcomes in teaching tacts of private events to children with ASD. These strategies can inform future practitioners of effective methods for promoting communication, independence, and safety in a clinical setting.

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Figure 1

Actor-Action Matrix

	Fly	Drive
Superman	Train	
Batman		Train

Note: This is an example of the matrix training arrangement. The targets "Superman fly" and "Batman drive" would be directly taught. The targets "Superman drive" and "Batman fly" would be tested for recombinative generalization.

Figure 2

Body Part-Sensation Matrix for Wayne

	Soft	Sticky	Smooth	Rough	Dry	Wet
Neck	Train					
Knee	Submatrix 1	Train				
Tummy			Train			
Foot	Submatrix 2			Train		
Elbow					Train	
Back	Submatrix 3					Train

Note. Bold lines separate each submatrix, and each submatrix was assigned to a tier in the multiple probe design. Shaded boxes along the diagonal were directly trained targets (e.g., neck, soft). The white boxes are untrained targets that were probed for generlization (e.g., neck, sticky).

Figure 3

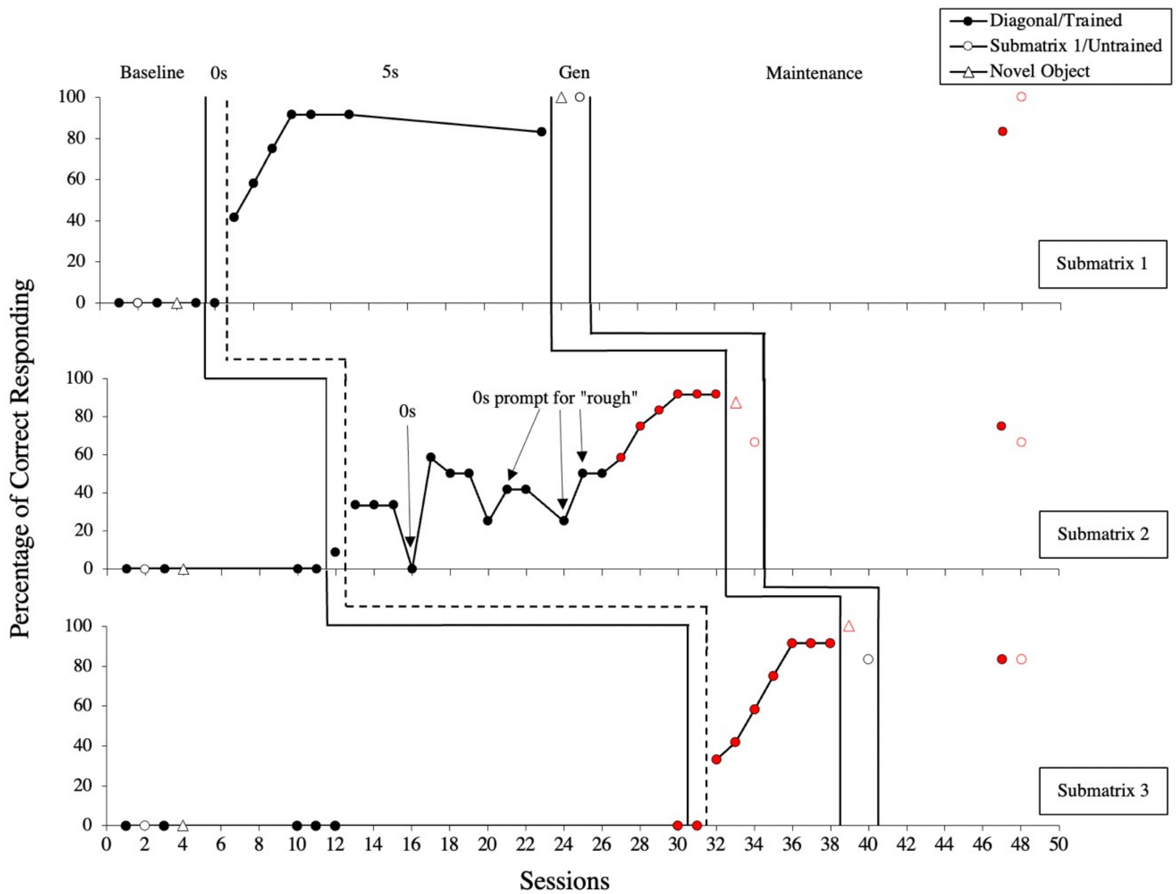
Body Part-Sensation Matrix for Katie

	Soft	Sticky	Smooth	Rough	Dry	Wet
Head	Train					
Hand	Submatrix 1	Train				
Arm			Train			
Foot	Submatrix 2			Train		
Knee					Train	
Tummy	Submatrix 3					Train'

Note. Bold lines separate each submatrix, and each submatrix was assigned to a tier in the multiple probe design. Shaded boxes along the diagonal were directly trained targets (e.g., head, soft). The white boxes are untrained targets that were probed for generlization (e.g., head, sticky).

Figure 4

Percentage of Correct Body Part- Sensation Tacts for Wayne



Note. Red data points indicate hypothetical data.

