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A Framework for Studying Sensitivity to Auditory Stimuli: An Exploratory Study

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A Framework for Studying Sensitivity to Auditory Stimuli: An Exploratory Study

by

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Abstract

Children diagnosed with Autism Spectrum Disorder (ASD) are frequently reported to show sensitivity to auditory stimuli. While auditory preference assessments can show relative preference of one sound over another, they don't provide information on the extent to which a sound might be aversive. The present study developed an escape and avoidance assessment in attempt to capture any sensitivity to auditory stimuli by comparing the results from this assessment to a standard auditory preference assessment, examining avoidance and escape responses of children to different speech types, and comparing the responses of children with an ASD diagnosis to typically developing children.

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Chapter I: Introduction and Literature Review

From "refrigerator mothers" to pesticide use, the etiological theories of autism spectrum disorder (ASD) have evolved over the last several decades. While no specific cause has been identified, much of the current research points to both genetic and environmental factors (Amaral, 2017). Viewing ASD symptomology from a behavioural perspective requires that we concentrate on the development of autistic behaviours over time, particularly as they relate to environmental factors. Thus, certain autistic behaviours would be strengthened through the process of reinforcement and weakened through punishment. However, this view would suggest that parenting practices might be the cause of autism, which has long been challenged by researchers (e.g., Rutter, 1968). Furthermore, it is highly unlikely, given the current prevalence of ASD (1 in 68; Christensen et al., 2016), that a large population of parents have explicitly reinforced autistic behaviour and punished early language and social development.

Bijou and Ghezzi's behaviour interference theory (as cited in Hixson, Wilson, Doty, & Vladescu, 2008) proposed an alternative explanation for how autistic behaviours develop over childhood. Behaviour interference theory purports that children with an ASD diagnosis have sensory abnormalities that make certain auditory and tactile stimuli aversive. Hixson et al. (2008) explained that, in typically developing children, social stimuli such as a parent's voice or touch acquires generalized reinforcing properties through pairings with food, warmth, and other primary reinforcers. These generalized conditioned reinforcers play a large role in the development of language and social skills. The theory hypothesizes that when infants or young children have abnormal sensory systems that result in their avoidance of social stimuli, it prevents the acquisition of basic language and social skills that serve as prerequisites for more complex social behaviours. It is also proposed that stereotypy may compensate for language and social skills deficits or help the child to escape aversive stimuli (Bijou & Ghezzi, as cited in Hixson et al., 2008).

Responses to Auditory Stimuli in Children with an ASD Diagnosis

Adults and children with a diagnosis of ASD have frequently reported auditory problems such as hypersensitivity to loud noises (Tomchek & Dunn, 2007) and pain from high-pitched sounds (Jones, Quigney, & Huws, 2003). Tomcheck and Dunn (2007) surveyed caregivers using the Short Sensory Profile and found that more than half of caregivers who had children with a diagnosis of ASD indicated that their child always or frequently responds negatively to unexpected loud noises compared to 8% of caregivers of typically developing children. In addition, 73% of caregivers of children with an ASD diagnosis reported that their child often appears to not hear what they say compared to only 4% of caregivers with typically developing children. Similar reports of an abnormal awareness to sounds were found in a study by Talay-Ongan and Wood (2000). The authors administered the Revised Sensory Sensitivity Questionnaire to parents of autistic children and parents of typically developing children. Results showed that many children who had been diagnosed with ASD were reported to be more aware of non-speech sounds such as from vehicles and the television and less aware of human voices in comparison to their typically developing peers.

The literature is dense with papers on sensory features in ASD; however, many studies rely on parent questionnaires or self-report (Shaaf & Lane, 2015). While this type of research has provided a useful overview of the observations of caregivers and personal experiences of people diagnosed with ASD, it is also important to consider behavioural research as a more controlled measure of sensory preferences through the direct manipulation of sensory stimuli. One way to obtain a behavioural measure of preference between two auditory stimuli is the head turn preference procedure (HPP). Kemler-Nelson et al. (1995) described the procedure as a viable tool to measure preference in infants because of their tendency to orient toward sounds and their ability to learn and maintain a response that is followed by a reinforcing stimulus. Kuhl, Coffey-Corina, Padden, and Dawson (2005) used the HPP to conduct an auditory preference test with preschool-aged children diagnosed with ASD and their typically developing peers. The test compared samples of child-directed speech to non-speech analogs. Child-directed speech, also known as motherese, typically has a higher pitch, a slower tempo, and a wider range of pitch contours than adult-directed speech (Fernald & Simon, 1984) and has shown to be the preferred register for young listeners (Fernald, 1985). The child-directed speech samples used by Kuhl et al. (2005) consisted of recordings of adult women talking to their infants and the non-speech analogs were computer synthesized and matched in frequency and amplitude to the child-directed speech samples. The participants sat facing a three-sided enclosure that contained small lights attached to loudspeakers which were located on either side of the participant and a video screen located directly in front. Initially, familiarization trials were used to acquaint the participants to the auditory stimuli that would be used in the preference test. A video played on the screen to direct the child's attention to the middle of the enclosure before the initiation of each trial. The participant's attention was then directed towards a light that was activated on the left or right side of the participant. Once the participant turned towards the light, the sound assigned to that side was played. During the test trials, a 30-degree head turn to the left or right resulted in the presentation of the sound assigned to that side. Preference was measured by the percentage of head turns towards the speech or non-speech samples. The results showed that typically developing children did not show preference to one sound over the other; however, the majority of children in the ASD group did show a preference. Of these children, 74% preferred the non-speech sounds over the child-directed speech samples. The authors also administered an event-related potential test using consonant-vowel syllables and found that the children who preferred the non-speech sounds had different neural patterns and showed less discrimination of speech sounds than the children with preference to the speech samples (Kuhl et al., 2005).

Curtin and Vouloumanos (2013) measured preference of speech and non-speech analogs in 12-month-old infants. Half of the infants were the sibling of a typically developing child and were considered low-risk for being later diagnosed with ASD; the remaining half of the participants had a sibling diagnosed with ASD and were considered high-risk for later diagnosis. Each infant was seated on his/her parent's lap in front of a screen. A flashing light directed the infant to the screen and either a speech or non-speech sample was played concurrently with an image of a checkerboard. Preference was indicated by the length of time the infant looked at a screen while each sound was playing. Overall, both groups of infants preferred speech sounds over the non-speech analogs; however, when speech sounds were played, infants in the low-risk group looked at the screen longer than infants in the high-risk group. Curtin and Vouloumanos also assessed each group at 18 months using the Autism Observation Scales for Infants (AOSI) which helps to detect early autism symptoms. In the children from the high-risk group, there was a correlation between relative preference for speech sounds and scores on the AOSI; those who preferred speech generally had lower scores and fewer markers for ASD at 18 months.

Watson, Roberts, Baranek, Mandulak, and Dalton (2012) measured sustained attention to child-directed speech versus non-social stimuli in young boys with an ASD diagnosis compared to a chronologically age-matched group and a language age-matched group. Three different child-directed speech vignettes were created, including a video of an adult reading a story, a live puppet show, and a video of an adult playing with and using nonsense words to describe a toy. Non-social stimuli consisted of a video containing toys and moving patterns with music. The proportion of time spent looking at each stimulus was used as a measure of preference. It was found that the ASD group showed less attention towards the child-directed speech vignettes than age-matched typically developing peers. However, the level of sustained attention of the ASD group was comparable to their language-matched peers except for the live child-directed speech vignette in which the typically developing group attended for longer.

Klin (1991) compared the auditory preferences of children with a diagnosis of autism, typically developing children, and intellectually disabled children by measuring the time spent between two toys with push buttons that played audio. One toy held a tape with a recording of the participant’s mother speaking to the participant and the other played the continuous sounds of a busy canteen without any clear speech sounds. A free-choice procedure was used so that the children had unlimited access to the toys in their own home while a device inside each toy recorded data on how long a child listened to the sound recordings. All typically developing and intellectually disabled children showed a strong preference for their mother’s voice, whereas seven of the 12 children in the ASD group showed no preference and five showed preference to the canteen noise. Klin (1991) suggested the possibility that the typically developing and intellectually disabled group may not have preferred their mother's recording but instead found the canteen sound aversive and activated it less.

Preference for sounds in children with ASD may not only be influenced by the content, but the playback source as well. Buckley and Newchok (2006) completed an auditory stimulus assessment to determine if a certain playback source would evoke ear covering and screaming in a seven-year-old boy with a history of aberrant behavior in the presence of certain auditory stimuli. This information was used later in implementing an intervention (differential negative reinforcement of other behaviour) to decrease this behaviour in response to certain noises. The auditory stimulus assessment allowed the participant to have free access to preferred materials while he was exposed to four genres of music (pop, classical, jazz, and rock) and two playback sources (CD and tape). Music was turned off contingent on ear covering and screaming. It was found that taped music, regardless of genre, was associated with increased rates of problem behaviour. The authors were unsure as to why one playback source was preferred over another, but noted that the participant may have been more familiar with CDs.

Ramdoss (2013) attempted to identify the preferences of four children diagnosed with ASD for speech output on a speech generating device (SGD). Two types of speech output were compared: natural speech recorded on a SGD and a synthetic voice recorded through a speech synthesis engine onto a second SGD. Participants were trained to use the SGDs to make a request by activating a switch on a panel. After this initial acquisition phase, they were provided with both devices and several opportunities to request preferred items. Preference was measured by the number of times a SGD was selected to make a request for the preferred item. One participant was excluded from the choice assessment because he did not achieve mastery in using the devices. Only two of the remaining three participants provided clear results; one participant preferred the synthetic output, and another preferred the natural recorded voice. The third participant demonstrated a side bias so preference could not be determined. While the results did not suggest a preference for one type of speech output over another, it may be worthwhile to include synthetic and natural voices in other types of auditory preference assessments with a larger sample of children.

Characteristics of Speech

Most studies on auditory preferences have compared speech to non-speech sounds but have not further examined preference for certain prosodic features of speech such as pitch. Fernald and Mazzie (1991) noted large differences in pitch ranges of an adult speaker using child-directed or adult-directed speech. Based on their data, the mean maximum fundamental frequency (an objective measure of pitch) was 388 Hz for child-directed speech with a range of 195 Hz whereas the mean maximum fundamental frequency for adult-directed speech was 284 Hz with a range of 112 Hz. The way that adults speak to children is clearly different from how they speak to other adults. However, some of the aforementioned studies on auditory preference indicated that children with an ASD diagnosis tend to prefer non-speech sounds over child-directed speech. Considering Bijou and Ghezzi’s behaviour interference theory, if there is a possibility that child-directed speech is less preferred or even aversive for a child with presumed sensory abnormalities because of its higher pitch and wider pitch range, it could potentially have an effect on early development. Although it would be difficult to test this theory as a whole, testing the aversiveness of certain speech characteristics would offer some insight into some early developing contingencies.

If a certain type of sound is aversive, then using a preference procedure such as the HPP or measuring looking time may not provide this information—we are only able to conclude that one stimulus is selected, or attended to, less frequently. Furthermore, it is unclear if the selection of one sound over another is a measure of putative reinforcement. One could potentially select an aversive stimulus simply to avoid a more aversive stimulus. Certainly, a paired stimulus preference assessment with multiple items would at least provide information on ranking. However, the current preference assessments are unable to specifically measure the degree to which a stimulus is perceived to be aversive.

Conjugate Reinforcement

Alternatively, measuring responses on a conjugate schedule of reinforcement could be advantageous for assessing the preference of certain acoustic properties of auditory stimuli. A conjugate reinforcement schedule is a continuous schedule that has a direct relation between response intensity and reinforcer magnitude: more intense responding produces a more intense stimulus (Rapp, 2008). Advantages of conjugate reinforcement procedures include the ability to evaluate multiple parameters of a stimulus as well as the requirement of an ongoing response to change the intensity of the reinforcing stimulus (Rapp, 2008). For example, MacAleese, Ghezzi, and Rapp (2015) examined conjugate schedules through key presses that would result in conjugate changes in the clarity of a preferred picture. The authors used three different experiments to study the effects of conjugate reinforcement on key presses and found that responses were sensitive to schedule changes (i.e., smaller increases in clarity change resulted in higher rates of responding to increase clarity), responses could be acquired under a conjugate schedule with minimal instruction, and responses could be decreased through extinction or conjugate punishment (i.e., pressing the key decreased clarity).

A key-pressing procedure similar to MacAleese, Ghezzi, and Rapp (2015) could be used to determine the level of preference or aversiveness of auditory stimuli and allow for an examination of how children diagnosed with ASD respond on a schedule that results in a directly proportional change of the acoustic properties of a sound. While MacAleese, Ghezzi, and Rapp (2015) used conjugate positive reinforcement and conjugate negative punishment, a conjugate negative reinforcement procedure would allow for escape or avoidance of potentially aversive stimuli at a response-dependent rate. More specifically, the ability to reduce the volume through key presses on a conjugate schedule may provide more information regarding the aversiveness of an auditory stimulus.

The purpose of this proposed study is to (a) develop a method of assessing sensitivity to auditory stimuli through negative reinforcement, (b) compare the results of an avoidance/escape assessment with a preference assessment to evaluate level of correspondence, (c) examine the responses of children with ASD to different types of speech, and (d) compare the responses of children with ASD to a sample of typically developing children.

Chapter II: Method

Participants and Setting

Eight children between the ages of three and seven participated in the study. Six children diagnosed with ASD were recruited from a local agency that provides early intervention services to children with developmental disabilities and their families. Two typically developing children also served as participants in the study. Participants were selected based on their ability to follow simple directions, make choices between two stimuli, and attend to a task for a minimum of three minutes. While ten families initially gave their consent, one child did not meet the prerequisites required to participate and another family moved outside of city limits which made data collection difficult; these participants were excluded from the study.

Participants were screened through a brief questionnaire filled out by their parents. The questionnaire prompted parents to answer questions about their child's sound preferences or aversions as well as give information about their child's favourite movie/TV show or character so that a personalized sound sample could be developed for the assessments.

Assessments typically occurred at the agency's office so that the children could participate in the study during their snack break at the onsite preschool. For children that did not attend the onsite preschool, the experimenter travelled to their homes to conduct the assessment outside of session or school hours. In all cases, the assessments took place in a quiet room to prevent the interference of outside noise.

Materials

iPhones. Two iPhones with recorded sounds were used for the preference assessment. These phones were connected to two different speakers via Bluetooth.

Computer. A MacBook Air laptop was used for the escape and avoidance assessment along with a wireless keyboard. A star sticker was placed on the keyboard's spacebar so that the key could be easily located.

Child-safe headphones. Child-safe headphones were worn by the participants throughout the avoidance/escape assessment so that they were not exposed to volumes over 80 dB (the U.S. Department of Health and Human Services (2014) advises against prolonged exposure to noise at or above 85 dB).

Assessment software. The experimenter worked with a software developer to create assessment software with the capability of recording and time-stamping all participant responses. The software allowed for the presentation of different auditory stimuli in a controlled order with the ability to manipulate the volume of the stimuli by key press. This manipulation occurred on a conjugate schedule so that key presses and degree of change to the volume of the presented stimulus were positively correlated. The software recorded the rate of key presses per minute measured every second based on a three-second moving average. The per-minute rate of responding directly corresponded with a percent increase or decrease in volume. The degree of change was initially set to 25 presses per minute for each 20% change and then was increased to 65 presses per minute for each 20% change after the first five assessments in order to increase response effort (i.e., a maximum of 125 presses per minute did not require a lot of response effort). Therefore, 65 presses per minute resulted in a 20% increase or decrease in volume, 130 presses per minute resulted in a 40% change, 195 presses resulted in a 60% change, 260 presses resulted in an 80% change, and 325 presses per minute either eliminated the sound entirely or increased the sound to its highest volume. Constant responding was required to keep up the change in volume; a pause in responding caused the volume to return to its original level.

The program also collected data on response latency and allowed for extraction of data for easy graphing.

The software was calibrated using an adult participant to ensure accurate recording of data through the program as well as to make subjective judgements on sound volume based on the different response rates per minute.

Auditory stimuli. Seven, 15-second sound samples were initially used for the preference assessment with four more sounds added later on for a few of the participants. The initial seven stimuli consisted of five pre-recorded samples of a voice reading identical passages from a story (Winnie the Pooh; 1926) and two samples that were specific to each participant. A rain sound effect was used during the explanation of the escape/avoidance assessment to the subjects. Four new sound samples were used for six of the eight participants and were selected based on a study that had adult subjects rate unpleasant sounds (Kumar, Forster, Bailey, & Griffiths, 2008). Each of the sound samples used in the study are described below:

1. Synthetic speech. The text-to-speech feature on an iPhone 5s was used to produce a synthetic female voice reading the story passage.
2. Monotone speech. A female adult read the same story passage in a monotone voice (i.e., without the pitch contours normally found in natural speech).
3. Adult-directed speech. A female adult read the story in a tone that would be directed toward adults with a wider range in pitch than monotone or synthetic speech.

4. Child-directed speech. Child-directed speech typically has a higher mean pitch and wider pitch range than adult-directed speech (Fernald & Mazzie, 1991). The child-directed speech sample consisted of the same female voice reading an identical story passage as the other speech samples but with a higher mean pitch and wider range (i.e., as if someone was speaking to a child).
5. Exaggerated child-directed speech. The exaggerated child-directed speech sample was similar to the child-directed speech sample, but with a higher pitch and even wider pitch range (i.e., as if someone was speaking in an excited voice to a child).
6. Participant's own speech. A 15-second sample of each participant speaking or making vocalizations was recorded while the participant and the experimenter looked at and described pictures in a book. The prosodic features of these voices varied between individuals.
7. Preferred voice sample. Based on feedback from the participant's parent or the participant themselves, 15 seconds of a preferred song was included in the sound sample. This sample varied between participants. All samples were edited using the Audacity application on a MacBook Air as means to remove long pauses between vocalizations or statements and to remove inappropriate language from one participant.
8. Rain. The sound of rain was used during the demonstration of how to work the software for each participant. This sound sample was included in the software by the developer.

