Relations between Heart Rate and Precursors to Aggression with Children with Autism Spectrum Disorder

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by

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Abstract

Title: Relations between Heart Rate and Precursors to Aggression with Children with Autism Spectrum Disorder

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Aggression is a commonly reported problem behavior for individuals diagnosed with autism spectrum disorder. When assessing and treating aggression, there are risks of injury to the client and staff when the problem behavior is aggression. Investigating physiological arousal states of clients may be fruitful if this physiological measure can be used to predict occurrences of problem behavior, such as aggression. Previous research has shown varied results when investigating the relations between heart rate and problem behaviors. For some individuals, heart rate increased preceding problem behavior and for others heart rate decreased (Barrera et al., 2007). The temporal relation between heart rate and problem behavior has also been variable, where some individuals have a heart rate change before problem behavior and others after (Freeman and Horner, 1999). Goodwin et al. (2019) demonstrated that by analyzing physiological biosensor data, aggression could be predicted one minute before it occurred for twenty individuals diagnosed with autism spectrum disorder. Predicting aggression before it occurs could provide enough time to make the environment safer and intervene proactively.

One strategy used to create a safer environment for assessing and treating aggression is to identify precursor behaviors. Precursor behaviors occur before the target behavior and are often less severe and maintained by the same consequences as the target behavior. Thus, the purpose of Study 1 was to identify precursors to aggression for three children diagnosed with autism spectrum disorder between the ages of 5 and 10 years old. In Study 2, these same individuals participated in a precursor functional analysis. Heart rate data were analyzed during the first occurrence of the precursor behavior for the differentiated condition in the precursor functional analysis. Results were idiosyncratic across individuals when analyzing heart rate 60s before and 60s after the instance of the first precursor. For one participant, there was a heart rate pattern identified in the 6s preceding the first precursor. For two participants there was an increase in heart rate in the one minute before to the precursor behavior. For one individual there was a decrease in heart rate from the one minute before to the occurrence of the precursor.
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Chapter 1 : Relations between Heart Rate and Precursors to Aggression with Children with Autism Spectrum Disorder

Aggression is a commonly reported problem behavior for individuals diagnosed with autism spectrum disorder (ASD). Aggressive behaviors (e.g., hitting, kicking, pushing others) has been reported to occur in up to 68% of individuals diagnosed with ASD at some point in their life (Hodgetts et al., 2013). Aggression can greatly influence everyday life not only for the individual but for their families as well. Aggressive behavior is the strongest predictor of parental stress, which can increase risks for depression and marital discord in families (Hodgetts et al., 2013).

Current treatments for aggressive behaviors typically include psychopharmacological, behavioral, or a combination of the two interventions. Some medications have proven useful (e.g., risperidone, aripiprazole), however, there are various harmful side effects that could emerge from using these medications (e.g., increased aggression, cardiac dysfunction, blurred vision, nausea, dizziness, and increased appetite/weight gain to name a few) (Sindhura et al., 2022). In behavioral interventions, a functional analysis is an assessment used to identify the environmental variables that maintain the behavior prior to developing function-based treatments. Once the maintaining contingency is identified, clinicians alter the contingencies, typically by reinforcing alternative, replacement behaviors to aggression (Northup et al., 1991). In a review of published studies on the functional analysis of problem behavior between 2001 and 2012, there were 107 studies using a functional analysis for aggression, 95 of which produced differentiated results (Beavers et al., 2013). This suggests that a functional analysis is a reliable assessment to determine the function of aggression and provides the necessary information for selecting treatment.
The use of a functional analysis to identify treatment options has been considered the gold standard in behavior analysis, however, one concern with this assessment is the increased risk of injury for both the client and the staff conducting the assessment. One strategy used to decrease the risk of injury is to identify and assess precursor behaviors (Beavers et al., 2013). A precursor precedes the occurrence of a target behavior and is often less severe and maintained by the same consequences (Fahmie & Iwata, 2011). In a previous study by Najdowski and colleagues (2008), a precursor functional analysis (PFA) was used for three participants who engaged in severe problem behavior. Participants were taught appropriate ways to access the identified maintaining consequences. The results indicated that participants showed an increase in communicative responses and a decrease in precursor behaviors (Heath & Smith, 2019).

Borrero and Borrero (2008) used comparative probability calculations to identify potential precursors to severe problem behavior for two boys, ages 11 and 12, diagnosed with ASD who engaged in a combination of aggression, self-injurious behavior (SIB), and property destruction. The potential precursor for both participants was vocalizations, defined as vocal utterances at a volume louder than normal conversation. Descriptive data were obtained for each participant using methods described by Vollmer et al., (2001). Observers used a computerized data collection system to record three potential reinforcers (e.g., attention delivery), problem behavior, potential precursors, and potential establishing operations (EOs). Establishing operations involve any change in the environment that alters the effectiveness of a stimulus as a reinforcer (Michael, 1982). In this case, presenting different situations such as attention deprivation may function as an establishing operation and increase the value of attention as a reinforcer and thus evoke the problem behavior. Potential reinforcers and EOs were recorded as a duration measure, while instances of problem behavior and potential precursors were recorded.
as frequency measures. Descriptive observations occurred during the participant’s regularly scheduled activities and lasted either one hour, or until 45 instances of problem behavior and 45 instances of the potential precursor had occurred, whichever came first. Descriptive data were then analyzed to assess two conditional probability values (probability of a precursor given problem behavior, and the probability of problem behavior given a precursor) and two unconditional probability values (the unconditional probability of problem behavior and unconditional probability of a precursor). Lag-sequential analyses were conducted to assess the probability of a potential precursor during the 50 s before (lag –50) an instance of problem behavior and the 50 s after (lag +50) an instance of problem behavior. Results of the comparative probability analysis indicated that, for both participants, there was a higher probability of problem behavior given the precursor relative to their unconditional probabilities. Results of the lag-sequential analysis showed that the probability of a precursor greatly increased immediately preceding an instance of problem behavior, and the probability of problem behavior occurring reached its highest value in the 1-s interval immediately after an instance of the precursor. Next, experimenters assessed whether the identified precursor and the problem behavior share the same function, and determined they were members of the same response class. To do this, a functional analysis was conducted for both the problem behavior and the precursor. The procedures for the functional analysis of problem behaviors were similar to those used by Iwata et al. (1982/1994) and included either 3 or 4 test conditions and a control condition that were alternated in a multielement design. Sessions were conducted twice a week and lasted 5 min in duration. The test conditions included attention, tangible, escape, and no-consequence, and a control condition was included in which no programmed consequences were delivered. The functional analysis of precursors was similar to the functional analysis of problem behaviors, except condition-specific
consequences were provided for instances of the precursor (vocalizations) only, whereas no consequences were provided for instances of the problem behavior. Results of the functional analysis for the first participant show high rates of problem behavior in the tangible condition, and even though there were no programmed consequences for vocalizations, this behavior also occurred at high rates in the same condition. During the precursor functional analysis for this participant, low rates of problem behaviors occurred and differentiated levels for vocalizations were observed in the tangible condition. For the second participant, results of the functional analysis of problem behavior showed differentiated results in the tangible and escape conditions. Even though vocalizations resulted in no programmed consequences, there were high rates of vocalizations in the tangible condition and initially elevated levels of vocalizations in the escape condition during the first two escape sessions. Results of the precursor functional analysis for the second participant show differentiated levels of vocalizations in the tangible and escape conditions. These findings indicate that the precursor and problem behaviors were members of the same operant classes, thereby validating that functional analyses of precursor behavior may be used in lieu of assessing aggressive behavior directly.