Figure 5

Percentage of Correct Body Part- Sensation Tacts for Katie

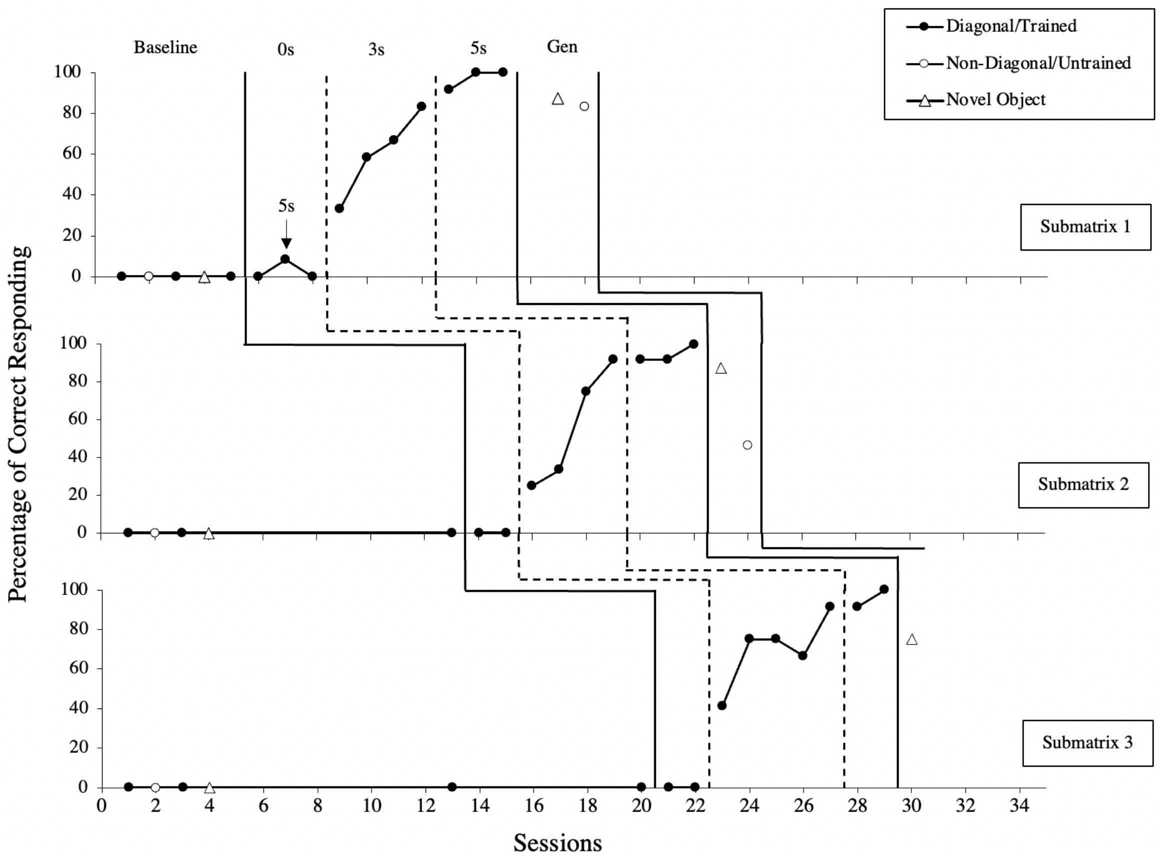


Table 1

List Of Tactile Stimuli Used To Produce Sensations

Sensations	Teaching Stimuli	Generalization Stimuli
Soft	Stuffed animal	Paint Brush
	Feathers	Blanket
	Faux fur	
Sticky	Tape	Lollipop
	Post it note	Sticky hand
	Lint roller	
Smooth	Marker	Moisturizer Applicator
	Plastic ball	Lego
	Spoon	
Rough	Velcro	Dish Sponge
	Nail file	Sandpaper
	Wool	
Dry	Sponge	Paper towel
	Washcloth	Makeup brush
	Cotton ball	
Wet	Wet Sponge	Wet paper towel
	Wet Washcloth	Wet makeup brush
	Water bead	

Note. Targets were counterbalanced across participants.

Appendix A: Data Sheets

Baseline/Teaching (Version 1, submatrix 1, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		lint roller	knee	"Knee feels sticky"						
2		animal	neck	"Neck feels soft"						
3		post-it	knee	"Knee feels sticky"						
4		feather	neck	"Neck feels soft"						
5		fur	neck	"Neck feels soft"						
6		tape	knee	"Knee feels sticky"						
7		post-it	knee	"Knee feels sticky"						
8		fur	neck	"Neck feels soft"						
9		animal	neck	"Neck feels soft"						
10		tape	knee	"Knee feels sticky"						
11		feather	neck	"Neck feels soft"						
12		lint roller	knee	"Knee feels sticky"						

Baseline/Teaching (Version 2, submatrix 1, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		Faux fur	Neck	"Neck feels soft"						
2		Post-it	Knee	"Knee feels sticky"						
3		Tape	Knee	"Knee feels sticky"						
4		Feathers	Neck	"Neck feels soft"						