The sounds samples that were added for some participants included:

9. Angle grinder. The sound of an electric drill was obtained from a sound effects album on iTunes. A similar sound was rated to be unpleasant (mean rating of 6.44 out of 9 on a

scale of 0 to 9, with 0 being the least unpleasant and 9 being the most unpleasant) in the Kumar et. al (2008) study.

10. Nails on a chalkboard. The sound of nails scratching a chalkboard was obtained from a sound effects album on iTunes. A similar sound was rated to be unpleasant (mean rating of 6.48 out of 9) in the Kumar et. al (2008) study.
11. Frogs chirping. The sound of several frogs chirping was obtained from a sound effects album on iTunes. A similar sound was rated to be less unpleasant (mean rating of 2.68) in the Kumar et. al (2008) study.
12. Water running in a stream. The sound of running water was obtained from a sound effects album on iTunes. A similar sound was rated to be one of the least unpleasant sounds (mean rating of 0.98) in the study by Kumar et. al (2008).

A free software program (PRAAT 6.0.35; Boersma & Weenink, 2017) was used to determine the mean pitch and pitch range for samples one through five. See Table 1 for pitch values.

Dependent Variable and Response Measurement

Rate of key presses. The rate of key presses per minute were recorded through the assessment software as a measure of avoidance and escape from the auditory stimulus.

Latency to first key press. The time between the onset of the auditory stimulus and the first down press of the key were also used as a measure of avoidance and escape.

Procedure

A parametric analysis was used to assess for differences in preference and avoidance or escape responses to a variety of auditory stimuli. Initial sessions consisted of a preference assessment with subsequent sessions focusing on the avoidance and escape assessment.

Preference Assessment. During the preference assessment, each participant sat facing the experimenter between two tables with a small speaker placed on each. The researcher read the following instructions: “I am going to play you some sounds. I want you to point to the one you want to hear again”.

Only the first five seconds of each 15-second sample was played during the preference assessment to keep the pairings short and to limit the total length of the assessment. Every auditory stimulus was presented with every other auditory stimulus once. In the initial sessions, sound samples one through seven were compared with a total of 21 pairings per session. During later sessions, sound samples seven and nine through 12 were compared with a total of ten pairings per session. During longer sessions (i.e., 21 pairings), the participants took breaks halfway through to interact with the experimenter before continuing. One to two preference assessments occurred per day and were continued until a stable preference appeared in the most preferred and two least preferred stimuli for two to three sessions. In some cases where there was no clear order of preference other than the most preferred stimulus, the experimenter chose the stimuli that did not appear as a preferred stimulus in at least two assessments.

Preferences were recorded on a standard paired stimulus preference assessment data sheet and ranked from most to least preferred based on the number of times the stimulus was selected out of the total number of presentations. The highest ranked stimulus and the two lowest ranked stimuli were selected for use in the escape/avoidance assessment. There were two versions of each preference assessment to ensure a reversal of the sound order and to help detect a side bias in some participants.

Participants had an opportunity to choose a small prize from a box once they finished the assessment.

Escape/Avoidance Assessment. During the escape/avoidance assessment, participants sat in front of a laptop computer with a wireless keyboard within reach. Before the first assessment, the following instructions were read:

> You are going to hear a few different sounds. You can press this button to make the sounds quieter or louder. I will show you how it works.

The experimenter demonstrated how to tap the space bar to alter the volume of the sound that was played into the headphones using the rain sound sample and then asked the participant to try. The participants completed three pre-training trials, one for each coloured screen. Each trial lasted 30 seconds and allowed the participants to experience the volume change based on each condition.

Once the demonstration was complete, the headphones were placed over the participant's ears and the assessment begun. The three stimuli selected from the preference assessment were presented for 15 seconds in alternating order as either escape, avoidance, or contingency reversal trials for a total of nine trials per sitting. There was a three second pause with a black screen in between trials. Escape trials were indicated by a red screen and began at maximum volume (i.e., no more than 80 dB). The volume of the sound sample decreased as the participant pressed the space bar. If the spacebar was not pressed during the escape condition, the sound remained at full volume until the 15 seconds were complete. Avoidance trials were indicated by a yellow screen and began at minimum volume (0 dB). In this condition, the volume of the sound increased over the course of the 15-second sample unless the participant continuously pressed the space bar to decrease the volume. If there were no key presses during the avoidance trials, the sound increased to maximum volume (i.e., no more than 80 dB) before switching to a new sound. Contingency reversal trials were indicated by a green screen. In this condition, the software provided a three-second preview on a green screen that said “preview” in a white box. The volume of the sound remained at 0 dB unless the spacebar was pressed, which increased the volume. If key pressing paused, the volume decreased again to 0 dB.

Pressing the spacebar changed the volume on a conjugate reinforcement schedule; the faster the spacebar was pressed (based on a three-second moving average of presses per minute), the faster the volume changed (i.e., increased or decreased). It was required that the spacebar was released between presses as it would not change the volume if simply held down.

Each sitting consisted of one escape, one avoidance, and one reversal trial for each of the three selected stimuli for a total of nine trials per sitting. Initially, the order of stimuli was set up so that no two conditions or sound samples played consecutively. However, for some children where conditional discriminations were hypothesized to be a barrier to the assessment, the stimuli were grouped by colour. During these assessments, one colour was presented at a time with a break in between so that the experimenter could specifically explain the next condition (e.g., “Pressing the key will make the sound quiet”). Sound samples were presented twice for each condition with six stimuli in each condition and a total of 18 stimuli presented per sitting. All sittings lasted approximately three to seven minutes.

Reliability. The assessment was calibrated by two different adults before it was used as an assessment tool. Calibration consisted of both adults producing pre-determined patterns of responses, one for each sound sample. The response patterns included one key press per second, fast key presses for the duration of the sample, and alternating slow and fast key presses. The graphs that were created from the software program matched the response pattern emitted on each sound sample for both adults.

Chapter III: Results

Figure 1 displays the results of the parent questionnaire. Seven out of eight parents responded (five parents of children with an ASD diagnosis and two parents of children without a diagnosis). Most parents did not indicate that their children disliked or were overly sensitive to different noises. Only one parent indicated that their child avoided or responded negatively to loud noises and nobody indicated that their child avoided or responded negatively to high pitched noises. Only one parent indicated that their child did not enjoy the sound of their own voice.

Table 2 displays the sounds selected by or for each participant for the escape/avoidance assessment. Six of the eight participants were presented with the original stimuli during the paired preference assessment (i.e., synthetic, monotone, adult-directed, child-directed, exaggerated child-directed, preferred sound, and the child's own voice). The paired preference assessment showed inconsistent results in the types of sounds that the participants preferred the most or the least and appeared to be independent of diagnosis. For instance, two participants, one from the ASD group (Noah) and the other from the typically developing group (Alex), preferred their own voice the most; another participant with an ASD diagnosis (Liam) preferred his own voice the least and frequently voiced his distaste (i.e., "I don't like this one") when the sound sample played. Most participants showed the highest preference for songs from preferred television shows, video games, or movies, which were uniquely selected for each individual participant based on the parent survey. Three participants in the ASD group (Sarah, Kate, and Noah) showed a low preference for the exaggerated child-directed voice; however, they also showed a low preference for the monotone or synthetic voices, which were acoustically very different from the exaggerated voice. Furthermore, the neurotypical participant (Alex) showed a low preference for the child-directed voice.

One participant (Mark) did not show any consistency in preference across five difference preference assessment sessions and often chose the sound on the same side for seven or more consecutive trials. For this reason, Mark was presented with the new stimuli, in an attempt to add contrast to the different sounds. However, after three paired preference assessments using the new auditory stimuli, it was determined that Mark did not show a consistent preference for any sounds and three sounds were chosen for him (a putative preferred, moderately preferred and non-preferred)

Besides Mark, two of the eight children (Joshua and James) participated in a paired preference assessment using the new stimuli. For Sarah and Kate, the new sounds were assigned by the experimenter for the purpose of providing greater contrast between the different sounds. Out of the two children who participated in the paired preference assessment with the new stimuli, both chose their preferred sound the most often and the angle grinder less often, relative to the other stimuli. James also chose nails on a chalkboard and Joshua chose frogs chirping as a non-preferred sound.

The second-by-second graph shows the rate of responding in key presses per minute (PPM) for every second of each 15-second assessment. The graphs are grouped together by condition in order to collectively show the difference in responding between stimuli across several sessions. Generally speaking, the sharper curves signal a quick transition between low and high response rates and straighter lines indicate steadier responding. Several curves represent an alternation between high and low responding, suggesting that the participant responded on the key which allowed the sound to increase or decrease in volume and then responded again in response to the sound changing back to baseline (i.e., becoming loud or quiet again, depending on the condition).

Sarah

Sarah's second-by-second response rate is shown in Figure 2. Based on the paired preference assessment, Sarah's preferred sound was the Paw Patrol theme song and her non-preferred sounds were the exaggerated child-directed and the synthetic voices. For Sarah, the PPM requirement increased from 25 to 65 PPM after Session 2 so that faster key pressing was needed to increase or decrease the volume of the sound. The stimuli were changed after Session 4 to include Hakuna Matata, the angle grinder, and nails on a chalkboard, and conditions were grouped together in Session 6 (as opposed to being presented randomly) so that an explanation could occur before each condition. As the stimuli were grouped together, there were two presentations of each stimulus in every condition instead of one; the data represented are an average of the responses to these two stimuli.

Overall, Sarah showed a pattern of responding that became steadier over time across all stimuli and conditions. Initially, Sarah responded at higher rates to her preferred stimulus during the escape and avoidance assessments, although this response eventually become undifferentiated from responses to the non-preferred stimuli in Sessions 5 and 6. Some non-responding occurred in some conditions during Sessions 1, 2, and 3, presumably as a result of Sarah learning the assessment. The highest rate of responding (200 PPM) was seen in the first session with the Paw Patrol song and exaggerated child-directed voice in the escape condition and the synthetic voice in the reversal condition. This rate of responding was also observed in the second session with the Paw Patrol song in the avoidance condition, and the third sessions with the Paw Patrol song in the reversal condition.

The response latencies for Sarah are shown in Figure 3. Latency was calculated as time to first key press after each condition began, signalled by a coloured screen. If a participant didn't respond at all during a condition, the latency was considered to be 15 seconds.

Sarah's latency shortened in all conditions over the six sessions. In the first two sessions, Sarah either did not respond at all or it took her up to nine seconds to respond, except during the avoidance condition for her preferred stimulus in the first session where she responded almost immediately (however, this response may have been a continuation of her response from a previous trial). By the last session, Sarah responded within three seconds across all three conditions.

Sarah's combined averages are reflected in Figure 4. Combined averages were calculated by grouping together the combinations of stimuli and conditions that would presumably result in relatively higher responding or lower responding. Specifically, the non-preferred stimuli in the escape and avoidance conditions and preferred stimuli in the reversal condition would yield higher response rates and preferred stimuli in the escape and avoidance conditions and non-preferred stimuli in the reversal conditions would yield lower response rates.

In Sessions 1, 2, 3, and 4, conditions where a higher rate of responding would be expected saw a relatively lower average rate of responding (with an average of 24, 56, 86, and 84 presses per minute, respectively) and conditions where a low rate would be expected saw a relatively higher average rate of responding (with an average of 77, 85, 107, and 101 presses per minute, respectively). In sessions five and six, the relatively high and low responding rates of these conditions reversed; in conditions where a higher rate of responding would be expected, there were averages of 110 and 122 presses per minute, respectively, and in conditions where a lower rate of responding would be expected, there were averages of 99 and 121 presses per minute in Sessions 5 and 6, respectively. The discrepancy in average presses per minute shortened over the six sessions, with a difference of 53 seconds in session one and a difference in 2 seconds in session six.

Joshua

Joshua's second-by-second response rate is displayed in Figure 5. Based on the paired preference assessment, Joshua's preferred sound was the Paw Patrol theme song and his non-preferred sounds were the frogs chirping and the angle grinder. No changes were made to PPM requirements, stimuli, or grouping of stimuli over the three assessments.

Joshua pressed the key at a relatively higher rate in response to his preferred sound across all three sessions in both the escape and avoidance conditions. During the escape conditions in Sessions 1 and 2, he also responded to the angle grinder at a similar rate to his preferred sound and in Session 3, his pattern of responding to the frogs chirping was similar to his preferred sound but at slightly lower intensity. He did not respond at all to either of his non-preferred sounds during the avoidance conditions and only made a few key presses during the reversal condition to the Paw Patrol song in Session 2 and frogs chirping sound in Session 3. Joshua made comments about his preferred song being too loud in the headphones, which was likely associated with his pattern of responding across all three conditions. Joshua's highest rate of responding was 300 PPM, in response to the angle grinder in the escape condition of Session 2. However, there were also higher intensity responses in the escape condition for the angle grinder in Session 1 (220 PPM) and the Paw Patrol song in Sessions 1 and 2 (200 and 240 PPM respectively).

Joshua's response latencies are displayed in Figure 6. Joshua had the shortest latency for his preferred stimulus in both the escape and avoidance conditions. In the escape condition, Joshua didn't respond in the presence of the frogs chirping sound until the third session, when he responded after 10.0 seconds of the sound playing. He responded to the angle grinder after almost 6.0 seconds in the first session, 8.2 seconds in the second session, and didn't respond at all in the third. In the presence of the preferred stimulus in the escape condition, Joshua responded within 3.4 seconds in the first session, 2.9 seconds in the second, and 10.7 seconds in the third session.

In the avoidance condition, Joshua did not respond at all to either of the non-preferred stimuli in across all three sessions. He responded to the preferred stimulus within 5.6 seconds during the first session, within 0.8 seconds in the second session and within 5.3 seconds in the third session.

In the contingency reversal condition, Joshua only responded to the frogs chirping in the third session after 12.4 seconds and didn't respond at all to increase the sound of the angle grinder. He didn't respond in the first or third sessions to increase the preferred stimulus but responded after 5.5 seconds in the second session.

Joshua responded at a relatively higher average rate in conditions where a lower rate of responding would be expected, and at a relatively low average rate in conditions where a higher rate of responding would be expected. His combined averages are displayed in Figure 7. Joshua's combined average rate of key presses per minute within the escape conditions with non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal with a preferred stimulus for sessions one, two, and three were 10, 21, and 6, respectively, for each session. His combined average rate of responding per minute within the escape and avoidance conditions of preferred stimuli and contingency reversal conditions for the non-preferred stimuli for sessions one, two, and three were 28, 47, and 35, respectively. These averages were affected by a few conditions with no responding, which brought the overall average lower.

Mark

Mark's second-by-second response rate is displayed in Figure 8. Mark's preferred sound was the Paw Patrol theme song, his moderate sound was running water, and his non-preferred sound was nails on a chalkboard. All sounds were chosen for Mark due to lack of stability during paired preference assessments; therefore, this is a presumed ranking of preference. No changes were made to PPM requirements or stimuli. Conditions were grouped together in Session 3 (as opposed to being presented randomly) so that an explanation could occur before each condition. Since the stimuli were grouped together, there were two presentations of each stimulus in every condition instead of one and the data represented are an average of the responses to these two stimuli.

During the first two sessions, Mark only responded to his preferred (Paw Patrol) and moderately preferred (water running) stimuli in the escape condition. He did not respond at all to any stimuli during the avoidance or contingency reversal condition during Sessions 1 and 2. During Session 3, Mark responded at a relatively higher rate to all stimuli. During this session, responses to stimuli were mostly undifferentiated except for some short bursts of responding in the escape condition to the preferred stimulus and the moderately preferred stimulus as well as the non-preferred stimulus (nails on a chalkboard) in the avoidance condition. Responses were relatively similar and occurred at a steady rate in the contingency reversal condition. As responses were averaged in Session 3, the graph does not represent the actual intensity of responding, which ranged from 0 to 280 PPM for the same stimulus in the same condition.

Mark's response latencies are shown in Figure 9. Mark did not respond to his non-preferred stimulus at all in the first two sessions of the escape condition, but then responded in 8.7 seconds in the third session. In both the avoidance and reversal conditions, Mark did not respond at all during the first two sessions. Once the stimuli were grouped by colour, with each condition explained beforehand, Mark responded in under 10.0 seconds in both conditions.

Mark's combined averages were almost identical between the two groups. His averages are displayed in Figure 10. He responded at an average of 6, 3, and 81 presses per minute in Sessions 1, 2, and 3, respectively, where higher response rates were expected and responded at an average of 4, 9, and 74 presses per minute in Sessions 1, 2, and 3, respectively, where lower response rates were expected.

Kate

According to the paired preference assessment, Kate's preferred sound was the Bubble Guppies theme song and her non-preferred sounds were the exaggerated child-directed and the synthetic voices. For Kate, the PPM requirement increased from 25 to 65 PPM after Session 2 so that faster key pressing was needed to increase or decrease the volume of the sound. The non-preferred stimuli were changed after Session 4, with nails on a chalkboard and the angle grinder replacing the exaggerated child-directed and the synthetic voices, respectively. These sounds were chosen by the experimenter and were not based on a preference assessment. The preferred sound remained the same throughout all of the assessments, and conditions were grouped together in Session 6 (as opposed to being presented randomly) so that an explanation could occur before each condition. Since the stimuli were grouped together, there were two presentations of each stimulus in every condition instead of one; the data represented are an average of the responses to these two stimuli.

Kate’s second-by-second responding is shown in Figure 11. During the escape and avoidance conditions, Kate responded to her preferred stimulus in all but the last session. Her responses to her non-preferred stimuli were highly variable and tended to fluctuate without a clear pattern from session to session in the escape and avoidance conditions. However, while her responding was variable in the first three sessions of the contingency reversal condition, the last three sessions showed a higher rate of responding in the presence of the preferred stimulus relative to the other stimuli. It is unclear whether the change in PPM requirement increased Kate’s response effort; however, her average responses per minute overall (i.e., across stimuli and conditions) increased from 57 to 86 PPM between Sessions 2 and 3. Her average PPM decreased again in Sessions 5 and 6, but it is not certain whether this was due to the new non-preferred stimuli that were introduced (the preferred sound stayed the same) or if it was due to periods of inattention that were observed during these assessments.