Treatments developed based on functional analyses that used precursor responses have been shown to be effective. Fritz et al., (2013) evaluated the effectiveness of using precursors for the assessment and treatment of severe problem behavior for 16 individuals with intellectual disabilities. First, the experimenters began with the precursor assessment which consisted of discrete trials where antecedent conditions that may serve as EO were introduced. To increase the likelihood of observing a precursor and decrease the likelihood of engaging in the target behavior, trials were terminated immediately after a consequence was provided and the next trial only began after the participant stopped engaging in the target behavior for 30 s. The results of
the precursor functional analysis were then compared to the results of the functional analysis of the target behavior. The findings indicate that all precursor responses were maintained by the same sources of reinforcement as the target behavior for seven of eight participants. The treatment evaluated based on the precursor functional analysis included a combination of noncontingent reinforcement and differential reinforcement of alternative behavior. The treatment package was successful in decreasing the rate of precursors, achieving near-zero rates of severe problem behavior, and increasing independent mands.

One area of research that has not received much attention is the use of physiological measures in the assessment and treatment of severe problem behavior. Physiological arousal occurs in response to stimulation either from the external world or from the individual’s own body, which can affect important executive functions such as information processing, attention, learning, memory, and stress reactivity (Lydon et al., 2013). Many researchers have theorized that physiological arousal is abnormal in individuals diagnosed with ASD. This theory first arose from Hutt et al. (1964) stating that individuals diagnosed with ASD experience hyper-arousal, which can lead to increased reactivity to environmental stimuli, failure to habituate appropriately to these stimuli, and their avoidance of unfamiliar or novel situations (as cited in Lydon et al., 2013). Previous research has found that social stress is related to a significant decrease in heart rate variability in individuals diagnosed with autism spectrum disorder compared to neurotypical individuals (Cheng et al., 2020). It is important for behavior analysts to investigate physiological arousal as it is a private event that is not observable to others that may impact problem behavior of their clients. Additionally, if heart rate is demonstrated to be a reliable predictor of problem behavior this measure could be used in treatment planning for behavior analysts.
Barrera et al. (2007) included heart rate as a physiological measure in a functional analysis of SIB for three adults with developmental and intellectual disabilities. The experimenters examined heart rate during each second of the 5 s interval preceding and following SIB, then compared these traces to a percentage of randomly selected points in the session when no SIB occurred. The results indicate that all three participants showed a distinct heart rate pattern that was unique for each individual, but overall there was an increase in heart rate within 1-2 s prior to the occurrence of SIB, and a decrease in heart rate either during SIB or 2-3 s immediately following the occurrence of SIB (Barrera et al., 2007). Additionally, this effect was seen regardless of topography, duration, body positioning, movement, respiratory action, and differing ongoing background levels of heart rate activity (Barrera et al., 2007). Interestingly, all participants showed this distinct heart rate pattern regardless of the function maintaining the behavior.

Researchers have also examined the use of physiological measures in naturalistic settings. Freeman and Horner (1999) measured heart rate during a descriptive assessment with two individuals who engaged in severe problem behavior such as SIB, aggression, and property disruption. The participants were video-taped wearing the heart rate monitor for 20 to 60 minutes each day during baseline and heart rate data-collection phases (Freeman & Horner, 1999). A scale measuring perceived levels of distress was included to discriminate aversive and non-aversive states using a 4-point Likert-type scale. A sequential analysis procedure was used to assess conditional probabilities of heart-rate change and problem behavior. The experimenters found that for one participant, there was a low likelihood of heart rate increase in the 15 seconds preceding problem behavior, but a higher likelihood of heart rate increase following self-injury and aggression, but not disruptions (Freeman & Horner, 1999). For the second participant, there
was a significant increase in heart rate that occurred with an increase of 7 heartbeats per minute in the 15 seconds preceding SIB (Freeman & Horner, 1999). A unique outcome of this investigation showed that the average heart rate for one individual increased from 60 bpm to 111 bpm over a 9-day period, even though there were no changes in physical exertion and sessions were recorded during the same time each day during a structured routine to eliminate the possibility of heart rate increase due to circadian rhythm (Freeman & Horner, 1999). With this individual, the level of problem behaviors changed on days with high versus low heart rate. Specifically, when their average heart rate was low, there were higher levels of problem behavior compared to when their average heart rate was higher. On days when average heart rate was low for this participant, they were more likely to have an increase in heart rate following SIB and disruptive behaviors, and overall affect showed high levels of frustration or fatigue. On days when average heart rate was high, the frequency of heart rate increases was lower following the occurrence of SIB and disruptive behaviors, and overall affect appeared overexcited and happy. These findings emphasize the importance of further investigation in the role of physiological measures in clinical settings.

Lydon and colleagues (2013) also analyzed the effects of heart rate in a naturalistic context with three individuals diagnosed with ASD between the ages of 10 and 16 years who frequently engaged in SIB, stereotypy, and destructive behaviors. Data on heart rate were analyzed during the 5 s preceding and following the occurrence of the target behaviors, and each occurrence of the target behavior was compared to a non-occurrence of the target behavior. Behavioral observation and heart rate monitoring took place across 5 school days for a total of 20 h 16 min for participant 1, 23 h 24 min for participant 2, and 19 h 20 min for participant 3. Findings from this study showed that the same heart rate patterns were found to occur with SIB
and stereotypy. In this study, one participant was less physiologically aroused during occurrences of SIB and tantrum behaviors, which were triggered by loud noises. The experimenters hypothesized that the participant’s display of the overt stress response but not the physiological arousal response may indicate possible physiological abnormalities in individuals diagnosed with ASD, and that years of highly aroused reactions to noises may have reduced the capacity of this participant’s central nervous system to respond appropriately to such stimuli (Lydon et al., 2013). In addition, it is possible that the elevation in heart rate during SIB occurrences could be in response to the antecedent that occasioned the behavior, or due to the pain caused by SIB (Lydon et al., 2013).