5		Lint roller	Knee	"Knee feels sticky"						
6		Animal	Neck	"Neck feels soft						
7		Post-it	Knee	"Knee feels sticky"						
8		Animal	Neck	"Neck feels soft"						
9		Faux fur	Neck	"Neck feels soft"						
10		Tape	Knee	"Knee feels sticky"						
11		Feathers	Neck	"Neck feels soft"						
12		Lint roller	Knee	"Knee feels sticky"						

Baseline/Teaching (Version 3, submatrix 1, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		Feathers	Neck	"Neck feels soft"						
2		Lint roller	Knee	"Knee feels sticky"						
3		Animal	Neck	"Neck feels soft"						
4		Tape	Knee	"Knee feels sticky"						
5		Faux fur	Neck	"Neck feels soft"						
6		Post-it	Knee	"Knee feels sticky"						
7		Animal	Neck	"Neck feels soft"						
8		Lint roller	Knee	"Knee feels sticky"						
9		Post-it	Knee	"Knee feels sticky"						
10		Faux fur	Neck	"Neck feels soft"						
11		Tape	Knee	"Knee feels sticky"						
12		Feathers	Neck	"Neck feels soft"						

Baseline/Teaching (Version 1, submatrix 2, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		Marker	Tummy	Tummy feels smooth						
2		Nail file	Foot	Foot feels rough						
3		Wool	Foot	Foot feels rough						
4		Plastic ball	Tummy	Tummy feels smooth						
5		Spoon	Tummy	Tummy feels smooth						
6		Velcro	Foot	Foot feels rough						
7		Wool	Foot	Foot feels rough						
8		Marker	Tummy	Tummy feels smooth						
9		Nail file	Foot	Foot feels rough						
10		Spoon	Tummy	Tummy feels smooth						
11		Plastic ball	Tummy	Tummy feels smooth						
12		Velcro	Foot	Foot feels rough						