Kate’s response latencies are shown in Figure 12. Overall, Kate’s latency in responding to her preferred stimulus in the escape and avoidance conditions increased (i.e., she took longer to respond over time). Meanwhile, her latency in responding to her non-preferred stimuli decreased in both conditions. Her latency to first response to her preferred stimulus decreased in the reversal conditions over the six sessions and her latency to responding to non-preferred stimuli were variable throughout.

Kate’s combined averages are displayed in Figure 13. Her combined averages in the conditions where lower response rates were expected decreased over the course of six sessions, beginning with 88 responses per minute, then 77 in the second session, increasing to 112 in the third session, and then dropping to 32, 45, and 10 in Sessions 4, 5, and 6, respectively. Her combined averages in the conditions where relatively higher responding would be expected increased over the first four sessions with 33, 41, 65 and 106 average presses per minute, and then decreased in Session 5 to 49 and then again to 40 in Session 6. Although these averages decreased in the last two sessions, the two groups changed in relative value at Session 4, where responses in conditions expected to be higher rose to a relatively higher rate than the other group of conditions.

Noah

Based on the paired preference assessment, Noah’s preferred sound was his own voice and his non-preferred sounds were the exaggerated child-directed and the monotone voices. For Noah, the PPM requirement increased from 25 to 65 PPM after Session 1 so that faster key pressing was needed to increase or decrease the volume of the sound

Noah’s second-by-second responses are shown in Figure 14. In the escape condition of the first session, Noah responded on the key to his preferred stimulus (his own voice) at a moderate rate, turning down the volume twice within 15 seconds. For Sessions 2 and 3 in the escape condition and all sessions in the avoidance condition, he responded to his own voice at a relatively low rate. In the reversal condition, Noah responded to his own voice at a low rate during the first session and then relatively moderate rates for the second and third session. During the escape and avoidance conditions, Noah pressed the key in response to the monotone voice in Session 1, but then mostly responded to the exaggerated child-directed voice in Sessions 2 and 3 in both conditions. The last two sessions of the reversal conditions were highly variable, with the most intense responding to the exaggerated child-directed voice in Session 2 (300 PPM).

Noah's response latencies are shown in Figure 15. In Session 1, Noah responded almost immediately to his preferred stimulus in both the escape and avoidance conditions but it took 12.6 seconds for him to respond to the same sound in the reversal condition. His responses were varied between the non-preferred stimuli in Session 1. In Session 2 and 3, all first key presses occurred within 5 seconds, with the exception of the response to the exaggerated child-directed sound in the escape condition, which took 12.6 seconds.

Noah's combined averages are shown in Figure 16. While his averages were very similar in the first session (28 and 27 average PPM for the conditions where high responding would be expected and conditions where low responding would be expected, respectively), his combined averages for the expected low responding groups increased to relatively higher levels in the last two sessions (66 and 61 average PPM) than the expected high responding group (32 and 36 presses per minute).

Liam

Based on the paired preference assessment, Liam's preferred sound was the Captain Underpants theme song and his non-preferred sounds were the monotone voice and his own voice. These stimuli were changed after Session 2, with the angle grinder and nails on a chalkboard replacing the monotone voice and his own voice, respectively, as a way to increase contrast between the sounds. These sounds were chosen by the experimenter and were not based on a preference assessment. The preferred sound remained the same throughout all of the assessments.

Liam's second-by-second responding is shown in Figure 17. In Session 1, Liam responded at a very low rate during the escape condition to his first non-preferred stimulus (monotone voice) and to both non-preferred stimuli at a low rate in the avoidance and reversal conditions. In Session 2, rates increased for all three stimuli in the escape condition, particularly in response to his preferred stimulus (Captain Underpants theme song). During the same session, there was no responding in the avoidance condition and relatively lower rates of responding in the reversal condition across all three stimuli with slightly higher responding in the presence of his own voice. In Session 3, Liam responded at relatively high rates to the preferred and angle grinder in the escape condition and at similarly high rates to the nails on a chalkboard sound in the avoidance condition. During the reversal condition, he responded with lower and undifferentiated rates to all three stimuli. His highest response rate was to the nails on a chalkboard sound effect at 300 PPM.

Liam's response latencies are shown in Figure 18. In response to his preferred stimulus, Liam did not press the key at all during the first session within the escape and avoidance conditions and it took him 13.9 seconds in the reversal condition. His latency shortened in the second and third sessions in the escape and reversal conditions but he continued to not respond at all to his preferred stimulus during Sessions 2 and 3 of the avoidance condition. Liam's response to non-preferred stimuli shortened by Session 3, where all responses to non-preferred stimuli occurred within 5.0 seconds, with the exception of the response to the nails on a chalkboard sound in the escape condition, which did not occur at all.

Liam’s combined averages are shown in Figure 19. During the first session, Liam’s averages were nearly identical between the conditions where high responding was expected and low responding was expected (an average of 7 and 6 PPM, respectively) with a slight increase in both averages in the second session (16 and 21 PPM, respectively). In the third session, there was a larger discrepancy between averages with 51 PPM, on average, for the conditions where high response rates were expected, and 16 PPM, on average, for the conditions where low responding was expected.

Alex

Based on the paired preference assessment, Alex’s preferred sound was his own voice, and his non-preferred sounds were the child-directed voice and the Paw Patrol theme song. No changes were made to PPM requirements or stimuli.

Alex’s second-by-second graph is displayed in Figure 20. Alex participated in only two sessions; therefore, there was not enough data to observe patterns. In Session 1, Alex responded at the highest rate to his own voice in the escape condition, to the Paw Patrol theme song in the avoidance condition, and to the child-directed voice in the reversal condition, which he appeared to increase twice within the fifteen second sound sample. He responded differently again in Session 2, with a higher rate of key presses in the presence of the Paw Patrol song in the escape condition and to his own voice and the child-directed voice in the avoidance condition. His responding in the reversal condition was undifferentiated.

Alex's response latencies are shown in Figure 21. Alex showed variable latencies in Sessions 1 and 2 across all conditions, except for the reversal condition, where response latencies remained short and stable for the non-preferred stimuli and shortened from 13.6 to 3.0 seconds with the preferred stimulus.

Alex's combined averages are shown in Figure 22. Alex's average responses in conditions where low response rates were expected remained stable across Sessions 1 and 2 at an average of 54 and 51 PPM, respectively. His responses in the conditions where high response rates were expected increased slightly across Sessions 1 and 2 with an average of 26 and 44 PPM, respectively.

James

Based on the paired preference assessment, James' preferred sound was the Mario theme song and his non-preferred sounds were the angle grinder and nails on a chalkboard. No changes were made to PPM requirements or stimuli. Conditions were grouped together in Session 3 (as opposed to being presented randomly) so that an explanation could occur before each condition. Since the stimuli were grouped together, there were two presentations of each stimulus in every condition instead of one and the data represented are an average of the responses to these two stimuli.

James' second-by-second responding is shown in Figure 23. James pressed the key at a low rate in the presence of both non-preferred stimuli during the escape condition for Sessions 1 and 3 and did not respond at all during same condition for Sessions 2 and 4. James never worked to escape his preferred sound (Mario song) in any of the sessions. His rates of responding in the avoidance sessions decreased over the course of four sessions, with relatively higher rates of responding the angle grinder in the first session. During the reversal condition, James maintained a lower rate of responding for all three of the stimuli across 4 sessions. It appeared that he worked to increase the volume slightly and then repeated this behaviour once the volume decreased to baseline, particularly with his preferred stimulus in Session 4. Stimuli were grouped together during the last two sessions but it is unclear if this changed responding in any way.

James' response latencies are shown in Figure 24. James never responded in the presence of the Mario song in the escape condition and always responded within 3.0 seconds in the reversal condition. His latency fluctuated in the avoidance condition, alternating between a response and non-response to the same stimulus. Latencies for his non-preferred stimuli fluctuated across all sessions with no responding during the second and fourth sessions in the escape and avoidance conditions and the fourth session in the reversal condition in response to the nails on a chalkboard sound.

James' combined averages are displayed in Figure 25. There was a very small discrepancy between conditions where high response rates were expected (an average of 18, 4, 6 and 3 PPM across Sessions 1, 2, 3, and 4, respectively) and conditions where low response rates were expected (an average of 91, 13, 9, and 2 PPM across Sessions 1, 2, 3, and 4, respectively).

Chapter IV: Discussion

The present study created a prototype assessment that was the first of its kind to use conjugate schedules of reinforcement as a means to assess the sensitivity of children with an ASD diagnosis to auditory stimuli. As the study was exploratory without similar studies in the literature to guide it, there were numerous limitations which I believe led to varied results between participants. These limitations prevent any conclusions from being made based on the data presented but provide valuable information for consideration in future studies that may attempt to replicate and carry forward the intent to develop a similar tool.

Interpretation of the results is difficult, given the many idiosyncrasies of the participants and the ad-hoc changes made in stimuli, presentation of stimuli, and required response effort. However, there were some interesting global and individual patterns of behaviour that are worth discussing, along with possible explanations of these patterns, associated limitations, and suggestions for improvements in future research.

First of all, all participants except for Mark showed stability in their most preferred sound (i.e., the sound selected most often) across at least two paired preference assessments. Despite this stability, no participant consistently worked to increase a putative preferred sound during the contingency reversal in the escape/avoidance assessment. Furthermore, the participants that showed stability in their least preferred sounds (i.e., the sounds that were selected the least often in comparison to other sounds) did not consistently work to escape or avoid these sounds in the escape/avoidance assessment.

One possible explanation for the lack of correspondence between assessments is that the sounds assumed to be non-preferred could have simply been neutral. The less-often selected stimuli in the preference assessment were labelled as non-preferred stimuli for use in the escape/avoidance assessment. However, selecting a stimulus less often relative to another stimulus does not mean that it is aversive; it is simply not as highly preferred as the other option. For instance, Liam had a preference for the Captain Underpants theme song; he chose the song in every paired presentation during the preference assessment and giggled when it played. Conversely, he disliked the sound of his own voice; he never chose it in any paired presentation of stimuli and consistently expressed his distaste. Nevertheless, during the escape/avoidance assessment, Liam listened to his own voice longer and pressed the key at a lower rate during the escape and avoidance trials in comparison to the preferred stimuli. Perhaps the sound of his own voice was disliked, but it wasn’t worth the response effort to maintain key pressing for an extended period of time.

Another potential explanation for the inconsistency between responses in each assessment could have been that the paired preference assessment was an ineffective tool for identifying a preference hierarchy of auditory stimuli. Alex, in particular, had contradictory results within the paired preference assessment. Initially, he had selected the Paw Patrol theme song the most often in comparison to other sounds. During the subsequent assessments, however, he selected his own voice most often and the Paw Patrol theme song the least often, which was stable across two different assessments. Thus, the Paw Patrol theme song was labelled as a non-preferred stimulus in the escape/avoidance assessment. Interestingly, the data represented in the escape/avoidance assessment almost directly contradicted the information from the preference assessment; Alex did not work at all to escape the Paw Patrol sound sample in either of the escape sessions and avoided the sound in one session. He also worked to maintain the sound in both reversal conditions, with a very high response rate of up to 320 presses per minute. Perhaps the paired preference assessment was not an effective way to select stimuli for use in the escape/avoidance assessment and led to incorrect assumptions about preference. Alex's preference may have changed over time, or he could have been uncertain about the expectation (e.g., selected sounds he thought to be "correct."); either way, it's possible that the paired preference assessment misinformed the escape/avoidance assessment for Alex and potentially other participants.

Another problem with the paired preference assessment was that many children from the ASD group had difficulty localizing sounds (from the right or left speaker) which led to the potential for many unintended errors in their responses. For instance, when a preferred sound was presented before or after a comparison sound, sometimes a participant would point to the wrong speaker but tact the title of the preferred sound. In addition, there were three participants from the ASD group whose paired preference assessments had to be repeated several times because they showed a right or left side bias by choosing the same speaker several consecutive times without any stability in sound selection. While the presentation of stimuli during the preferences assessment was limited to the technology available to the experimenter (e.g., iPhones and basic Bluetooth speakers), future studies may consider adaptations to make the direction of the sound more salient. One possible modification could be adding a visual stimulus, such as a light, that is activated in conjunction with a sound. Visual stimuli could help the participants identify from which direction the sound is coming as well as make it easier to remember each sound that was played. Another future consideration would be to use the HPP (Kemler-Nelson et al.,1995) which is already an established preference assessment procedure for infants and young children (e.g., Kuhl, Coffey-Corina, Padden, & Dawson, 2005). Although, using this particular procedure would be time-consuming if comparing any more than two categories of stimuli, as familiarization trials would need to take place before introducing any new stimuli, with only two comparisons being made per session.

A limiting factor that may have accounted for some differences between the paired preference and escape/avoidance assessments was the minimal control for volume. Although the vocal stimuli were recorded on the same device, there were natural deviations in volume between samples. In addition, any sound effects or music purchased from iTunes tended to be louder than any recorded stimuli. It was possible to control the volume during the paired presentation of auditory stimuli, as they were manually played from two different devices; however, the escape/avoidance assessment software did not have a volume control option and allowed for variability between samples. The only volume limiter was the headphones, which were designed for children and prevented the volume from reaching levels over 80 dB. In addition, the preferred samples were acoustically very different from all other samples. For example, the recorded voice samples had one sound (an adult's voice or the child's own voice) with no background noise. Similarly, stimuli that were added later (nails on a chalkboard, angle grinder, frogs chirping, water running), involved one single sound, with the exception of the frogs chirping, which had a few other quiet pond sounds. Most of the preferred stimuli were songs from favourite TV shows or movies and included vocals, drums, guitars, synthesizers, sound effects, etc., which may have made the sound to be perceived as much louder in comparison to the other sounds. Volume was clearly an issue for Joshua, who responded differently between the paired preference assessment and the escape/avoidance assessment. During the paired preference assessment, Joshua selected the Paw Patrol theme song each time it was presented in contrast with another sound. In many trials, he picked up the speaker and hugged it when the song played to show his preference. However, once the same song was played on the headphones, Joshua responded by key press at a relatively higher rate than the other stimuli to escape or avoid the sound. When asked at the end of the third assessment why he pressed the key when the Paw Patrol song played, he stated that it was "too loud." Future studies would need to add a volume control option to the software so that the volume of the auditory stimuli could be held constant. It would also be worth exploring playback source (i.e., Bluetooth speakers vs. headphones) as an influencing factor to the preference or aversiveness of certain sounds, similar to the Buckley and Newchok (2006) study which found that taped music was associated with increased rates of problem behaviour

A helpful addition to the data exported after each assessment would have been the decibel level at which each stimulus was maintained for the participants. Many participants maintained a slow rate of pressing the key, which would have either decreased the volume slightly or increased the volume slightly, depending on the condition. For example, James maintained a low response rate (i.e., no more than 20 presses per minute) during his preferred sound for the contingency reversal condition across all four sessions. As a single key press resulted in a very small increase in volume, it appeared that James wanted to hear the sound but never worked harder to increase the volume. Programming the software so that it exports data on volume would be incredibly useful. This modification would allow the experimenter to identify the average volumes at which the participants preferred each sound. It some sense, this measure would be more useful than presses per minute, as the reversal condition did not require as many presses per minute to hear a sound at a low volume in comparison to the escape condition, where a high rate of key pressing was required to reduce the volume to a similar level.

Another interesting observation was the unanticipated selection of stimuli thought to be aversive over stimuli thought to be preferred during the paired preference assessment. When new stimuli were included in preference assessments for Joshua, Mark, Kate, and James, three of the four participants selected the sound of nails on a chalkboard more often than the sound of frogs chirping. It's possible that the participants' lack of experience with these sounds affected their responses. The newly added stimuli were selected based on a study using adult's perceptions of unpleasant sounds (Kumar et al., 2008), but adults may have a very different perception of sounds based on their history with these sounds. More specifically, classical conditioning of sounds paired with experiences may be responsible for positive or negative associations. For example, the sounds of running water in a stream or frogs chirping in a pond are typically paired with outings in nature, something that adults could have a long history of experiencing on television or in person, but a child may have limited experience with. Similarly, nails on a chalkboard could be associated with the unpleasant feeling of nails on a chalkboard or a similar surface, but a child may never have experienced this themselves. Furthermore, the in-person experience of a sound like an angle grinder can be unpleasant due to the decibel level and duration of the sound, but when it is represented at a lower decibel level and shorter duration, may not be as aversive for someone without experience of an angle grinder. In one paired preference assessment, Mark tacted, "Tools!" with a positive affect in response to the angle grinder, signalling that he recognized the sound but it potentially wasn't aversive.

One issue that made the assessment results difficult to interpret was the lack of differential responding between conditions or stimuli for the escape/avoidance assessment for many of the participants, particularly in the first one or two sessions of the assessment. Factors that may have affected responding included difficulties in making conditional discriminations, overgeneralized responding, and attentional difficulties.

A large limitation with the escape/avoidance assessment was that it required the participants to make conditional discriminations that may have taken several sessions to learn. Specifically, the participants had to consider both the colour on the screen and the auditory stimuli before responding on the key: if a preferred sound played and the screen was red, their response would turn the volume down, but if the screen was green, it would turn the volume up. Since the stimuli and conditions were randomly mixed for each assessment, the participants may have not been able to quickly learn the different conditions and therefore did not discriminate between them. Kate, for example, consistently responded on her preferred stimulus for the first three assessments no matter the condition. During these sessions, her response turned down the volume on her preferred sound (Bubble Guppies theme song), even though it was a highly preferred sound based on the data from the paired preference assessment and behavioural observations (i.e., she would request the song and dance to it when it played during the preference assessment). Over time, she appeared to begin to discriminate between conditions, but a greater number of assessments would be required to confirm this.