Goodwin and colleagues (2019) took the analysis of heart rate during problem behavior one step further and aimed to predict episodes of aggression before it occurred for twenty individuals diagnosed with ASD between the ages of 4-20 years old. Aggression was operationally defined as hitting, kicking, biting, scratching, grabbing, pulling, pinching, or throwing objects at others (Goodwin et al., 2019). A brief desensitization protocol was implemented which involved increasing exposure to the wearable biosensor. The wearable biosensor included in the study was the E4 by Empatica, Inc. that took data on physiological arousal and motion activity. Specifically, the E4 uses photoplethysmography (PPG) that records blood volume pulse (BVP) and inter-beat-interval (IBI) data at 64 Hz from which heart rate and heart rate variability can be derived (Goodwin et al., 2019). Additionally, the E4 records electrodermal activity (EDA) that reflects autonomic innervation of sweat glands, and alterations in sympathetic nervous system arousal (Goodwin et al., 2019). Finally, the E4 records motion-based activity using a 3-axis accelerometer (ACCx, ACCy, ACCz). The E4 has been empirically validated against the gold-standard laboratory-based devices during physical activity, emotional
provocation, and high cognitive load in typically developing individuals (Goodwin et al., 2019).

Sixty-nine naturalistic observations totaling 87 hours were conducted while participants wore the E4 during their daily routines. Experimenters coded the start and stop times of each aggression episode within an observation session using a laptop computer that synced to the internal clock of the wearable biosensor. The E4 time-series features for BVP, IBI, ACCx, ACCy, and ACCz were extracted using successive 15-second sliding windows for first, last, maximum, minimum, mean, and median values; number of unique values; and sum, standard deviation, and variance of values falling in a window (Goodwin et al., 2019). Experimenters also coded two binary aggression labels: aggression observation flag (AOF) which indicates when an aggression has occurred, and time since past aggression (TPA) indicating the latency since the last observed aggression. The standard deviation for each feature was also included in all prediction models.

To make binary aggression predictions over time, a ridge-regularized logistic regression was used with the extracted time-series features. Predictor variables included: only temporal information (AOF, TPA), only motion activity (ACC), only physiological activity (BVP, IBI, EDA), motion and physiological activity features combined (BVP, IBI, EDA, ACC), and all extracted features combined (AOF, TPA, ACC, BVP, IBI, EDA) (Goodwin et al., 2019). By comparing each of the predictor variables mentioned, this enabled experimenters to determine the relative impact each variable had on aggression prediction accuracy. For the prediction model, 3 minutes of prior data were used to make predictions in an upcoming time range. When comparing predictor models, the results show that models which included physiological and motion activity were better predictors than just temporal features (when an aggression occurred, and latency since past aggression). Correlations were calculated between model fit and total time observed, number of aggression episodes, and duration of aggression episodes, and the results suggest that the amount
of data available to the model had a greater influence on prediction performance than duration of aggression episodes (Goodwin et al., 2019). The overall results demonstrated that aggression could be predicted in one minute prior to its occurrence with 84% average accuracy. This finding is influential as it could provide sufficient time to rearrange the environment to make it safer, provide redirection, calm the individual directly, or promote other self-management supports to decrease the risk of escalation to dangerous aggression (Goodwin et al., 2019). The authors mentioned the potential use of creating a mobile application that could display real-time information for parents and clinicians to indicate the imminent risk of aggression and prompt the user to help de-escalate the individual. This study contributed to the current research on the utility of physiological measures in the assessment and treatment of severe behaviors and laid the groundwork for expanding data collection on precursor behaviors associated with aggression.

The purpose of the current study is to evaluate the use of heart rate as a physiological measure to identify precursors in a functional analysis of aggressive behaviors for children with ASD. The previous research on the use of heart rate has shown a consistent distinct heart rate pattern preceding severe problem behaviors regardless of topography or function of the behavior. Using heart rate to identify precursors may provide a more systematic methodology and could even help to predict the behavior before it occurs, as seen in Goodwin et al. (2019). This analysis would provide a safer environment when assessing severe behaviors by decreasing the risk of injury for the participant as well as staff involved in a functional analysis. Additionally, the risk of severe behaviors can further be reduced by developing treatments based on the precursors identified. The importance of this study is to contribute to the growing literature on the use of physiological measures in the assessment and treatment of severe behaviors to create a safer environment for clients and staff in clinical settings.
Chapter 2 : General Method

Participants and Setting

Three children between the ages of 5 and 10 years old participated in the study. Although we began data collection for a fourth participant, we removed them from the study during phase 1 due to medical reasons unrelated to the study. All participants had a formal diagnosis of autism spectrum disorder (ASD). Jon is a 5-year-old boy who engaged in high rates of aggression within the past month before the study (up to 45.33 instances/hour), thus meeting criteria for inclusion in the study due to engaging in high rates of aggression. Jon’s topography of aggression included hitting, kicking, pulling on, or pushing against another individual. Camilla is a 10-year-old female with a diagnosis of ASD with intellectual disability, profound. Camilla was admitted to an intensive ABA program due to severe problem behavior including high rates of aggression (up to 38.44 instances/hour). Camilla’s topography of aggression included any instance of hitting another person with an open hand. Teddy was a 5-year-old boy who engaged in high magnitude aggression but at lower rates (up to 9.18 instances/hour), therefore disruptive behaviors were also targeted. The topography of aggression for Teddy included hitting, kicking, and scratching another person. The topography of disruptions included hitting, swiping, or throwing items. It should be noted that the motor movements involved in disruptions were similar to aggression.

Participants were recruited from a local university-based clinic that provides behavioral services. All sessions took place in a playroom at the university-based clinic. Session therapists included the registered behavior technicians (RBT) that provide ABA therapy services for the participants. All participants received 40-hours a week of ABA services, so the RBTs running the sessions worked multiple hours a week with the participant and have known the participant for between 6 months and 1 year.
**Participant safeguards.** To ensure the safety of the participant and experimenter, consequences (e.g., attention delivery, escape from demands) were provided as quickly as possible to minimize the duration of aggressive responses. Personal protective equipment was provided for experimenters during the precursor assessment and precursor functional analysis. Participants who continued to engage in aggression that results in a permanent product of injury to the experimenter for more than one session were excluded from the study, however, this did not occur.