Baseline/Teaching (Version 2, submatrix 2, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		Wool	Foot	"Foot feels rough"						
2		Plastic ball	Tummy	"Tummy feels smooth"						
3		Marker	Tummy	"Tummy feels smooth"						
4		Velcro	Foot	"Foot feels rough"						
5		Nail file	Foot	"Foot feels rough"						
6		Spoon	Tummy	"Tummy feels smooth"						
7		Nail file	Foot	"Foot feels rough"						
8		Spoon	Tummy	"Tummy feels smooth"						
9		Marker	Tummy	"Tummy feels smooth"						
10		Wool	Foot	"Foot feels rough"						
11		Velcro	Foot	"Foot feels rough"						
12		Plastic ball	Tummy	"Tummy feels smooth"						

Baseline/Teaching (Version 3, submatrix 2, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		Spoon	Tummy	"Tummy feels smooth"						
2		Velcro	Foot	"Foot feels rough"						
3		Wool	Foot	"Foot feels rough"						
4		Marker	Tummy	"Tummy feels smooth"						
5		Nail file	Foot	"Foot feels rough"						
6		Plastic ball	Tummy	"Tummy feels smooth"						
7		Plastic ball	Tummy	"Tummy feels smooth"						
8		Nail file	Foot	"Foot feels rough"						
9		Wool	Foot	"Foot feels rough"						
10		Marker	Tummy	"Tummy feels smooth"						
11		Velcro	Foot	"Foot feels rough"						
12		Spoon	Tummy	"Tummy feels smooth"						

Baseline/Teaching (Version 1, submatrix 3, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		Water bead	Back	Back feels wet						
2		Cotton ball	Elbow	Elbow feels dry						
3		Washcloth	Elbow	Elbow feels dry						
4		Wet washcloth	Back	Back feels wet						
5		Sponge	Elbow	Elbow feels dry						
6		Wet sponge	Back	Back feels wet						
7		Wet washcloth	Back	Back feels wet						
8		Sponge	Elbow	Elbow feels dry						
9		Wet sponge	Back	Back feels wet						
10		Cotton ball	Elbow	Elbow feels dry						
11		Water bead	Back	Back feels wet						
12		Washcloth	Elbow	Elbow feels dry						

Baseline/Teaching (Version 2, submatrix 3, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		Washcloth	Elbow	"Elbow feels dry"						
2		Water bead	Back	"Back feels wet"						
3		Sponge	Elbow	"Elbow feels dry"						
4		Wet sponge	Back	"Back feels wet"						
5		Cotton ball	Elbow	"Elbow feels dry"						
6		Wet washcloth	Back	"Back feels wet"						
7		Wet washcloth	Back	"Back feels wet"						
8		Cotton ball	Elbow	"Elbow feels dry"						
9		Sponge	Elbow	"Elbow feels dry"						
10		Wet sponge	Back	"Back feels wet"						
11		Washcloth	Elbow	"Elbow feels dry"						
12		Water bead	Back	"Back feels wet"						

Baseline/Teaching (Version 3, submatrix 3, 12 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER 1:
DATE:	PHASE:	BL/TX	

Trial	Prompt delay	Object	Body part	Target response	Participant response - topography | +/-/P/P-/NR		Praise + preferred	Problem behavior		
								Topography	Frequency	Duration
1		Cotton ball	Elbow	"Elbow feels dry"						
2		Wet sponge	Back	"Back feels wet"						
3		Wet washcloth	Back	"Back feels wet"						
4		Washcloth	Elbow	"Elbow feels dry"						
5		Water bead	Back	"Back feels wet"						
6		Sponge	Elbow	"Elbow feels dry"						
7		Wet sponge	Back	"Back feels wet"						
8		Sponge	Elbow	"Elbow feels dry"						
9		Wet washcloth	Back	"Back feels wet"						
10		Cotton ball	Elbow	"Elbow feels dry"						
11		Washcloth	Elbow	"Elbow feels dry"						
12		Water bead	Back	"Back feels wet"						