Furthermore, there were differences in responding between the stimuli in the escape and avoidance conditions; several of the participants responded to a sound during the escape condition but did not respond to the same sound in the avoidance condition (i.e., they allowed the sound to increase). In addition, many of the participants, including both of the typically developing participants did not respond on several of the contingency reversal trials (i.e., after the preview played and the sound went silent), which was likely due to a failure of the discriminative stimulus to evoke responding in this condition.

One way that the experimenter attempted to simplify the discrimination was to group together the conditions. For example, the experimenter would explain the green (contingency reversal) condition and then allow the participant to complete the assessment where the key press only increased the volume. Within one condition, the three stimuli were played two times each. Afterwards, the experimenter would explain the next condition and allow the participant to complete the next part of the assessment, and so on. This adjustment was made for three of the participants (Sarah, Mark, and James) but did not lead to any differentiated responding between stimuli. It did, however, increase the overall rate of responding for Mark, which signalled that he may have been unsure of how to respond during the previous trials.

Future studies may want to separate the conditions from the beginning so that learning can occur faster. It may also be beneficial to include a demonstration trial at the beginning of each condition rather than before the first trial of the session. Identifying ways to accelerate learning would be a necessary improvement, as assessments lose their utility when a participant needs several sessions just to learn the assessment before testing can take place.

Another factor that may have influenced response patterns was the participant’s history of compliance. Whether or not the participant was able to discriminate between conditions, they may have simply been following an instruction to press a key, which would have led to steady, undifferentiated rates of responding. A prize box was available to access at the end of the assessment, which may have functioned as reinforcement for the generalized response of key-pressing. Sarah, in particular, showed steadier and steadier rates of responding with each assessment until her responses in each condition were almost identical. As discussed in the case of Alex, who showed opposing results in his paired preference assessment, a history of reinforcement for making a correct response could also influence responding. Although all of the participants had, at some point, learned how to make a choice based on preference, the presentation of auditory stimuli would have been a novel variation, of which they would not be familiar. Therefore, choosing one stimulus over another could have been based on an entirely different factor than preference. While the experimenter was careful to not comment on or praise one choice over another, phrases of acknowledgement like “This one?” or “Ok” could have inadvertently reinforced certain responses. Although difficult to prove in the present study, theoretically speaking, this type of random, ambiguous responding could lead to superstitious behaviour such as choosing a certain sound or a certain speaker during the paired preference assessment.

Finally, each participant’s ability to attend to a task may have affected their response rates. Some participants engaged in stereotypic behaviour (e.g., singing or scripting) while others attempted to talk to the experimenter or were distracted by something else in the room. When participants were off task, response rates typically decreased, which could account for some of the variability seen across conditions and stimuli.

Several other methodological limitations were identified, including the relatively small number of assessments completed, the small sample size of typically developing children, and the utility of the response latency measure. The number of total assessments (i.e., preference assessments and escape/avoidance assessments inclusive) differed between participants and were based on their availability to complete the assessments. Some participated in over ten total sessions while others were available for as few as five. More assessments would have offered more longitudinal data on learning, especially for Kate and Liam, who appeared to be adapting their responses over time to the stimuli presented in each condition, and for Alex, who only participated in two escape and avoidance assessments. As the stimuli or the arrangement of stimuli was changed for many of the participants, several more sessions were needed to judge whether or not the change made a difference in responding. Future studies may want to include a greater number of assessment sessions so that more data can be available for analyzing patterns of behaviour. As new stimuli were added for better contrast between sound samples, a multiple-baseline design could be useful in the future to compare responding before and after the addition of new stimuli.

Furthermore, the small sample size of two typically developing children and six children with an ASD diagnosis offered an unbalanced comparison, especially because the typically-developing participants were each exposed to different stimuli in the paired preference and escape/avoidance assessments. Recruiting an equal number of typically developing and ASD-diagnosed individuals would allow for an easier comparison between groups.

Finally, the response latency measure was, at times, unreliable. There were many participants who were observed to press the spacebar at the end of a condition and continue pressing during the screen transition and into the subsequent condition. Therefore, the latency to the first key press did not always provide a representation of responses controlled by the current stimulus. In other words, these short latencies gave the impression that the participant was pressing the key quickly in response to the auditory stimulus, when really, it could be measuring a carryover response from the previous condition.

Similar studies in the future would benefit from better volume controls, the ability to export data on decibel level, separated conditions to improve discrimination, and a larger and more balanced group of participants, with and without an ASD diagnosis. Another consideration for future research would be a more selective recruitment process. All children in this particular study were over the age of three and, based on the parent questionnaire, the majority did not show sensitivity to loud or high-pitched sounds or to adult voices. All of the children with an ASD diagnosis in the present study had received at between one and three years of intensive ABA treatment, which put them in contact with a variety of different adults for several hours per day. Repeated pairings of adult voices with the delivery of reinforcement could have increased the value of vocal stimuli and minimized its aversiveness. It would be an interesting endeavour to screen out participants without auditory sensitivities as well as compare the responses to vocal stimuli of younger or newly diagnosed children who have not received clinical attention with those who have.

While the present study did not demonstrate reliability of an escape/avoidance assessment for auditory stimuli, it did raise questions about the utility of paired preference assessments, the influence of volume on sound preference, and how a participant's learning history may influence their responding on a new assessment. Future modifications to the assessment could contribute to more stable responding and, therefore, more certain conclusions, which may eventually provide small pieces of evidence to support or refute Bijou and Ghezzi's behaviour interference theory.

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Appendix A: Tables and Figures

Table 1

Average pitch and pitch range of each speech sound sample, measure in Hertz (Hz).

Stimulus	Average pitch	Minimum pitch	Maximum pitch	Range
Synthetic speech	169	76	240	164
Monotone speech	201	81	287	206
Adult-directed speech	188	69	443	374
Child-directed speech	230	67	507	440
Exaggerated child-directed speech	271	68	527	459

Table 2

Sound samples used in the escape/avoidance assessment

Participant	Preferred	Non-preferred 1	Non-preferred 2	Preferred (New Stimuli)	Non-preferred 1 (New Stimuli)	Non-preferred 2 (New Stimuli)
Sarah (ASD)	Paw Patrol Theme Song	Exaggerated Child-Directed	Synthetic	*Hakuna Matata*	*Angle Grinder*	*Nails on a Chalkboard*
Joshua (NT)	--	--	--	Paw Patrol Theme Song	Frogs Chirping	Angle Grinder
Mark (ASD)	--	--	--	*Paw Patrol Theme Song*	*Running Water**	*Nails on a Chalkboard*
Kate (ASD)	Bubble Guppies Theme Song	Exaggerated Child-Directed	Synthetic	Bubble Guppies Theme Song	*Nails on a Chalkboard*	*Angle Grinder*
Noah (ASD)	Own voice	Exaggerated Child-Directed	Monotone	--	--	--
Liam (ASD)	Captain Underpants Theme Song	Monotone	Own voice	Captain Underpants Theme Song	*Angle Grinder*	*Nails on a Chalkboard*
Alex (NT)	Own voice	Child-directed	Paw Patrol Theme Song	--	--	--
James (ASD)	--	--	--	Super Mario	Angle Grinder	Nails on a Chalkboard

Note: Italicized stimuli were experimenter-selected and not based on preference assessments. *Mark's Non-Preferred 1 stimulus was labelled as moderately preferred and was selected by the experimenter.

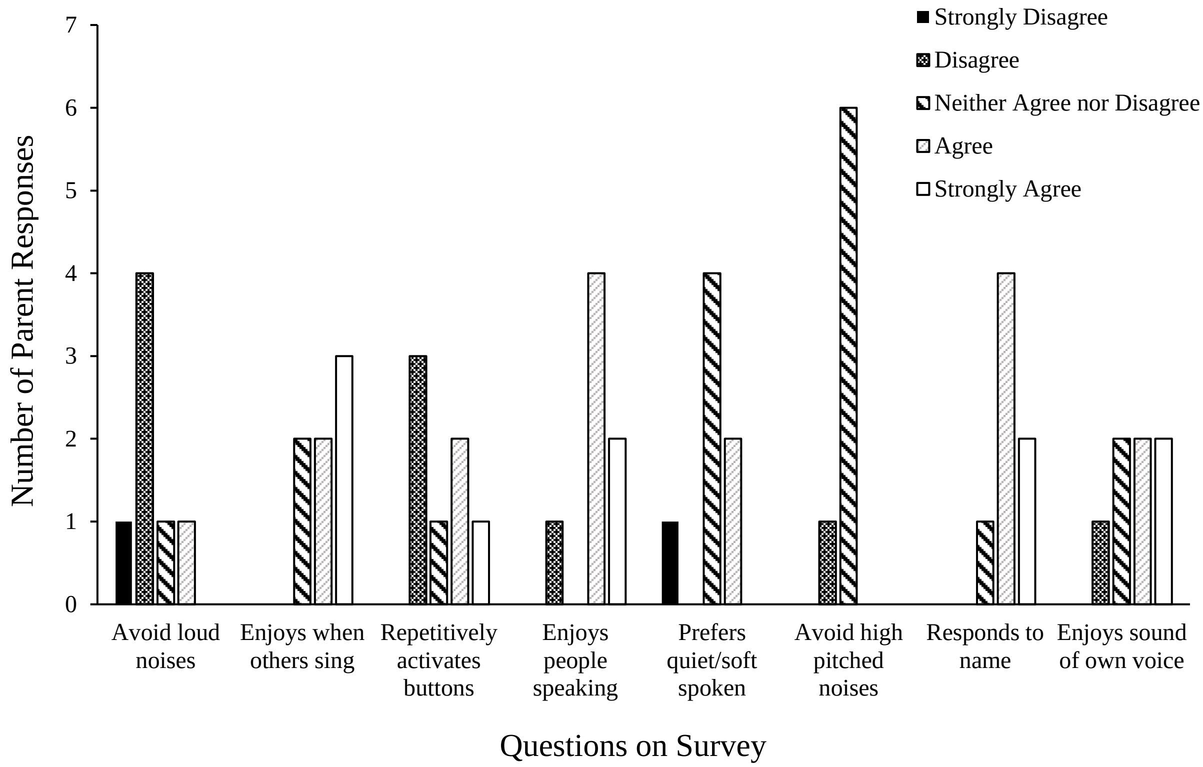


Figure 1. Responses to questions on parent survey regarding sensitivity to auditory stimuli.

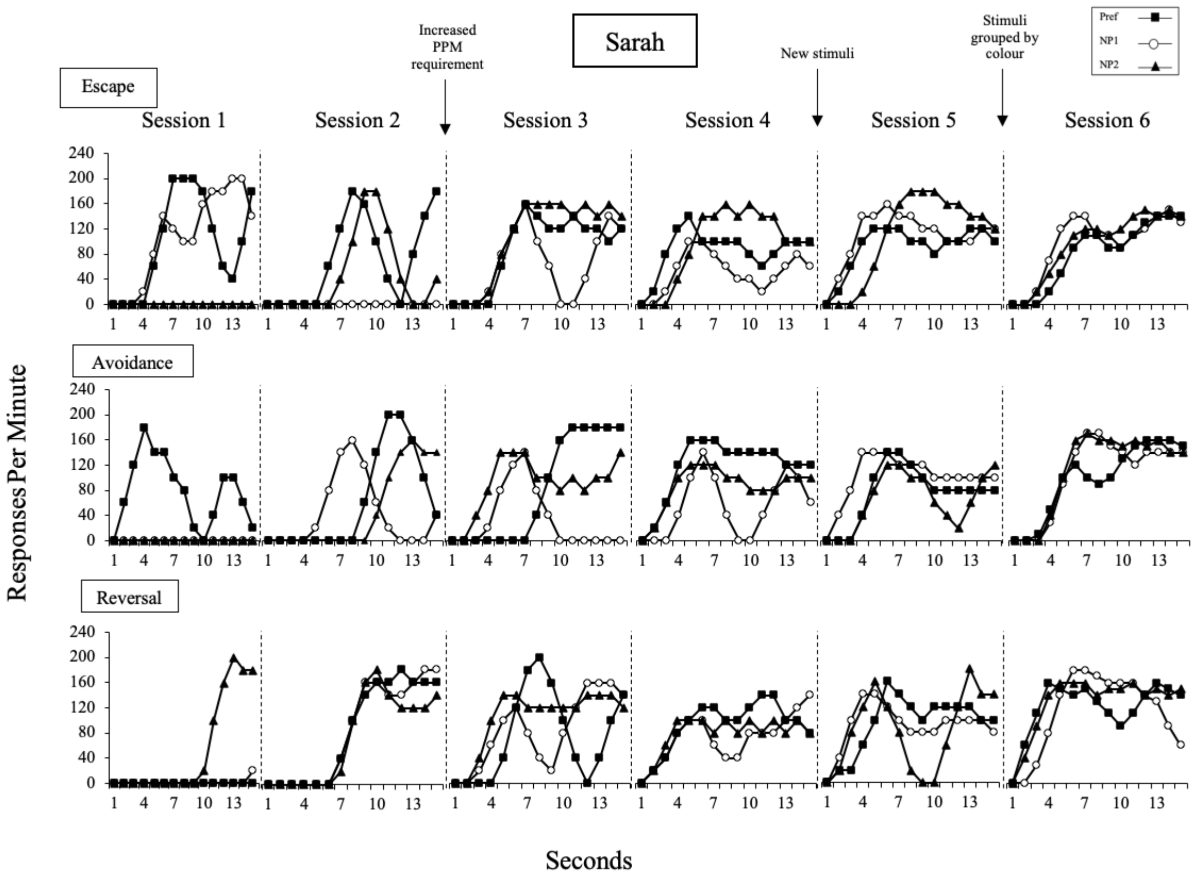


Figure 2. Sarah's second-by-second responses, measured by responses per minute. Sarah's preferred stimulus (Pref) was the Paw Patrol theme song. Her first non-preferred stimulus (NP1) was the exaggerated child-directed voice and her second non-preferred stimulus (NP2) was the synthetic voice. The response per minute requirement was increased in Session 3 from 25 to 65 key presses per minute. New stimuli were introduced at Session 5. Stimuli were grouped by colour during the assessment for Session 6. For Session 6, the data displayed is the average between two presentations of the same stimulus in the same condition.

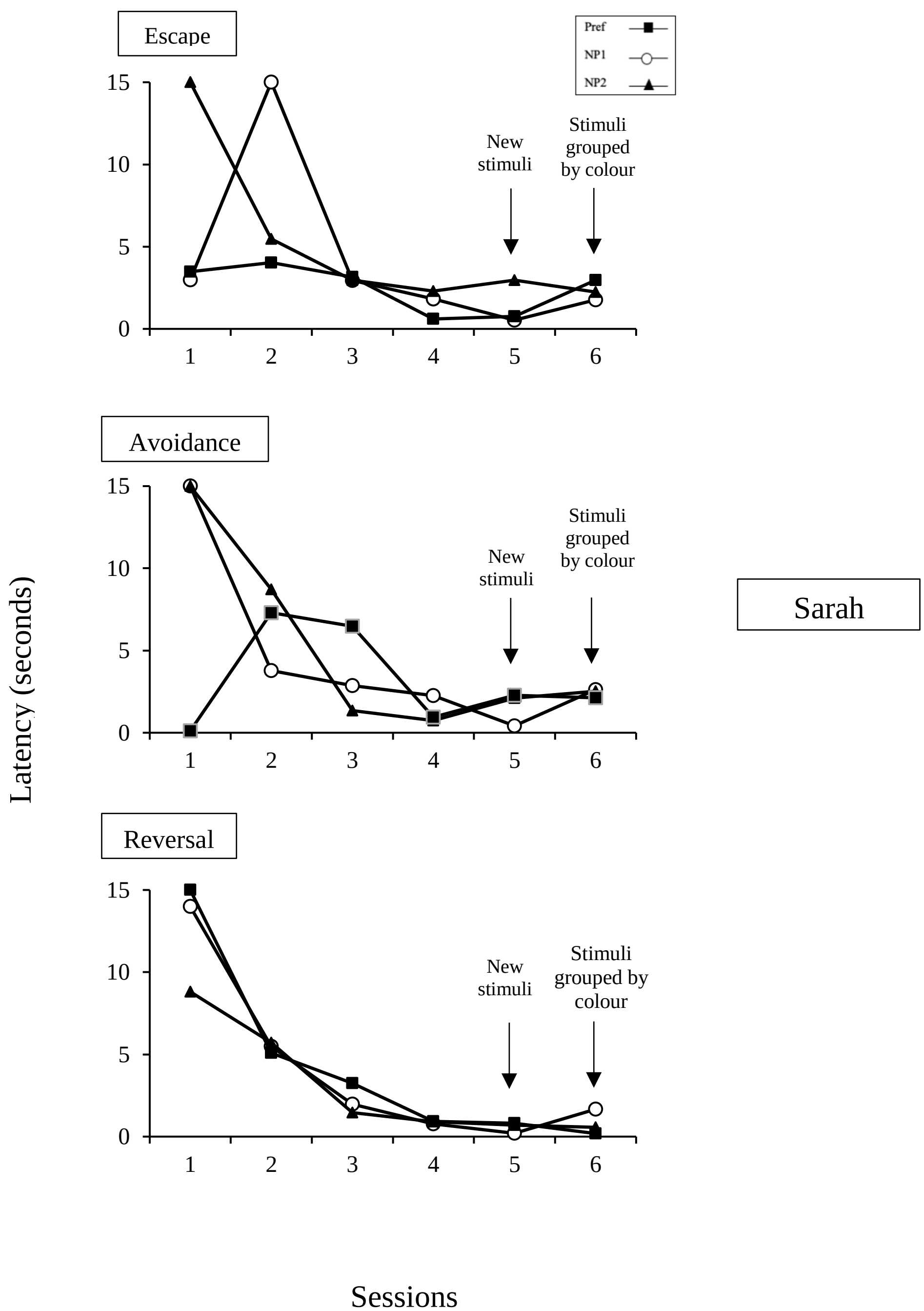


Figure 3. Sarah's latency to first key press, measured in seconds. Sarah's preferred stimulus (Pref) was the Paw Patrol theme song. Her first non-preferred stimulus (NP1) was the exaggerated child-directed voice and her second non-preferred stimulus (NP2) was the synthetic voice. New stimuli were introduced at Session 5. Stimuli were grouped by colour during the

assessment for Session 6. For Session 6, the data displayed is the average between two presentations of the same stimulus in the same condition.