**Heart Rate Monitoring and Data Analysis**

**Procedure.** Participants wore the Polar Unite Fitness Watch across all phases of the study. The Polar Unite Fitness Watch provided second-by-second data on heart rate. Data collection on heart rate were synced to sessions in Study 2 in order to analyze relations between heart rate and precursor behaviors. The Polar Unite Fitness Watch automatically calculated the age-predicted maximum heart rate. If the participant reached the maximum heart rate for a duration of 1 minute the session was terminated. This did not occur in the study.

**Desensitization.** First, a baseline probe was conducted to evaluate the participant’s tolerance of wearing the heart rate monitor watch. The experimenter secured the watch on the participant’s wrist and provided praise if the participant tolerated wearing the watch with no problem behaviors. The baseline probe lasted five minutes. If the participant engaged in problem behavior while the watch was being put on or removed the watch before five minutes elapsed, shaping and differential reinforcement were implemented. Praise and preferred items were provided contingent upon compliance for wearing the watch. The shaping procedure began at whichever point the problem behavior emerged. If a participant engaged in problem behavior in the presence of the watch, experimenters began by holding the watch 2 ft away from the participant and the distance of the watch to the participant increased only after the participant did
not display problem behavior for 5s. If the participant tolerated wearing the watch but not for the full duration, shaping and differential reinforcement were used until the participant could tolerate the watch for five minutes. The procedures continued until the participant wore the watch for five minutes with the absence of problem behavior.

*Heart rate control condition.* Prior to the precursor assessment, a presession control condition was conducted. The purpose of the presession control condition was to obtain heart rate data when the client is engaged in low levels of activity (calm play), high levels of activity (active play), and engaged in a topographically similar activity to aggression as a comparison for Study 2 results. To control for heart rate increases based on motor movements, the participant engaged in activities that are topographically similar to the form of aggression the participant exhibits. For example, if the participant engages in aggression in the form of hitting, the activity in the presession condition will be hitting a drum; if aggression occurs in the form of kicking, the activity will involve kicking a ball, and so on. If a participant engages in multiple different topographies of aggression, multiple activities will be integrated into a single session. The presession control condition was structured similar to the play condition in a functional analysis (Iwata et al., 1982/1994). If aggression occurred during this time, the session was terminated and not included in the heart rate analysis. Sessions lasted 5 minutes in duration and were conducted for a minimum of two sessions or until sufficient heart rate data were obtained for calm play, active play, and topographically similar activity.

*Data analysis.* For the heart rate control condition, averages for heart rate data across all sessions for each dependent variable (calm play, active play, and topographically similar activity) were calculated and represented in a bar graph for comparison in Study 2. A lag-sequential analysis was also conducted based on the methods described in Borrero and Borrero
(2008) to examine the changes in heart rate 60s before and 60s after the occurrence of the first precursor behavior during the functional analysis in Study 2.
Chapter 3: Identifying Precursors to Aggression

Method

Precursor Identification

The purpose of Study 1 was to identify precursors to aggression that were then used in Study 2. All trials were videotaped to have a permanent product of all responses that was scored later using a checklist outlined in Fritz et al. (2013). Based on the checklist, responses were categorized topographically as (a) vocalizations, (b) facial expression, (c) postures, (d) repetitive motor movements, (e) locomotion, (f) object manipulation, and (g) other problem behaviors. Examples for possible response topographies in each category were provided, but there was also space for the observers to write in behaviors observed that were not listed on the checklist. Behaviors that were included in the topographical definition of aggression, or were considered mild forms of aggression, were not included as potential precursors.

Observation was conducted in two phases. First, potential precursor topographies were identified and operationally defined. Second, for all assessment trials, the potential precursors were scored as an occurrence or nonoccurrence. Once the precursor assessment was complete, observers watched the videos and pinpointed potential precursor topographies for the trials in which the aggression occurred. Next, observers compared the topographies identified to the checklist and developed operational definitions for all potential precursors. The observers watched videos of the trials independently and scored either an occurrence or nonoccurrence of the precursor and aggression. Following each trial, observers compared their data and resolved any disagreements by reviewing the trial again, clarifying the operational definition, and rescoring the trial until 100% agreement was achieved (Fritz et al., 2013). This process was used to ensure precursor behaviors were accurately identified and precisely defined.
Response Measurement and Reliability

Data were collected on instances of precursors and aggression across trials via a computerized data collection system (BDataPro®). Topographies of precursors to aggression were individually operationally defined for each participant. Data were expressed as percent of trials with precursors, aggression, or both. Data were also collected on heart rate via the Polar Unite Fitness Watch that provided second-by-second output on heart rate across conditions. Sessions were synced to heart rate data to evaluate changes in heart rate surrounding specific antecedent events and target behavior (i.e., aggression and precursors).

Interobserver agreement was calculated on a trial-by-trial basis. Secondary observers collected data either in-vivo or from videos for a minimum of 33% of the sessions. For each trial, secondary observers recorded either the occurrence or nonoccurrence of aggression and the precursor behaviors. The total number of trials with agreement were divided by the total number of trials and then converted into a percentage. Mean agreement was 96% for Jon, 100% for Camilla, and 93% for Teddy.

Procedure

Precursor assessment. The procedure for the precursor assessment was based on the methods described in Fritz et al. (2013). The precursor assessment included the presentation of antecedent conditions that may function as establishing operations (EOs) for aggression (e.g., removal of attention, presentation of demands, removal of tangible items). The antecedent conditions were similar to the attention and demand conditions used in a functional analysis (Iwata et al., 1982/1994). Each session lasted 5 minutes or less in duration. Each trial began with at least 1 minute of access to the putative reinforcer to allow for heart rate data analysis. The consequence associated with the antecedent condition (attention, escape, or access to tangibles)
was delivered contingent upon the occurrence of aggression and lasted until aggression was not observed for 30s. A tangible condition was only included if the caregiver noted that the target behavior occurs when the participant is denied access to preferred items or during the removal of preferred items. To increase the likelihood of observing a precursor prior to the target behavior and decrease the likelihood of multiple consecutive occurrences of aggression, each trial was terminated immediately after a consequence was delivered (Fritz et al., 2013). The next trial began when the participant had not engaged in the target response for at least 30s.