Recombinative Gen (Submatrix 1 - 6 trials)			
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER:
DATE:	PHASE:		

Trial	Object	Body part	Target respfeelsse	Participant respfeelsse- topography | +/-/NR		Praise + preferred	Problem behavior		
							Topography	Frequency	Duratifeels
1	Faux fur	Knee	"Knee feels soft"						
2	Post it note	Neck	"Neck feels sticky"						
3	Animal	Knee	"Knee feels soft"						
4	Tape	Neck	"Neck feels sticky"						
5	Feathers	Knee	"Knee feels soft"						
6	Lint roller	Neck	"Neck feels sticky"						

Recombinative Gen (Submatrix 2 - 30 trials)				
PARTICIPANT:	SESSION:	PRIMARY / IOA	EXPERIMENTER:	
DATE:	PHASE:			

Trial	Object	Body part	Target respfeelsse	Participant respfeelsse-topography | +/-/NR		Praise + preferred	Problem behavior		
							Topography	Frequency	Duratifeels
1	Tape	Foot	"Foot feels sticky"						
2	Faux fur	Tummy	"Tummy feels soft"						
3	Animal	Foot	"Foot feels soft"						
4	Tape	Tummy	"Tummy feels sticky"						
5	Plastic ball	Neck	"Neck feels smooth"						
6	Spoon	Foot	"Foot feels smooth"						
7	Wool	Knee	"Knee feels rough"						
8	Marker	Knee	"Knee feels smooth"						
9	Velcro	Tummy	"Tummy feels rough"						
10	Wool	Neck	"Neck feels rough"						
11	Lint roller	Foot	foot feel sticky						
12	Feathers	Tummy	tummy feels soft						
13	Post it	Tummy	tummy feels sticky						
14	Faux fur	Foot	foot feels soft						
15	Velcro	Knee	knee feels rough						
16	Marker	Neck	neck feels smooth						
17	Plastic ball	Foot	foot feels smooth						
18	Wool	Tummy	tummy feels rough						
19	Nail file	Neck	neck feels rough						
20	Plastic ball	Knee	knee feels smooth						
21	Animal	Tummy	tummy feels soft						
22	Post it	Foot	foot feels sticky						
23	Feathers	Foot	foot feels soft						
24	Lint roller	Tummy	tummy feels sticky						
25	Nail file	Knee	knee feels rough						
26	Spoon	Neck	neck feels smooth						
27	Marker	Foot	foot feels smooth						
28	Velcro	Neck	neck feels rough						
29	Nail file	Tummy	tummy feels rough						
30	Spoon	Knee	knee feels smooth						

Recombinative Gen (Submatrix 3 - 54 trials)								
PARTICIPANT:			SESSION:	PRIMARY / IOA		EXPERIMENTER:		
DATE:			PHASE:					