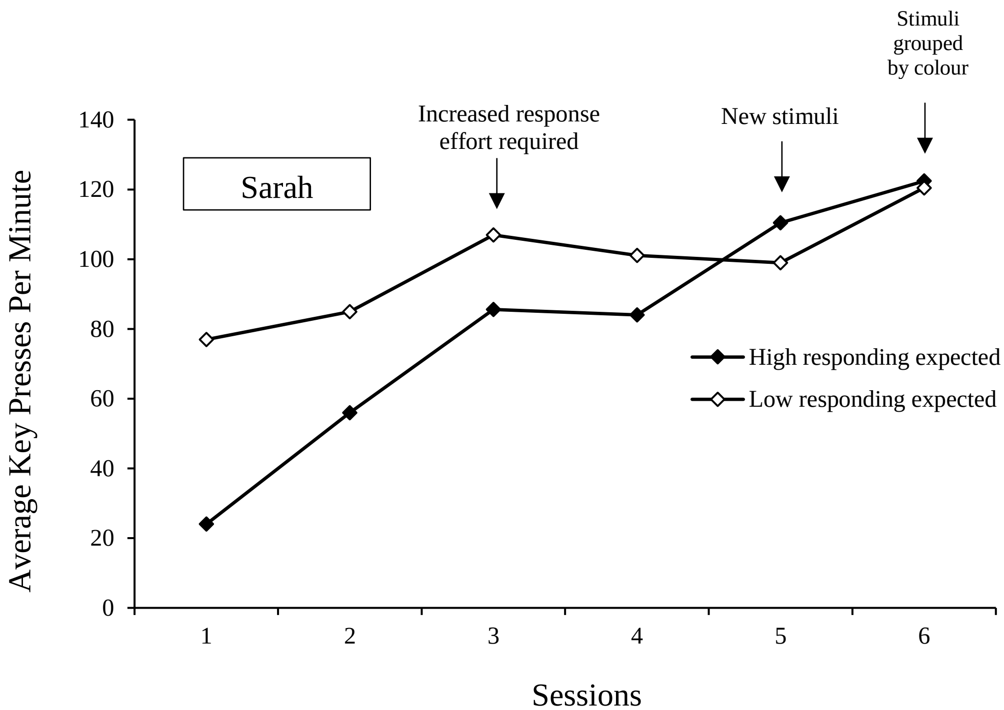


Figure 4. Average key presses per minute in response to auditory stimuli. High responding expected in escape conditions of non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal conditions of preferred stimuli. Low responding expected in escape conditions of preferred stimuli, avoidance conditions of preferred stimuli, and contingency reversal conditions of non-preferred stimuli.

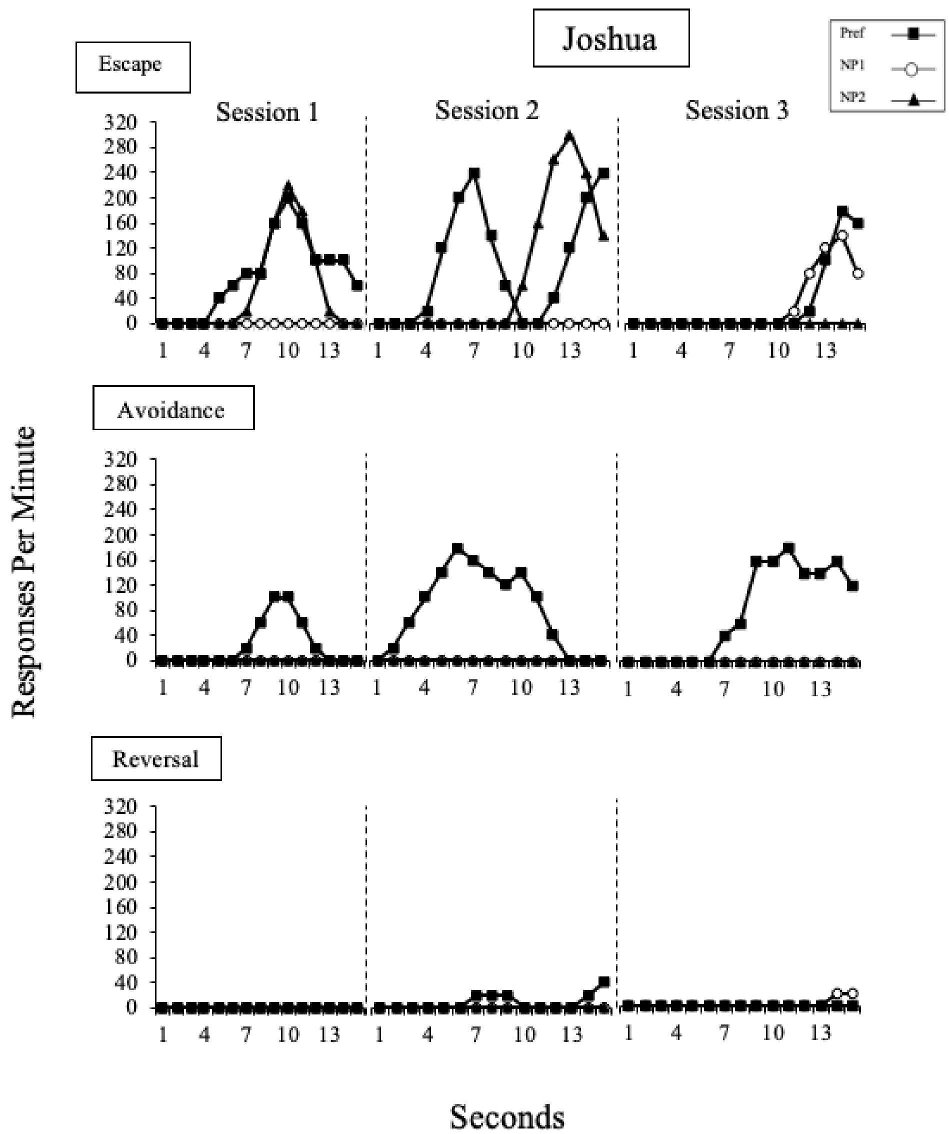


Figure 5. Joshua's second-by-second responses, measured by responses per minute. Joshua's preferred stimulus (Pref) was the Paw Patrol theme song. His first non-preferred stimulus (NP1) was the frogs chirping sound effect and his second non-preferred stimulus (NP2) was the angle grinder.

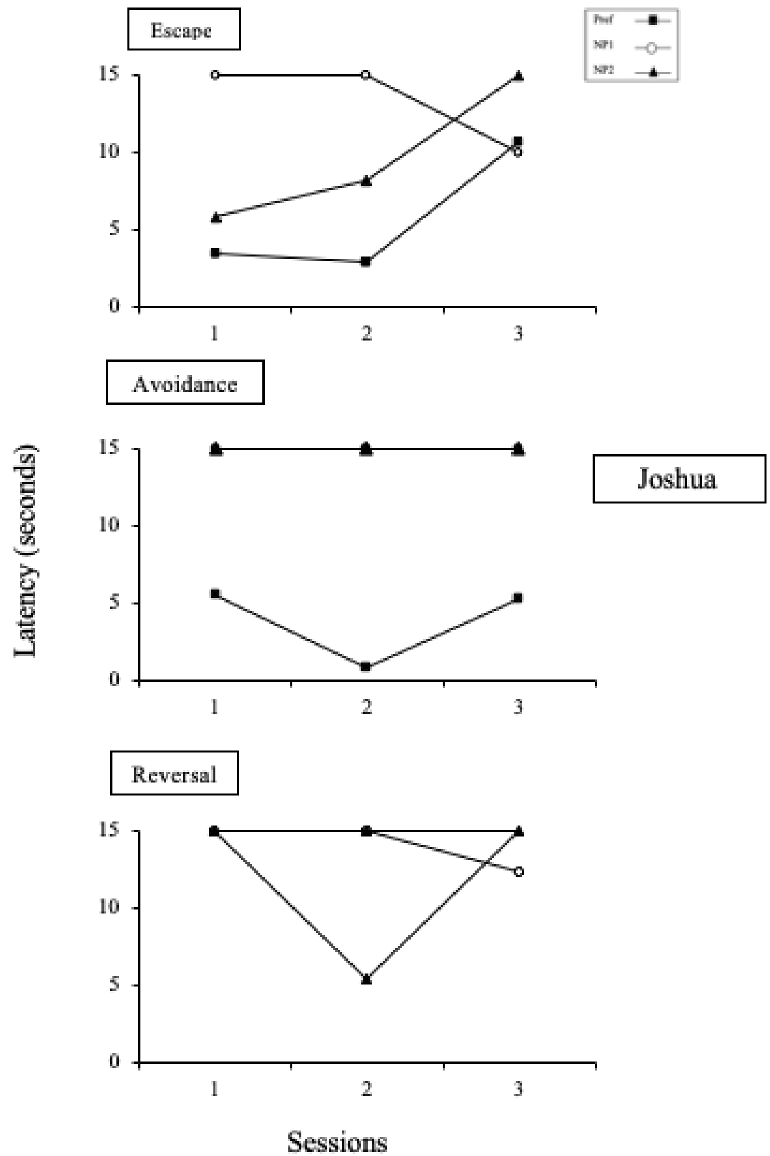


Figure 6. Joshua's latency to first key press, measured in seconds. Joshua's preferred stimulus (Pref) was the Paw Patrol theme song. His first non-preferred stimulus (NP1) was the frogs chirping sound effect and his second non-preferred stimulus (NP2) was the angle grinder.

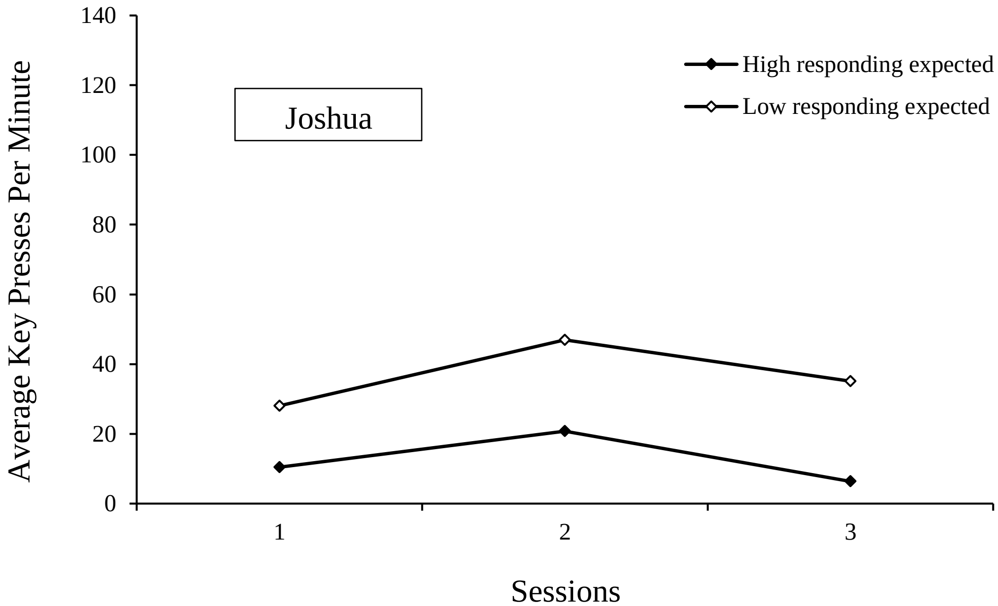


Figure 7. Average key presses per minute in response to auditory stimuli. High responding expected in escape conditions of non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal conditions of preferred stimuli. Low responding expected in escape conditions of preferred stimuli, avoidance conditions of preferred stimuli, and contingency reversal conditions of non-preferred stimuli.

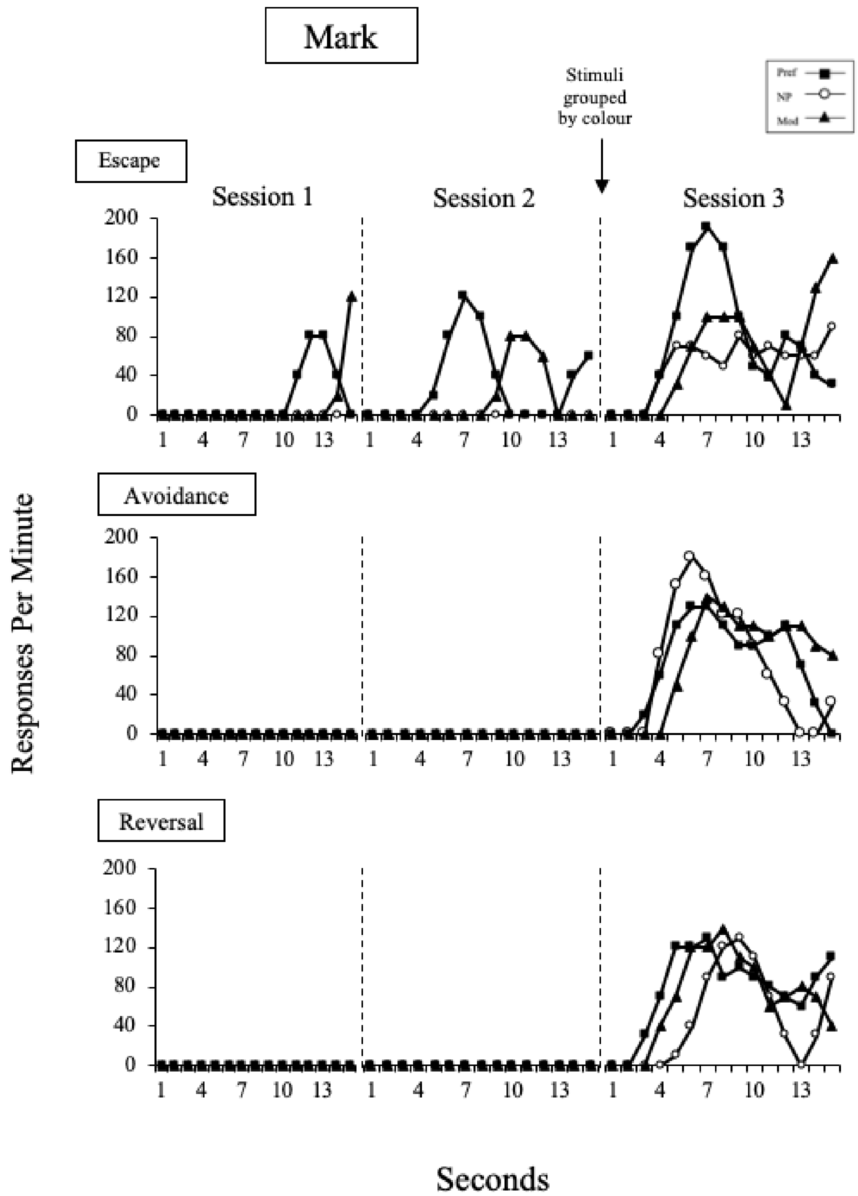


Figure 8. Mark's second-by-second responses, measured by responses per minute. Mark's preferred stimulus (Pref) was the Paw Patrol theme song. His moderately preferred stimulus (Mod) was the water running sound effect and his non-preferred stimulus (NP) was the nails on a chalkboard. All sounds were chosen for Mark due to lack of stability during paired preference assessments; therefore, this is a presumed ranking of preference. Stimuli were grouped by colour during the assessment for Session 3. For Session 3, the data displayed is the average between two presentations of the same stimulus in the same condition

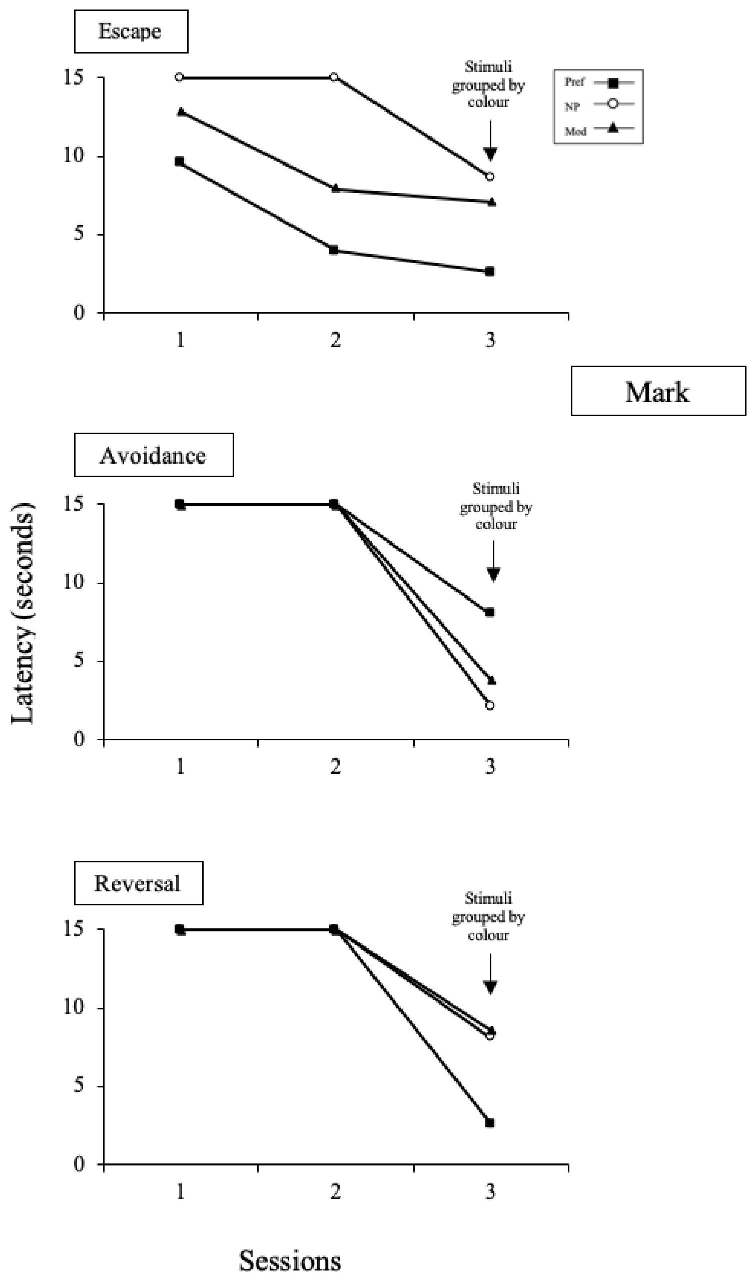


Figure 9. Mark's latency to first key press, measured in seconds. Mark's preferred stimulus (Pref) was the Paw Patrol theme song. His moderately preferred stimulus (Mod) was the water running sound effect and his non-preferred stimulus (NP) was the nails on a chalkboard. All sounds were chosen for Mark due to lack of stability during paired preference assessments; therefore, this is a presumed ranking of preference. Stimuli were grouped by colour during the

assessment for Session 3. For Session 3, the data displayed is the average between two presentations of the same stimulus in the same condition