In the attention trials, the therapist ignored all behaviors except aggression which resulted in a brief reprimand (e.g., “Don’t do that, it hurts”) and a gentle pat on the shoulder or back. The consequence was provided until the aggression was not observed for 30s. The next trial began once the target behavior had not been observed for 30s or if the target behavior did not occur before 5 minutes elapsed (whichever came first).

In the demand trials, the therapist instructed the participant to complete tasks relevant to their skill level. The therapist used a three-step prompting procedure (verbal instruction, model, physical guidance). Contingent upon the occurrence of the target behavior, the therapist moved away from the participant and terminated the instructional sequence. The next trial began once the participant did not display the target behavior for 30s, or if the target behavior did not occur before 5 minutes elapsed. If a tangible condition was included in the assessment, it followed the demand trial. If a tangible condition was not included, another attention trial followed the demand trial.

The tangible trial began with the therapist providing the participant brief access to preferred items. After 1-2 minutes of free access, the therapist removed the item. The therapist returned the items to the participant contingent upon the occurrence of aggression. After 30s in
which the target behavior does not occur, or if the target behavior is not observed for 5 min, another attention trial began.

The precursor assessment aimed to limit occurrences of aggression, but still provide sufficient trials to observe a precursor response. Thus, the assessment was considered complete after 10 trials in which aggression was observed, assuming that the 10 trials provided a sufficient number of trials in which aggression also did not occur (Fritz et al., 2013). If aggression was observed during the first 10 trials of the assessment, play trials were conducted in which the participant had noncontingent access to attention and preferred items and no demands were placed as a comparison condition.

_Treatment integrity._ Treatment integrity was measured by observing experimenter behavior based on six categories for at least 25% of the trials. A secondary observer scored whether the experimenter a) provided the consequence only for the occurrence of aggression, b) waited until aggression was not observed for 30 seconds before starting the next trial, c) provided the condition-specific consequence (e.g., attention, escape, or access to tangible), and d) if aggression was not observed the experimenter waited 5 minutes before terminating the trial. Treatment integrity will be calculated by dividing the number of correctly implemented components by the number of total components and converting the result into a percentage.

Treatment integrity for Jon and Teddy was 100% and for Camilla was 88%.

_Probability analyses._ Conditional and unconditional probability analyses were conducted based on the methods described in Fritz et al. (2013). The probability of aggression given the occurrence of each potential precursor \([p(A|P)]\) was calculated to compare the probability of aggression given the absence of the precursor \([p(A|\sim P)]\) and the unconditional probability of aggression \([p(A)]\). The probability of each precursor given the occurrence of aggression \([p(P|A)]\)
was calculated next to compare the probability of the precursor given the absence of aggression \( [p(P|\neg A)] \) and the unconditional probability of each precursor \([p(P)]\). For a behavior to be classified as a precursor in this study two criteria must be met. First, the probability of aggression given the precursor must be higher than the probability of aggression given the absence of the precursor \([p(A|P) > p(A|\neg P)]\) and the unconditional probability of aggression \([p(A|P) > p(A)]\). Second, the probability of the precursor given the occurrence of aggression must be higher than the probability of the precursor given the absence of aggression \([p(P|A) > [p(P|\neg A)]\) and the unconditional probability of the precursor \([p(P|A) > p(P)]\).

**Results and Discussion**

All participants tolerated the watch with no problem behaviors and did not require desensitization. The topography of aggression for Jon was primarily hitting and kicking. The topographically similar activity chosen was hitting a drum and kicking a ball. The heart control condition for Jon found an average heart rate of 94 bpm during calm play, 105 bpm during active play, and 110 bpm during a topographically similar activity (Figure 1). It should be noted that Jon often engaged in motor stereotypy in the form of jumping and stomping, which could impact his heart rate in certain conditions. Camilla’s topography of aggression was hitting with an open hand, so hitting a drum was Camilla’s topographically similar activity. Camilla had an average heart rate of 89 bpm during calm play, 101 bpm during active play, and 94 bpm during a topographically similar activity (Figure 2). The topography of aggression for Teddy was hitting and scratching, therefore hitting a drum was included as a topographically similar activity. The topography of disruptions was primarily swiping items, so the topographically similar activity included hitting a ball off the desk at a horizontal angle. Teddy had an average heart rate of 100
bpm during calm play, 106 bpm during active play, and 97 bpm during a topographically similar activity (Figure 3).

The precursor assessment identified precursor behaviors for all participants. For Jon, 8 potential precursor behaviors were identified, but only 4 behaviors met inclusion criteria based on the probability analyses. Jon’s precursor behaviors identified were eye contact, vocalization “Shh”, 45° bend at the hips oriented toward RBT, and standing behind RBT. Because eye contact is not a behavior the case manager would like to decrease, and the probability analyses were close to not meeting criteria, this behavior was not included as a precursor. The precursor assessment identified turning away, signing for tangible items, reaching for items, and disruptions for Camilla. Out of the four precursors identified, one (disruptions) met criteria. The precursor assessment identified five potential precursors for Teddy, four of which met the probability criteria. Teddy’s precursor behaviors included negative vocalizations, walking with a closed fist, jumping, and reaching with arms elevated. All of the precursors that met the conditional and unconditional probability criteria were included in Study 2 for the precursor functional analysis.

The results of the probability analysis for Jon are shown in Figure 4. The probability of the precursors “Shh”, 45° bend at hip, behind therapist, and eye contact given the occurrence of aggression was 0.30, 0.30, 0.02, and 0.80, respectively. The probability of aggression given the occurrence of the precursors “Shh”, 45° bend at hip, behind therapist, and eye contact was 0.75, 0.50, 1.00, 0.42. Both probability values for the identified precursors were higher than the unconditional probability values of the precursors (0.17, 0.25, 0.08, 0.25) and the unconditional probability values of aggression (0.42, 0.42, 0.42, 0.42). These values were also greater than the
probability of the precursor given the absence of aggression (0.07, 0.21, 0, and 0.79) as well as the probability of aggression given the absence of the precursor (0.35, 0.39, 0.36, and 0.4).

Figure 5 displays the results of the probability analysis for Camilla. The probability of disruption given the occurrence of aggression was 0.54. The probability of aggression occurring given the occurrence of disruptions was high, 0.88. Both probability values for disruptions were higher than the unconditional probability value of disruptions (0.20) and the unconditional probability of aggression (0.33). These values were also greater than the probability of the precursor given the absence of aggression (0.03) and the probability of aggression given the absence of the precursor (0.19).