Trial	Object	Body part	Target response	Participant response- topography | +/-/NR		Praise + preferred	Problem behavior		
							Topography	Frequency	Duration
1	Tape	Back	"Back feels sticky"						
2	Faux fur	Elbow	"Elbow feels soft"						
3	Water bead	Foot	"Foot feels wet"						
4	Marker	Elbow	"Elbow feels smooth"						
5	Cotton ball	Foot	"Foot feels dry"						
6	Nail file	Back	"Back feels rough"						
7	Wet washcloth	Knee	"Knee feels wet"						
8	Plastic ball	Back	"Back feels smooth"						
9	Velcro	Elbow	"Elbow feels rough"						
10	Washcloth	Neck	"Neck feels dry"						
11	Water bead	Knee	"Knee feels wet"						
12	Lint roller	Elbow	"Elbow feels sticky"						
13	Post it	Back	"Back feels sticky"						
14	Washcloth	Knee	"Knee feels dry"						
15	Sponge	Tummy	"Tummy feels dry"						
16	Wet sponge	Elbow	"Elbow feels wet"						
17	Sponge	Back	"Back feels dry"						
18	Wet sponge	Tummy	"Tummy feels wet"						
19	Wet washcloth	Foot	"Foot feels wet"						
20	Spoon	Elbow	"Elbow feels smooth"						
21	Velcro	Back	"Back feels rough"						
22	Washcloth	Foot	"Foot feels dry"						
23	Feathers	Elbow	"Elbow feels soft"						
24	Wet sponge	Neck	"Neck feels wet"						
25	Animal	Back	"Back feels soft"						
26	Marker	Back	"Back feels smooth"						
27	Wet sponge	Knee	"Knee feels wet"						
28	Nail file	Elbow	"Elbow feels rough"						
29	Tape	Elbow	"Elbow feels sticky"						
30	Cotton ball	Neck	"Neck feels dry"						
31	Water bead	Neck	"Neck feels wet"						
32	Sponge	Knee	"Knee feels dry"						
33	Water bead	Elbow	"Elbow feels wet"						
34	Washcloth	Tummy	"Tummy feels dry"						
35	Wet washcloth	Tummy	"Tummy feels wet"						
36	Cotton ball	Back	"Back feels dry"						
37	Sponge	Foot	"Foot feels dry"						
38	Animal	Elbow	"Elbow feels soft"						
39	Lint roller	Back	"Back feels sticky"						
40	Plastic ball	Elbow	"Elbow feels smooth"						
41	Wool	Back	"Back feels rough"						
42	Wet sponge	Foot	"Foot feels wet"						
43	Faux fur	Back	"Back feels soft"						
44	Feathers	Back	"Back feels soft"						
45	Post it	Elbow	"Elbow feels sticky"						
46	Wool	Elbow	"Elbow feels rough"						
47	Sponge	Neck	"Neck feels dry"						
48	Spoon	Back	"Back feels smooth"						
49	Wet washcloth	Neck	"Neck feels wet"						
50	Cotton ball	Knee	"Knee feels dry"						
51	Cotton ball	Tummy	"Tummy feels dry"						
52	Wet washcloth	Elbow	"Elbow feels wet"						
53	Water bead	Tummy	"Tummy feels wet"						
54	Washcloth	Back	"Back feels dry"						

Novel Object (Pre/Post-test, submatrix 2 - 8 trials)

PARTICIPANT: SESSION: PRIMARY / IOA: EXPERIMENTER:

DATE: PHASE: TEST / POST TEST

Trial	Object	Body part	Target response	Participant response-topography	+/-/NR	Praise + preferred	Problem behavior		
							Topography	Frequency	Duration
1	Dish sponge	Foot	Foot feels rough						
2	Moisturizer applicator	Tummy	Tummy feels smooth						
3	Sandpaper	Foot	Foot feels rough						
4	Lego	Tummy	Tummy feels smooth						
5	Lego	Tummy	Tummy feels smooth						
6	Dish sponge	Foot	Foot feels rough						
7	Sandpaper	Foot	Foot feels rough						
8	Moisturizer applicator	Tummy	Tummy feels smooth						

Novel Object (Pre/Post-test, submatrix 1 - 8 trials)

PARTICIPANT: SESSION: PRIMARY / IOA: EXPERIMENTER:

DATE: PHASE: PRE TEST / POST TEST

Trial	Object	Body part	Target response	Participant response-topography	+/-/NR	Praise + preferred	Problem behavior		
							Topography	Frequency	Duration
1	Sticky hand	Knee	knee feels sticky						
2	Blanket	Neck	neck feels soft						
3	Paint brush	Neck	neck feels soft						
4	Lollipop	Knee	knee feels sticky						
5	Lollipop	Knee	knee feels sticky						
6	Blanket	Neck	neck feels soft						
7	Sticky hand	Knee	knee feels sticky						
8	Paint brush	Neck	neck feels soft						