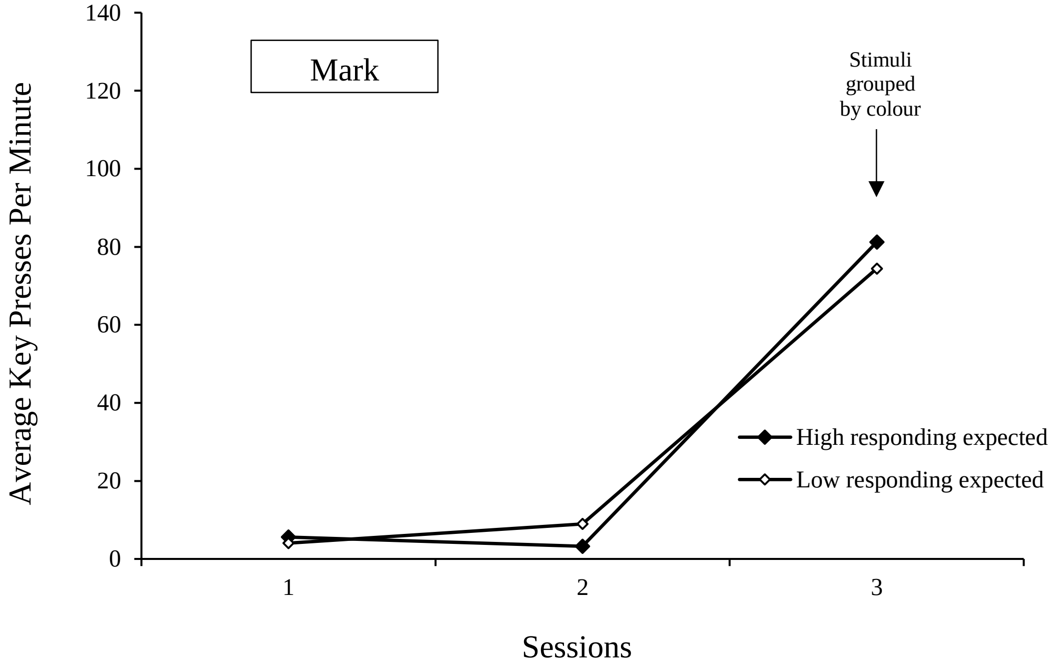


Figure 10. Average key presses per minute in response to auditory stimuli. High responding expected in escape conditions of non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal conditions of preferred stimuli. Low responding expected in escape conditions of preferred stimuli, avoidance conditions of preferred stimuli, and contingency reversal conditions of non-preferred stimuli.

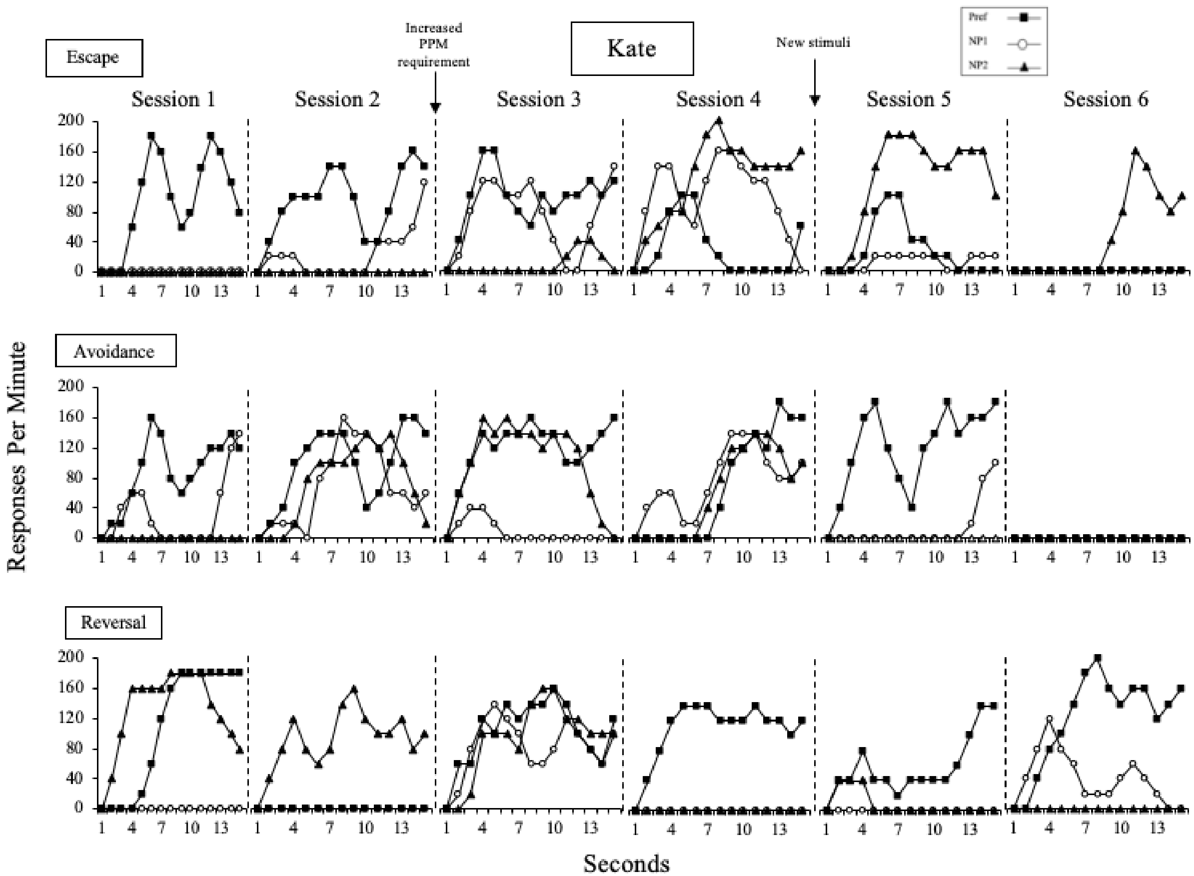


Figure 11. Kate’s second-by-second responses, measured by responses per minute. Kate’s preferred stimulus (Pref) was the Bubble Guppies theme song. Her first non-preferred stimulus (NP1) was the exaggerated child-directed voice and her second non-preferred stimulus (NP2) was the synthetic voice. The response per minute requirement was increased in Session 3 from 25 to 65 key presses per minute. New non-preferred stimuli were introduced at Session 5.

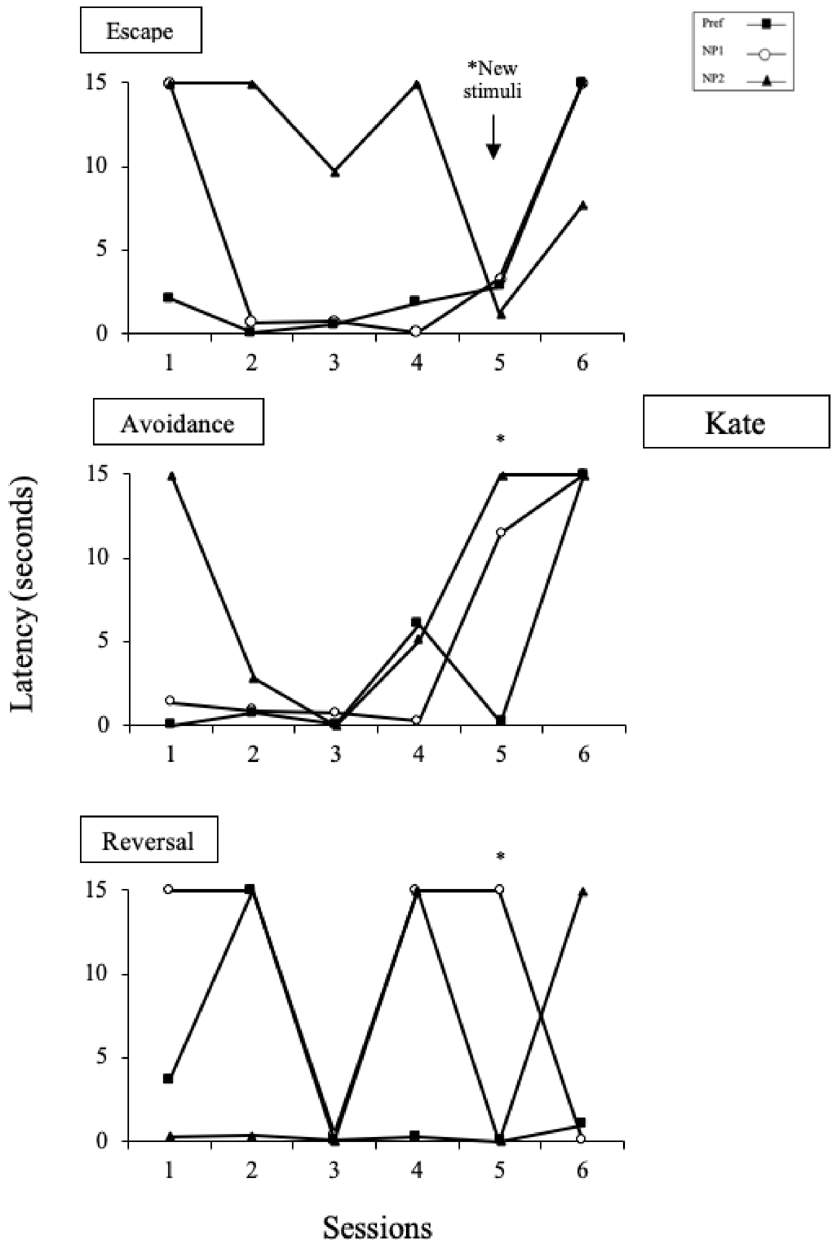


Figure 12. Kate’s latency to first key press, measured in seconds. Kate’s preferred stimulus (Pref) was the Bubble Guppies theme song. Her first non-preferred stimulus (NP1) was the exaggerated child-directed voice and her second non-preferred stimulus (NP2) was the synthetic voice. The response per minute requirement was increased in Session 3 from 25 to 65 key presses per minute. New non-preferred stimuli were introduced at Session 5.

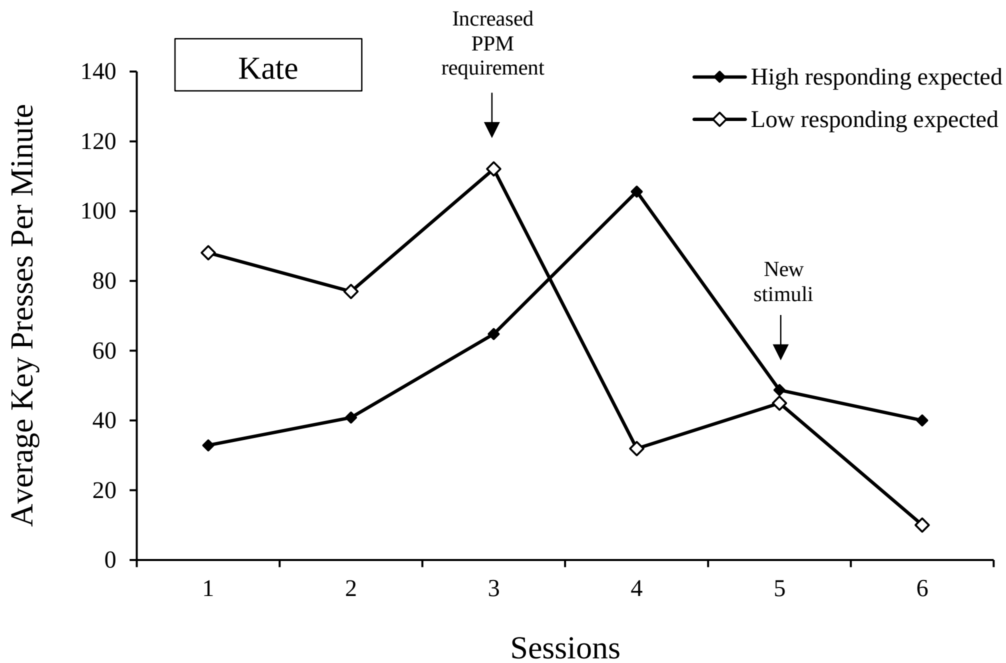


Figure 13. Average key presses per minute in response to auditory stimuli. High responding expected in escape conditions of non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal conditions of preferred stimuli. Low responding expected in escape conditions of preferred stimuli, avoidance conditions of preferred stimuli, and contingency reversal conditions of non-preferred stimuli.

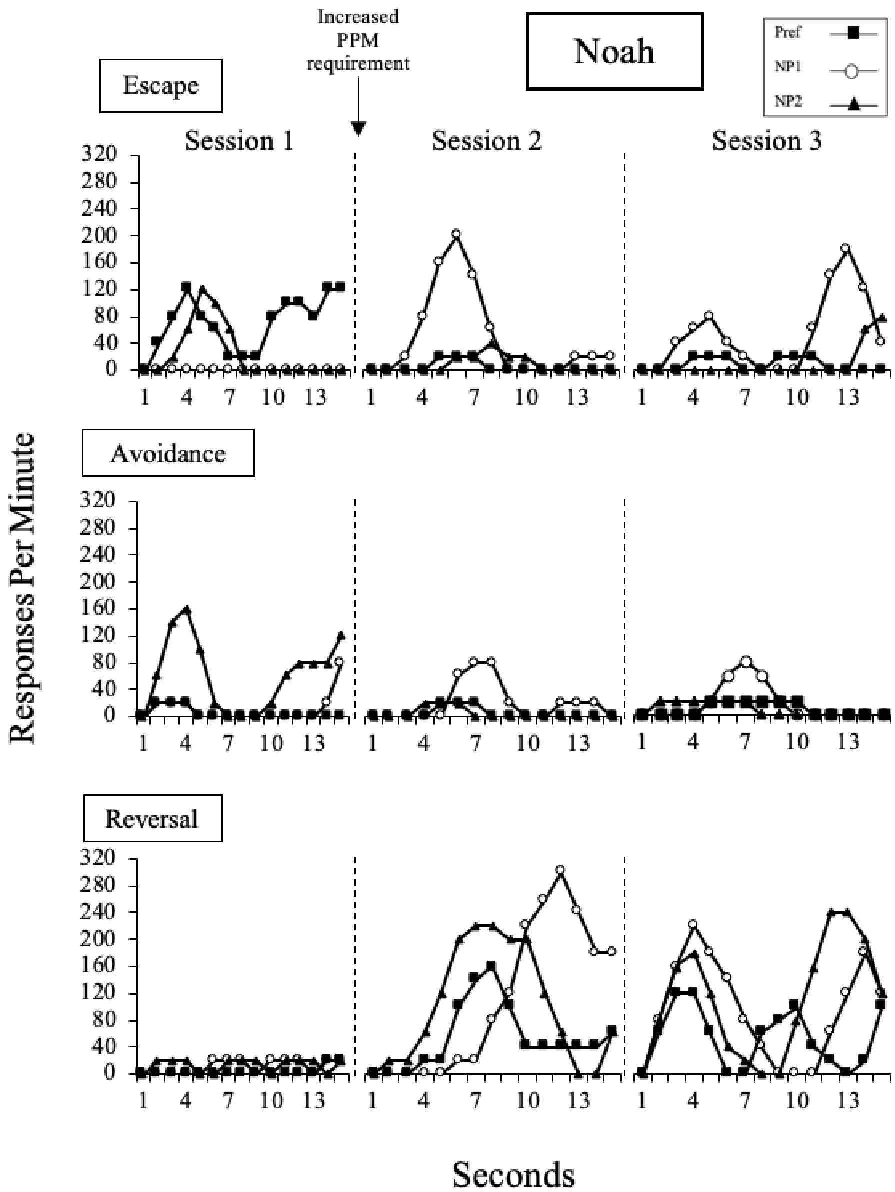


Figure 14. Noah's second-by-second responses, measured by responses per minute. Noah's preferred stimulus (Pref) was his own voice. His first non-preferred stimulus (NP1) was the exaggerated child-directed voice and his second non-preferred stimulus (NP2) was the monotone voice. The response per minute requirement was increased in Session 2 from 25 to 65 key presses per minute