Figure 6 shows the results of the probability analysis for Teddy. The probability of the precursor given the occurrence of aggression for negative vocalizations, walking with fist, jumping, and reaching was (0.88, 0.44, 0.44, 0.40). The probability of aggression occurring given the occurrence of the precursors was high (1.0, 1.0, 0.80, 0.67), respectively. Both probability values for the precursors were higher than the unconditional probability value of the precursors (0.71, 0.13, 0.33, 0.35) and the unconditional probability of aggression (0.59, 0.60, 0.60, 0.59). These values were also greater than the probability of the precursor given the absence of aggression (0.29, 0.11, 0, 0.11) and the probability of aggression given the absence of the precursor (0, 0.45, 0.55, 0.45).
Chapter 4 : Analyzing Heart Rate in a Precursor Functional Analysis Method

Participants and setting

Given that the precursor assessment identified precursor behaviors for all participants, the same three participants from Study 1 participated in Study 2. The session location was identical to Study 1.

Response measurement and reliability

Secondary observers recorded the frequency of aggression and the precursor behavior(s) identified in Study 1 for the precursor functional analysis using a computerized data collection system (BDataPro®). Topographies of precursors to aggression were individually defined for each participant. Data were collected for heart rate using the Polar Unite Fitness Watch that provided second-by-second output on heart rate across conditions in the precursor functional analysis. Interobserver agreement was calculated by a secondary observer who independently collected data on at least 33% of sessions. Proportional agreement percentages were calculated by comparing the two observers’ data on the frequencies of all responses in each 10s interval. The smaller number of responses were then divided by the larger number of responses in each interval, and the resulting fraction was averaged across all intervals. Mean agreement for Jon was 96%, for Camilla was 100%, and for Teddy was 93%.

Procedure

Design. A multielement design was used to evaluate the results of the precursor functional analysis. This design allowed for comparisons to be made across each condition in the functional analysis to determine the function of the precursor behaviors.
**Precursor functional analysis.** The procedures used for the precursor functional analysis were similar to those of Iwata et al. (1982/1994). All sessions in the precursor functional analysis lasted 5 minutes and were conducted until stable response patterns were observed. During the precursor functional analysis, consequences were only delivered for the occurrence of the precursor behaviors that were identified in the precursor assessment. There were no programmed consequences for aggression, but therapists were allowed to move away from the participant if aggression occurred for safety reasons. The conditions that were included in the precursor functional analysis were attention, play, and demand. A tangible condition was only included if the caregiver noted that problem behavior tends to occur during the removal of preferred items or during denied access to items.

In the attention sessions, the participant had access to two to three moderately preferred items. The items were identified using either a paired-stimulus (Fisher et al., 1992) or multiple-stimulus preference assessment (DeLeon & Iwata, 1996). The therapist began each session by saying, “I have some work to do, but you can play with these toys” then the therapist sat next to the participant and did not interact with the individual. The therapist delivered a brief reprimand (e.g., “Stop doing that; that’s not nice!”) and place their hand on the participant’s shoulder contingent on the precursor behavior.

In the play sessions, two to three of the highly preferred items identified from the preference assessment were provided to the participant. The therapist interacted with the participant at least every 30s or if the participant initiated interactions. No demands were placed during this session, and no consequences were delivered for occurrences of the precursor or aggression.
During the demand sessions, the therapist presented tasks that were relevant to the participant’s skill level. The therapist continuously presented tasks and used a three-step prompting sequence (verbal instruction, model, physical guidance). Following compliance with the tasks, the therapist provided brief neutral praise. A 30s break from the task was provided following each instance of a precursor behavior.

If a tangible condition was included in the precursor functional analysis, the session followed the play condition. The session began by the therapist removing all toys and staying in close proximity to the participant. If the participant attempted to initiate interactions during this condition, the therapist briefly responded and terminated the interaction (e.g., “We can talk later”) (Fritz et al., 2013). Access to the toys previously removed were provided for 30s contingent on the occurrence of the precursor behavior.

*Treatment integrity.* Treatment integrity was measured by scoring experimenter behavior on three criteria. Treatment integrity was scored for at least 25% of sessions. The three criteria that were scored included a) experimenter provided the consequence for the precursor behavior only, b) if aggression occurred, the experimenter did not provide any programmed consequences, and c) experimenter provided the appropriate consequence for the condition (attention delivery, tangible delivery, escape from demands). Treatment integrity was calculated by dividing the number of correctly implemented components by the total number of components and converting the result to a percentage. Treatment integrity was 100% for Camilla, and 95% for Teddy. Treatment integrity data were not obtained for Jon.

*Social validity.* To assess the safety and acceptability of the procedures used in this study, a social validity survey was distributed to the Board-Certified Behavior Analyst (BCBA) of the participants in this study (see appendix). The BCBA was chosen because their role is to assess
the behavioral challenges and create treatment plans for the participants at an ABA clinic. The survey used a five point Likert-type scale ranging from 1 “not at all” to 5 “very” to rate the overall satisfaction of the procedures used and to assess if the study provided any clinical benefit for the BCBAs when developing treatment plans. Case managers were encouraged to add any additional feedback on the open-ended areas of the survey.

Results and Discussion

It should be noted that heart rate data were not obtained during the 60s before the instance of the first precursor behavior for every session. This was due to technical error, experimenter error, or the participant moving or pausing the watch. The results of the precursor functional analysis for Jon are displayed in Figure 7. The precursor functional analysis initially identified tangible as the primary variable maintaining the precursors, however when a different therapist ran sessions for the precursor functional analysis, new precursor behaviors emerged. The other two participants also experienced two different therapists running the session. These therapists were a part of the participant’s regularly scheduled 40-hour weekly ABA services. No other participants showed varied precursors by therapist other than Jon. In addition, when the therapist would reinforce the previously identified precursor behaviors, Jon still engaged in aggression. Thus, the new potential precursors were assessed and met the probability criteria for inclusion. The new precursor behaviors included vocalization “no” and disruptions. After the precursors were redefined, the escape condition showed the highest rate of the precursors and aggression decreased in these sessions. The precursor behaviors for Jon were primarily maintained by negative reinforcement in the form of escape from demands, but may also be sensitive to positive reinforcement in the form of access to tangibles. Jon’s results also demonstrated that precursor behaviors may vary across different or novel people.
The lag-sequential analysis for Jon is shown in Figure 8. Heart rate was on average 96 bpm one minute before the occurrence of the first precursor, 94.6 bpm during the first precursor, and 93.4 bpm one minute after the precursor. There was a 1.4-bpm decrease in heart rate from the one minute before to the first occurrence of the precursor. There was an additional reduction in heart rate from the precursor to the one minute following the occurrence (1.2 bpm). Recall Jon’s heart rate during calm play was 94 bpm, active play was 105 bpm, and topographically similar activity was 110 bpm. The average heart rate during the first precursor was 0.6 bpm higher than calm play, 10.4 bpm lower than active play, and 15.4 bpm lower than the topographically similar activity. Overall, all sessions showed a decrease in heart rate in the two seconds following the first precursor until around lag(18) where Escape 22 heart rate increased while the rest of the sessions continued to decrease until around lag(36). Four out of five sessions showed an increase in heart rate around lag(36) to lag(54). The occurrence of subsequent precursors around lag(30) was likely due to the fact that the participant received a 30s break from the task contingent on engaging in a precursor behavior.