Novel Object (Pre/Post-test, submatrix 3 - 8 trials)

PARTICIPANT: SESSION: PRIMARY / IOA: EXPERIMENTER:

DATE: PHASE: PRE TEST / POST TEST

Trial	Object	Body part	Target response	Participant response-topography	+/-/NR	Praise + preferred	Problem behavior		
							Topography	Frequency	Duration
1	Makeup brush	Elbow	Elbow feels dry						
2	Wet makeup brush	Foot	Back feels wet						
3	Paper towel	Elbow	Elbow feels dry						
4	Wet paper towel	Foot	Back feels wet						
5	Wet makeup brush	Foot	Back feels wet						
6	Paper towel	Elbow	Elbow feels dry						
7	Makeup brush	Elbow	Elbow feels dry						
8	Wet paper towel	Foot	Back feels wet						

Appendix B: Treatment Integrity Checklist

Baseline /Generalization Probes/Untrained

Date:	Initials:	Session #:
Condition:	Experimenter:	

Step	Record +/- to indicate whether the step was correctly completed for every opportunity in a session
Materials prepared and <u>PRE-SESSION CHECKLIST COMPLETED</u> • Correct data collection materials • Research materials set up correctly • Preferred items available	
Correct object + body part stimulated on every trial.	
Data were collected after every trial.	
NO prompt was ever provided	
NO consequence was ever provided	
Stimulation always stopped after 5 s or after a response was emitted.	
Praise + edible (if applicable) provided every 3-4 trials non-contingent on responding	
If problem behavior occurred, duration data were collected, and the frequency of instances was tallied trial by trial.	

1-min break with access to preferred item/activity provided every 12 trials	
Session ended after 6/8/12/30/54 trials.	
Total steps completed correctly:	_______ /10 * 100 = _______%

Teaching/Trained

Date:	Initials:	Session #:
Condition:	Experimenter:	

Step	Record +/- to indicate whether the step was correctly completed for every opportunity in a session
Materials prepared and <u>PRE-SESSION CHECKLIST COMPLETED</u> • Correct data collection materials • Research materials set up correctly • Preferred items available	
Correct object + body part stimulated on every trial.	
Data were collected after every trial.	
Correct prompt was provided on every trial.	
Correct consequence was provided on every trial.	
Stimulation always stopped after 5 s or after a response was emitted.	
If problem behavior occurred, duration data were collected, and frequency of instances was tallied trial by trial	
1-min break with access to preferred item/activity provided every 12 trials	
Ended session after 12 trials	
Total steps completed correctly:	_______ /9 * 100 = _______%

Appendix C: Caregiver Social Validity Questionnaire

Please rate the degree to which you agree with the following statements by filling in the circle under the appropriate rating. Ratings range from "strongly disagree" to "strongly agree".

1. I found the procedures used in this study to be acceptable.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
O	O	O	O	O	O	O

2. This study could help children with autism to label feelings and body parts.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
O	O	O	O	O	O	O

3. I believe this study is acceptable to use with young children with autism.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
O	O	O	O	O	O	O

4. I believe labeling feelings and body parts is an important communication skill.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
O	O	O	O	O	O	O

5. I believe labeling feelings and body parts is an important safety skill.

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

6. The items used to produce stimulation in this study were as close to the sensation target as possible (e.g., blanket produced a soft feeling).

Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

Appendix D: Participant Social Validity Questionnaire

Thank you for helping me with my research! I am going to ask you some questions about research and what you felt on your body.

Did you like this research?			
No	Sometimes	Yes	I don't know
Was this research fun?			
No	Sometimes	Yes	I don't know
Will you do research with us again?			
No	Maybe	Yes	I don't know
Did anything in this research hurt?			
No	Sometimes	Yes	I don't know

Did you learn new things in this research?		
No 	Yes 	I don’t know ?

What was your favorite part? Or what did you like most?

Was there anything you did not like?

What does research mean? What did we do together?