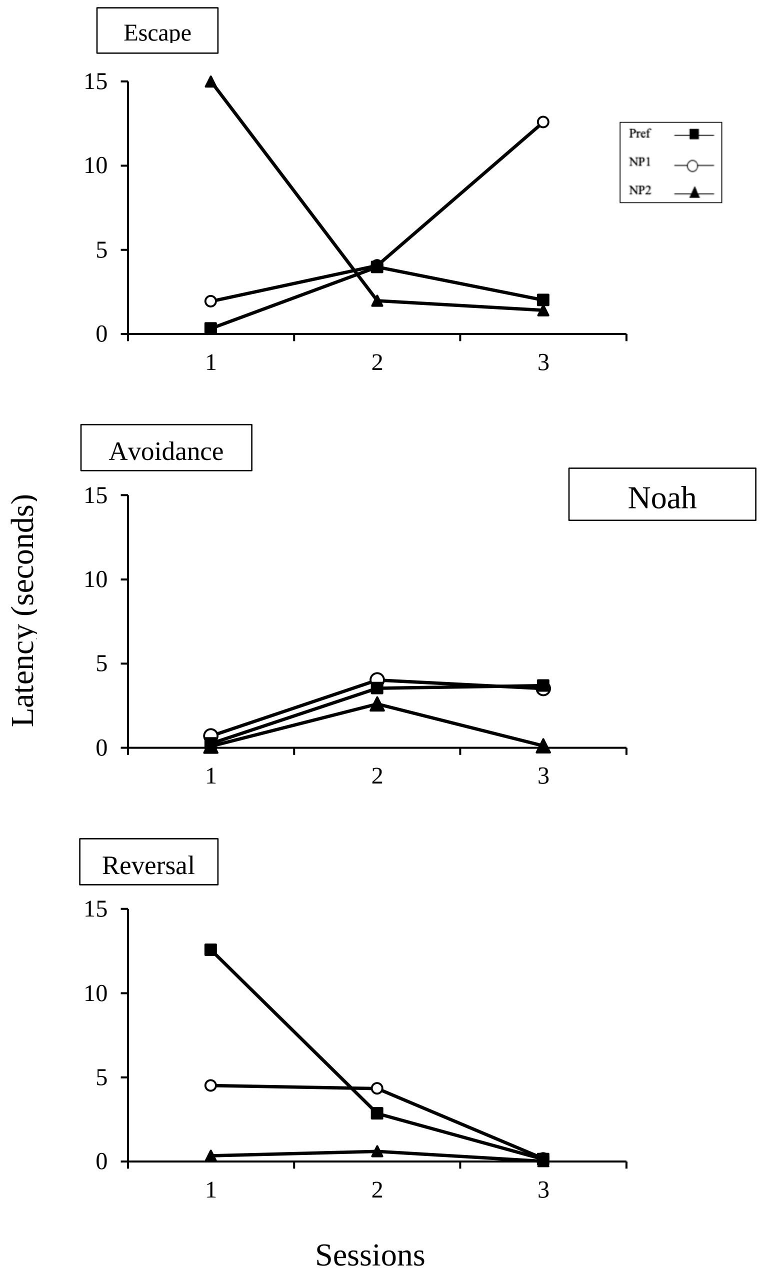


Figure 15. Noah’s latency to first key press, measured in seconds. Noah’s preferred stimulus (Pref) was his own voice. His first non-preferred stimulus (NP1) was the exaggerated child-directed voice and his second non-preferred stimulus (NP2) was the monotone voice. The response per minute requirement was increased in Session 2 from 25 to 65 key presses per minute

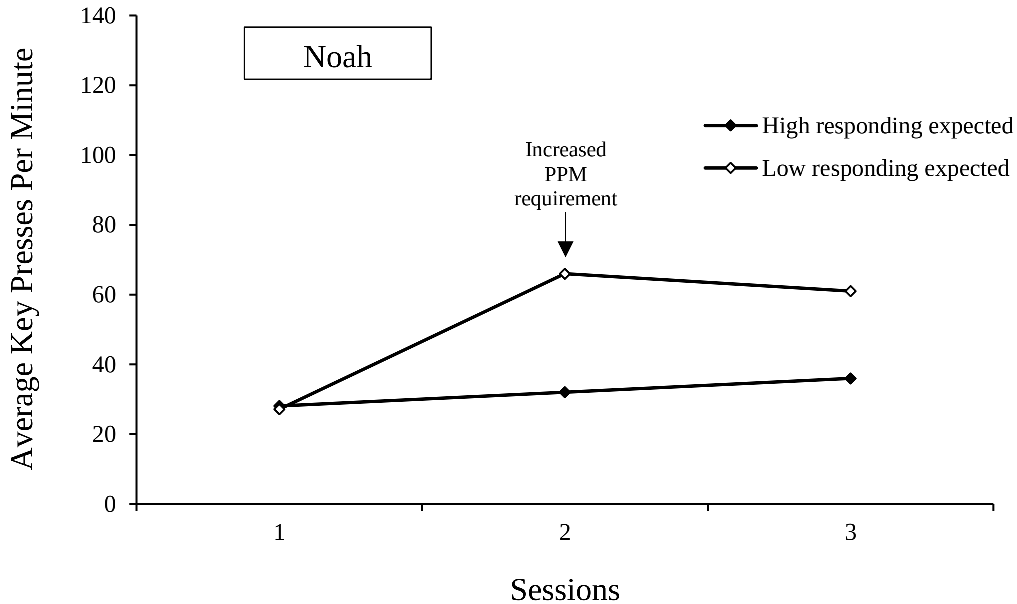


Figure 16. Average key presses per minute in response to auditory stimuli. High responding expected in escape conditions of non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal conditions of preferred stimuli. Low responding expected in escape conditions of preferred stimuli, avoidance conditions of preferred stimuli, and contingency reversal conditions of non-preferred stimuli.

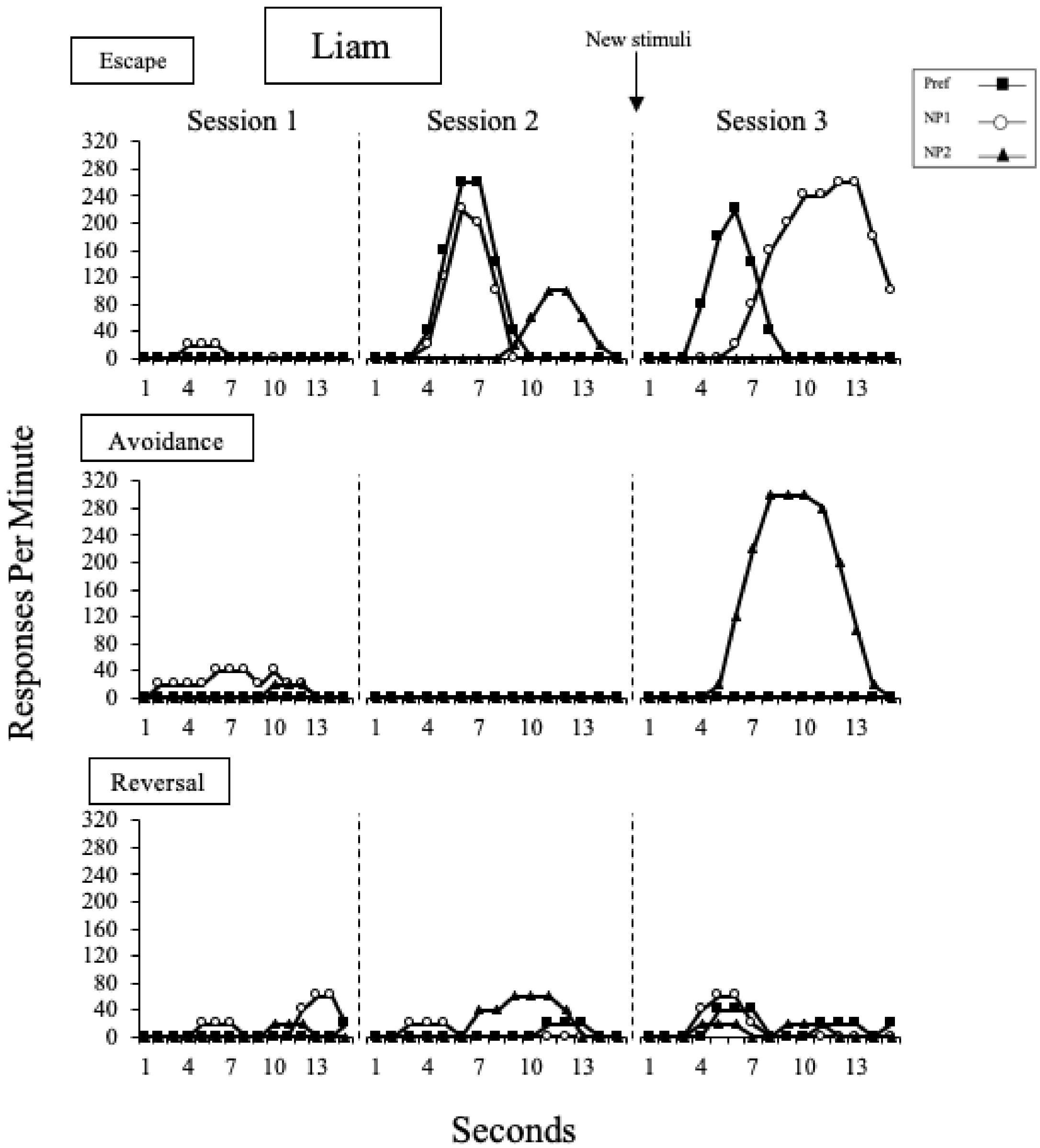


Figure 17. Liam's second-by-second responses, measured by responses per minute. Liam's preferred stimulus (Pref) was the Captain Underpants theme song. His first non-preferred stimulus (NP1) was the monotone voice and his second non-preferred stimulus (NP2) was his own voice. New non-preferred stimuli were introduced in Session 3.

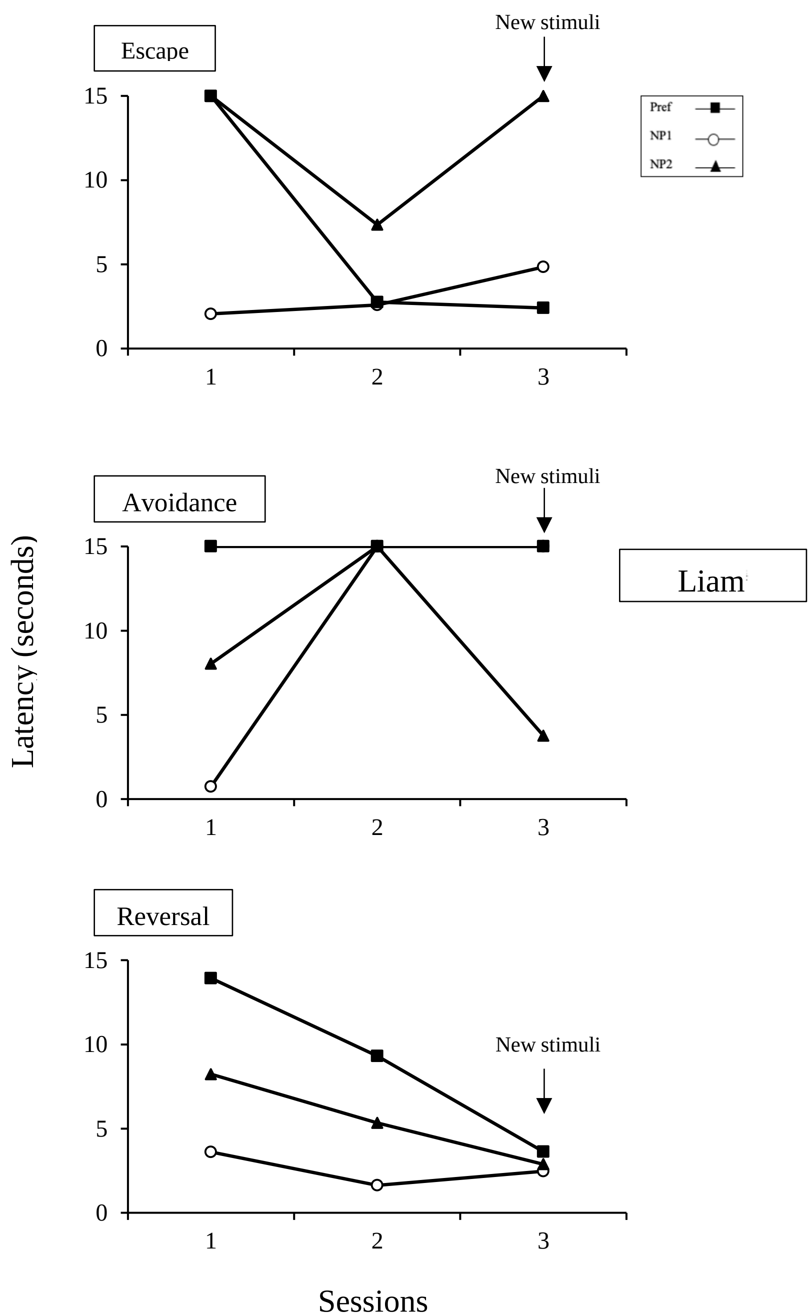


Figure 18. Liam's latency to first key press, measured in seconds. Liam's preferred stimulus (Pref) was the Captain Underpants theme song. His first non-preferred stimulus (NP1) was the monotone voice and his second non-preferred stimulus (NP2) was his own voice. New non-preferred stimuli were introduced in Session 3.

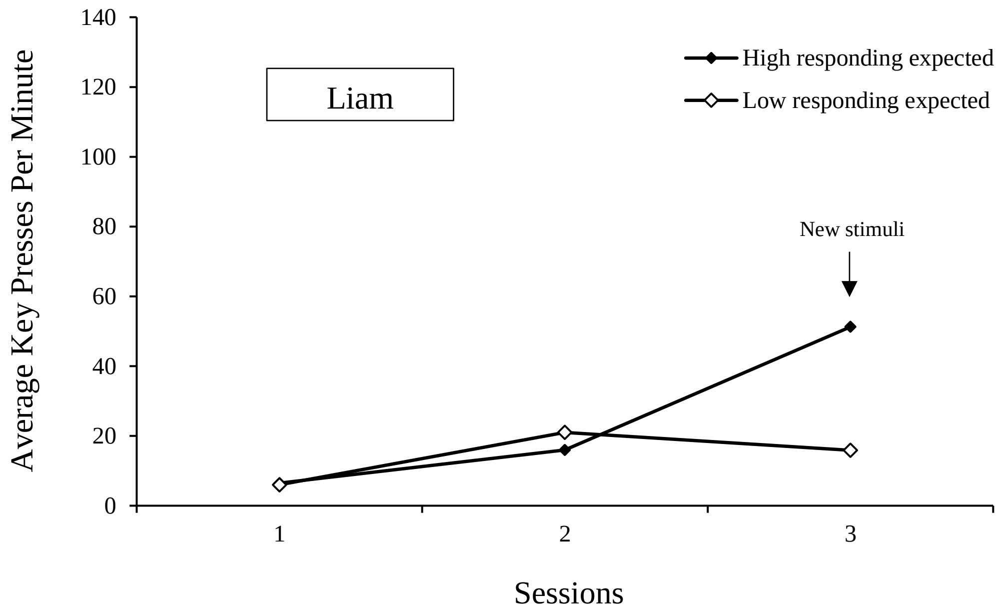


Figure 19. Average key presses per minute in response to auditory stimuli. High responding expected in escape conditions of non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal conditions of preferred stimuli. Low responding expected in escape conditions of preferred stimuli, avoidance conditions of preferred stimuli, and contingency reversal conditions of non-preferred stimuli.

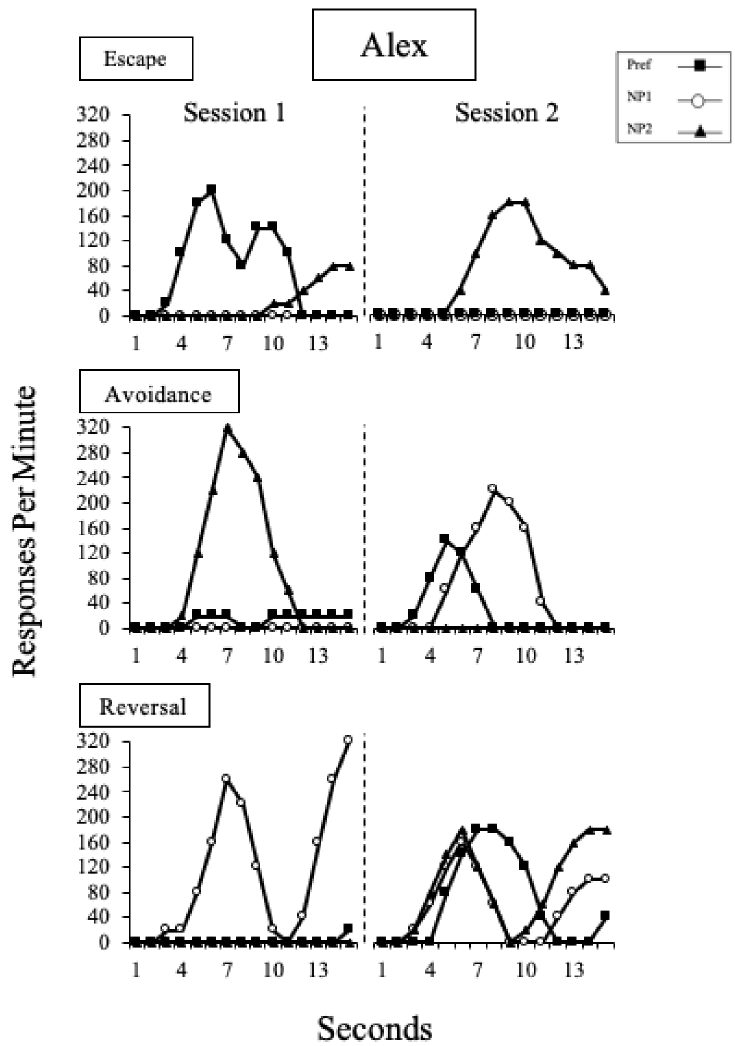
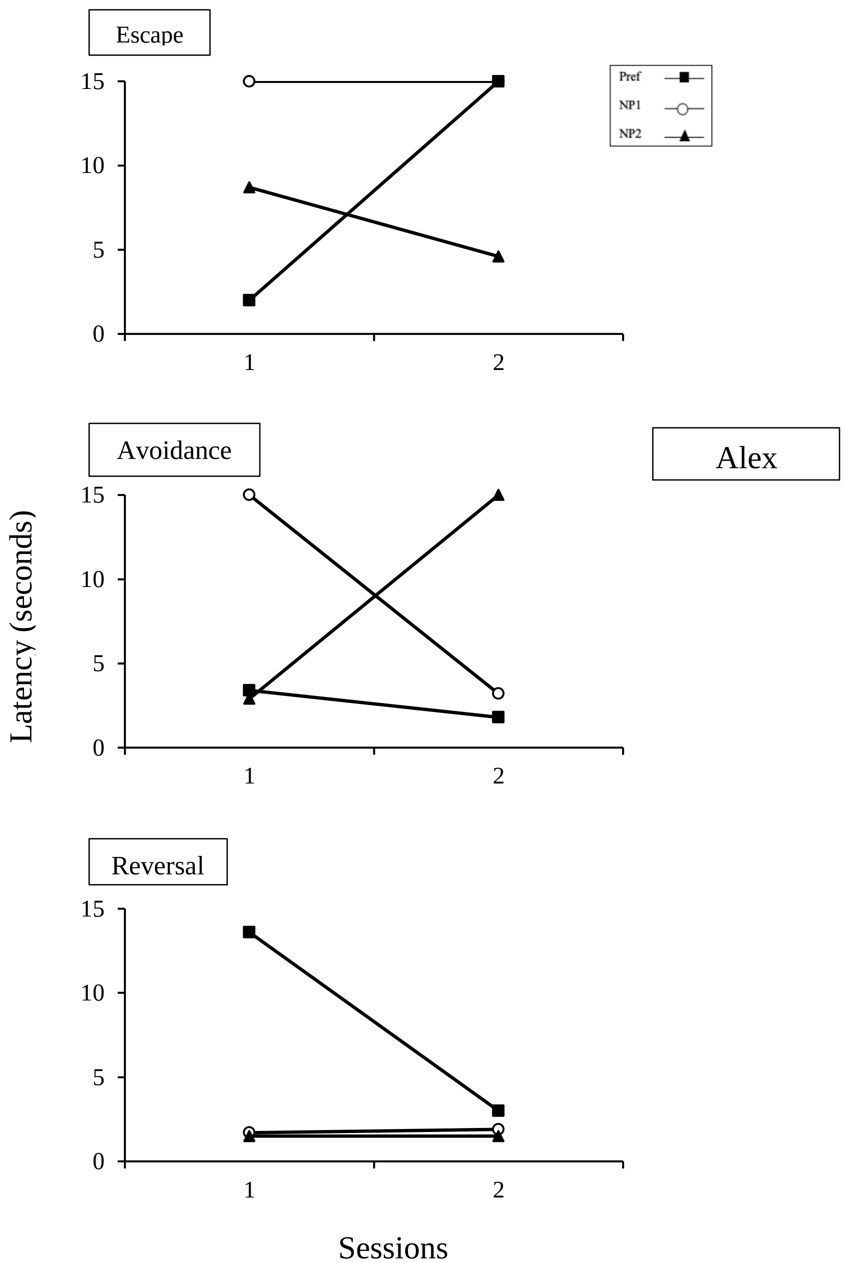