The results of the precursor functional analysis for Camilla are shown in Figure 9. For Camilla, the precursor functional analysis indicated differentiated results with the function of disruptions being escape from demands. There were no occurrences of aggression during the precursor functional analysis for Camilla. These results are consistent with Camilla’s precursor assessment in which aggression primarily occurred in the escape condition.

The lag-sequential analysis for the first occurrence of a precursor for Camilla is shown in Figure 10. Data for the 60s before the instance for Camilla was not gathered due to errors mentioned previously. Due to this, the closest heart rate to 60s before the instance was used as a comparison, which was at lag (-26). Average heart rate 26s before the occurrence of the first
precursor was 89 bpm, during the precursor was 94.6 bpm, and 60s after was 99.3 bpm. There was a 5.6-bpm increase in heart rate from the 26s before to the instance of the first precursor, and an additional 4.7-bpm increase from the first precursor to the one minute after the occurrence. In the heart rate control condition, Camilla’s heart rate was 89 bpm during calm play, 101 bpm during active play, and 94 bpm during a topographically similar activity. The average heart rate during the precursor was 5.6-bpm higher than calm play, 6.4 bpm lower than active play, and 0.6-bpm lower than a topographically similar activity. It makes sense that the topographically similar activity would have a similar heart rate to the precursor behavior as the precursor was disruptions and the motor movements are similar between the two behaviors. Overall, there was a heart rate pattern showing a decreasing trend in all sessions in the six seconds preceding the first occurrence of the precursor. Following the occurrence of the precursor, heart rate continued to decrease until lag (17) in which heart rate increased in all sessions. For Escape 9, there was an additional reduction in heart rate from lag (48) to lag (60).

Figure 11 displays the results of the precursor functional analysis for Teddy. There was a rapid increase early on in precursor behaviors in the attention condition, however behaviors subsided to near zero levels following this. Access to tangibles was the most stable condition which appears to be the primary maintaining variable, but these behaviors may also be sensitive to escape from demands, and on occasion attention.

The results of the lag-sequential analysis of heart rate during the first precursor for Teddy is displayed in Figure 12. Average heart rate one minute before the occurrence of the first precursor was 85 bpm, during the precursor was 96 bpm, and one minute after was 103.4 bpm. There was a 11-bpm increase in heart rate from the one minute before to the instance of the first precursor, and an additional 7.4-bpm increase from the first precursor to the one minute after the
occurrence. In the heart rate control condition, Teddy’s heart rate was 100 bpm during calm play, 106 bpm during active play, and 97 bpm during a topographically similar activity. The average heart rate during the precursor was 4-bpm lower than calm play, 10-bpm lower than active play, and 1-bpm lower than a topographically similar activity. Overall, following the occurrence of the precursor there was an increase in heart rate in all session except tangible 3. In tangible 3 another occurrence of the precursor was observed at lag(2) which could have impact heart rate. Heart rate was also observed to stabilize to around 105 bpm in the around lag(36) following the precursor behavior, which was also during the occurrence of subsequent precursors. Interestingly, 105 bpm is also the same heart rate as active play for this participant.

Two of the three BCBAs answered the questions on the social validity survey. Based on the survey, BCBA’s agreed or strongly agreed with all Likert-type scale questions except on one question. Questions using a Likert-type scale included information such as if the study was relevant for their client, safety of the procedures used, and if the results provided clinically meaningful information that can be used for the client’s treatment planning. For the question “Did the outcome of this study provide any clinical benefit” one BCBA answered ‘somewhat’ and one BCBA answered ‘very’. On the open-ended questions, one BCBA stated that the functional assessment was very helpful, and this information was used during treatment selection, which resulted in an 80% reduction in aggression from baseline levels. The other BCBA noted that the results were beneficial when discussing how precursor behaviors varied by therapist.
Chapter 5 : General Discussion

The purpose of this study was to evaluate if there was a relation between heart rate and precursors to aggressive or disruptive behaviors for children diagnosed with autism spectrum disorder. This investigation also contributed to the limited research on using technology to examine physiological arousal during severe problem behavior. Previous research has found a distinct heart rate pattern preceding occurrences of aggression (Barrera et al., 2007; Goodwin et al., 2019); therefore, it was expected to find a heart rate pattern preceding precursor behaviors as well. While no consistent heart rate pattern was identified for the participants, precursors had a higher heart rate than the one minute preceding for Camilla and Teddy, and for Jon the precursor had a lower heart rate than the one minute preceding. There was a distinct heart rate pattern in which there was a decreasing trend in the 6s preceding the occurrence of the first precursor for Camilla. Jon’s heart rate during the precursor (94.6 bpm) was close to the heart rate identified in calm play (94 bpm). Camilla’s average heart rate during the precursor was also 94.6 bpm which was the same as Jon. Camilla’s heart rate during the precursor was higher than calm play (89 bpm), lower than active play (101 bpm), and similar to the topographically similar activity (94 bpm).