Figure 20. Alex's second-by-second responses, measured by responses per minute. Alex's preferred stimulus (Pref) was his own voice. His first non-preferred stimulus (NP1) was the child-directed voice and his second non-preferred stimulus (NP2) was the Paw Patrol theme song.


Escape
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1
2
Pref
NP1
NP2
Avoidance
Alex
15
10
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0
1
2
Latency (seconds)
Reversal
15
10
5
0
1
2
Sessions

Figure 21. Alex's latency to first key press, measured in seconds. Alex's preferred stimulus (Pref) was his own voice. His first non-preferred stimulus (NP1) was the child-directed voice and his second non-preferred stimulus (NP2) was the Paw Patrol theme song.

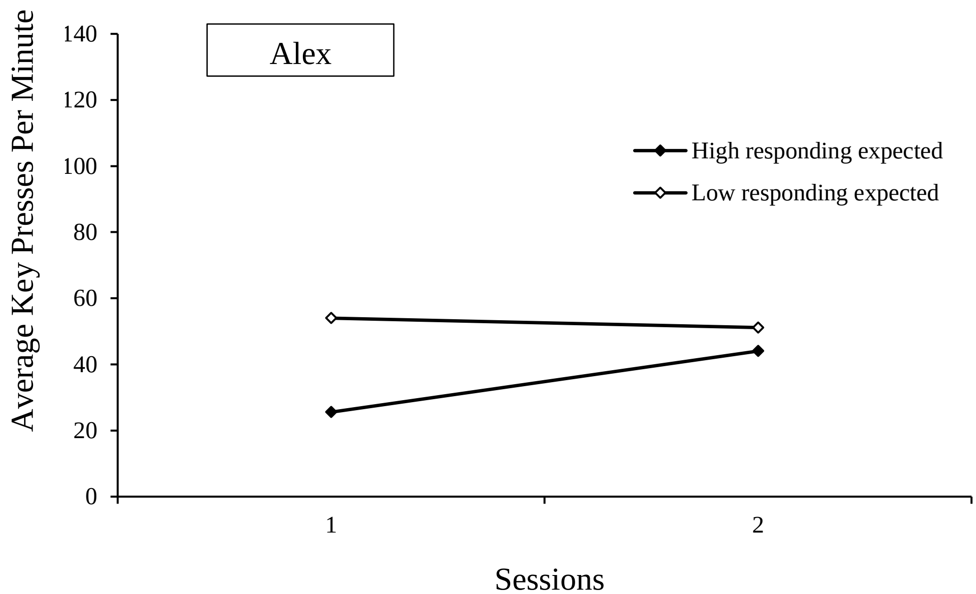

Figure 22. Average key presses per minute in response to auditory stimuli. High responding expected in escape conditions of non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal conditions of preferred stimuli. Low responding expected in escape conditions of preferred stimuli, avoidance conditions of preferred stimuli, and contingency reversal conditions of non-preferred stimuli.

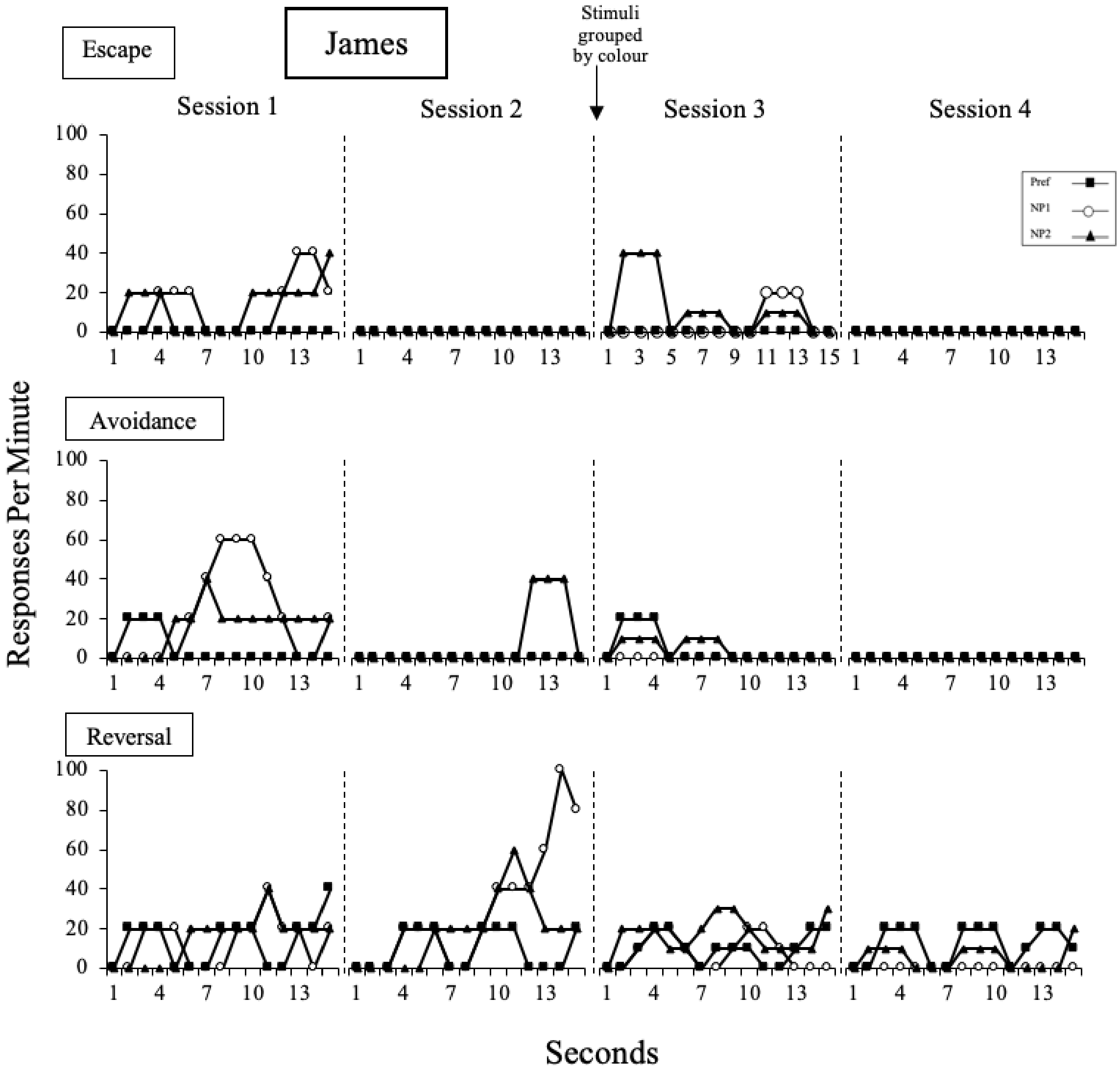

Figure 23. James' second-by-second responses, measured by responses per minute. James' preferred stimulus (Pref) was Super Mario. His first non-preferred stimulus (NP1) was the angle grinder and his second non-preferred stimulus (NP2) was the nails on a chalkboard sound effect. Stimuli were grouped by colour during the assessment for Session 3 and 4. For Session 3 and 4, the data displayed is the average between two presentations of the same stimulus in the same condition

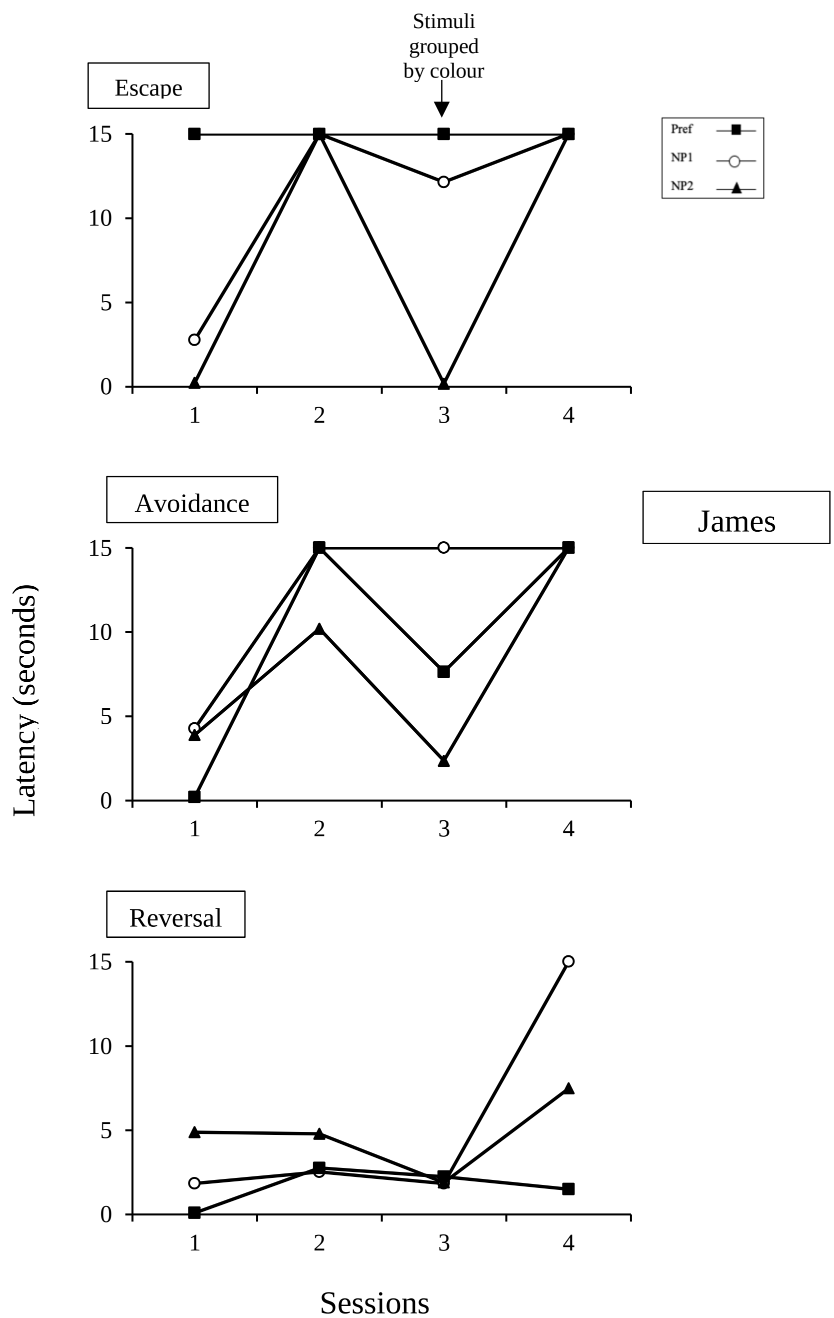

Figure 24. James' latency to first key press, measured in seconds. James' preferred stimulus (Pref) was Super Mario. His first non-preferred stimulus (NP1) was the angle grinder and his second non-preferred stimulus (NP2) was the nails on a chalkboard sound effect. Stimuli were grouped by colour during the assessment for Session 3 and 4. For Session 3 and 4, the data displayed is the average between two presentations of the same stimulus in the same condition

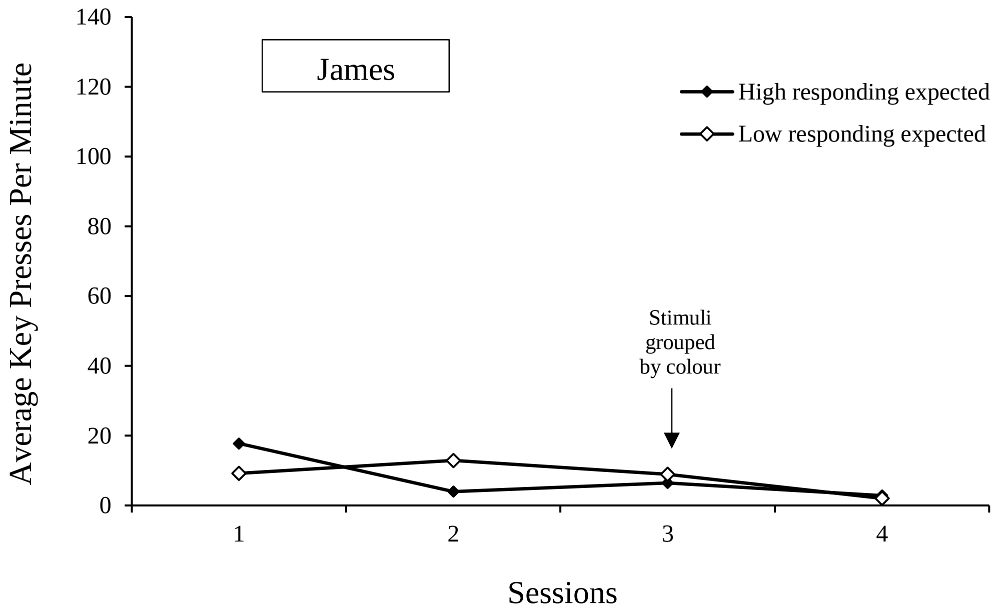

Figure 25. Average key presses per minute in response to auditory stimuli. High responding expected in escape conditions of non-preferred stimuli, avoidance conditions of non-preferred stimuli, and contingency reversal conditions of preferred stimuli. Low responding expected in escape conditions of preferred stimuli, avoidance conditions of preferred stimuli, and contingency reversal conditions of non-preferred stimuli.

Appendix B: Institutional Review Board Approval

ST. CLOUD STATE UNIVERSITY
EDUCATION FOR LIFE.

Institutional Review Board (IRB)

720 4th Avenue South AS 210, St. Cloud, MN 56301-4498

Name: Anastasia Pasyk

Email: apasyk@stcloudstate.edu

IRB PROTOCOL DETERMINATION:
Expedited Review-2

Project Title: Assessing Escape and Avoidance Responses Under a Conjugate Reinforcement Schedule

Advisor Ben Witts

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects. Your project has been: **APPROVED**

Please note the following important information concerning IRB projects:

- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).

- For expedited or full board review, the principal investigator must submit a Continuing Review/Final Report form in advance of the expiration date indicated on this letter to report conclusion of the research or request an extension.

-Exempt review only requires the submission of a Continuing Review/Final Report form in advance of the expiration date indicated in this letter if an extension of time is needed.

- Approved consent forms display the official IRB stamp which documents approval and expiration dates. If a renewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc.). The IRB reserves the right to review the research at any time.

If we can be of further assistance, feel free to contact the IRB at 320-308-4932 or email ResearchNow@stcloudstate.edu and please reference the SCSU IRB number when corresponding.

IRB Chair:

Dr. Benjamin Witts
Associate Professor- Applied Behavior Analysis
Department of Community Psychology,Counseling, and Family Therapy

IRB Institutional Official:

Dr. Latha Ramakrishnan
Interim Associate Provost for Research
Dean of Graduate Studies

OFFICE USE ONLY

SCSU IRB# 1776 - 2251	**Type:** Expedited Review-2	**Today's Date:** 2/22/2019
1st Year Approval Date: 2/13/2018	**2nd Year Approval Date:** 2/22/2019	**3rd Year Approval Date:**
1st Year Expiration Date: 2/12/2019	**2nd Year Expiration Date:** 2/21/2020	**3rd Year Expiration Date:**