The study revealed several interesting points worth discussing. First, Jon engaged in high rates of motor stereotypy in the form of jumping, stomping, and tensing the body. Data were not collected on motor stereotypy, so it is unclear if this behavior impacted heart rate. Future research should look at the relations between heart rate and motor stereotypy to understand more about physiological arousal during stereotypy. Second, while Jon’s aggression decreased after the precursor behaviors were redefined, aggression still occurred during the precursor functional analysis. There are many possible reasons for this occurrence. It is probable that the precursor
behaviors identified were part of a response chain; however, further data would be needed to assess this (Fritz et al., 2013). Another possibility is that aggression may be respondent behavior elicited from situations such as reinforcer loss or presentation of an aversive stimulus such as demands (Lloveras et al., 2022). Last, it is possible the precursor assessment did not accurately identify precursor behaviors. A no interaction condition was not included in the functional analysis; therefore, no conclusions can be made if aggression was maintained by automatic reinforcement (Lloveras et al., 2022). Across participants, it was observed that the magnitude of the response as well as heart rate decreased the more sessions were ran in the functional analysis. This may be due to habituation in which an aversive stimulus is presented repeatedly and the response decreases over time (Benito and Walther, 2015. One possible reason heart rate did not increase may be that the antecedent stimulus expected to increase heart rate was not intense or unusual enough to elicit activation syndrome. In addition, consequences may not have an impact on heart rate because activation syndrome (heart rate increase) is respondent behavior. Future research should analyze heart rate in a descriptive assessment as a more natural environment may be more likely to elicit activation syndrome.

The current study presented some limitations. First, treatment integrity data were not obtained for Jon due to experimenter error. It is likely that analyzing heart rate via visual analysis alone is not sufficient enough to capture minute changes in heart rate. Future research should look into statistical analyses to identify changes in heart rate as they relate to problem behavior as in Goodwin et al. (2019). There were also some instances during the study in which the Polar Unite Fitness Watch did not collect heart rate data due to losing contact briefly with the participant’s wrist. For this reason, heart rate data were not obtained for all sessions in the 60s preceding the precursor behavior. It may be recommended that future research gravitate toward
using a chest strap sensor. Resting heart rate was obtained by taking heart rate data while the
participant was seated and playing with preferred items. This measure was used as it was
unlikely participants would lay down for 5 minutes without moving to obtain resting heart rate as
recommended by the Polar Unite Fitness Watch. It is possible that this is not a conservative
enough measure to calculate resting heart rate as the presence of preferred items may also
increase heart rate. Future research should look into the effects of preferred items on heart rate.

Last, there were no medical professionals involved in the development of the study.
Collaborating with medical professionals could provide a better idea of participant’s
individualized medical history as it relates to heart rate and physiological arousal.

The implications of this research are twofold. First, there is little research in the literature
on the use of physiological measures in the assessment and treatment of problem behavior for
children with ASD. More research is needed on the interactions between physiology and problem
behavior to better understand the relationship between biological and behavioral mechanisms at
work. With a better understanding of the physiological effects that occur before or during
problem behavior, more precise measures could be used in the future within applied settings. The
second implication of this study is that by targeting precursors or antecedent interventions, a
safer environment can be created in applied settings for clients and staff. So far, all participants
showed a decrease in aggressive behaviors following the precursor functional analysis, and for
Camilla, there was an 80% reduction in aggression from baseline levels (38.44 instances/hour).

One of the primary focuses of this study was to create a safer environment for treating aggression
in children with autism spectrum disorder. Assessment and treatment of precursor behaviors to
aggression should be considered in applied settings as it has been demonstrated to show
reductions in aggression for the participants in this study. It may benefit behavior analysts to
investigate the physiological arousal states of their clients as this could provide information on setting events or other medical problems that individuals with autism spectrum disorder may not be able to identify or communicate.
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Appendix

Figure 1

*Heart Rate Control for Jon*

*Note.* Figure 1 depicts the results of the heart rate control condition for Jon. Jon had an average heart rate of 94 bpm during calm play, 105 bpm during active play, and 110 bpm during a topographically similar activity. Calm play had the lowest heart rate while the topographically similar activity had the highest heart rate (16 bpm higher than calm play, and 5 bpm higher than active play).
**Note.** Figure 2 shows the results of the heart rate control condition for Camilla. Camilla had an average heart rate of 89 bpm during calm play, 101 bpm during active play, and 94 bpm during a topographically similar activity. Calm play had the lowest heart rate and active play had the highest heart rate (11 bpm higher than calm play and 7 bpm higher than a topographically similar activity).
Figure 3

*Heart Rate Control for Teddy*

![Figure 3: Heart Rate Control for Teddy](image)

*Note.* Figure 3 shows the results of the heart rate control condition for Teddy. Teddy’s average heart rate was 100 bpm during calm play, 106 bpm during active play, and 97 bpm during a topographically similar activity. The topographically similar activity had the lowest heart rate and active play had the highest heart rate (6 bpm higher than calm play, 9 bpm higher than topographically similar activity).
Note. Figure 4 shows the results of the conditional and unconditional probability analysis for Jon. The probability of the precursors “Shh”, 45º bend at hip, behind therapist, and eye contact given the occurrence of aggression was 0.30, 0.30, 0.02, and 0.80 respectively. The probability of aggression given the occurrence of the precursors “Shh”, 45º bend at hip, behind therapist, and eye contact was 0.75, 0.50, 1.0, 0.42. Both probability values for the identified precursors were higher than the unconditional probability values of the precursors (0.17, 0.25, 0.25, 0.25) and the unconditional probability values of aggression (0.17, 0.42, 0.42, 0.42). These values were also greater than the probability of the precursor given the absence of aggression (0.07, 0.21, 0, and 0.79) as well as the probability of aggression given the absence of the precursor (0.35, 0.39, 0.36, and 0.4).
Conditional and Unconditional Probability Analysis for Camilla

Figure 5 displays the results of the conditional and unconditional probability analysis for Camilla. The probability of the precursor, disruptions, given the occurrence of aggression was 0.54. The probability of aggression occurring given the occurrence of disruptions was high, 0.88. Both probability values for disruptions were higher than the unconditional probability value of disruptions (0.20) and the unconditional probability of aggression (0.33). These values were also greater than the probability of the precursor given the absence of aggression (0.03) and the probability of aggression given the absence of the precursor (0.19).
Figure 6

*Conditional and Unconditional Probability Analysis for Teddy*

![Figure 6: Probability Analysis of Precursors for Teddy](image)

*Note.* Figure 6 shows the results of the probability analysis of precursor for Teddy. The probability of the precursor given the occurrence of aggression for negative vocalizations, walking with fist, jumping, and reaching was (0.88, 0.44, 0.44, 0.40). The probability of aggression occurring given the occurrence of the precursors was high (1.0, 1.0, 0.80, 0.67), respectively. Both probability values for the precursors were higher than the unconditional probability value of the precursors (0.71, 0.13, 0.33, 0.35) and the unconditional probability of aggression (0.59, 0.60, 0.60, 0.59). These values were also greater than the probability of the precursor given the absence of aggression (0.29, 0.11, 0, 0.11) and the probability of aggression given the absence of the precursor (0, 0.45, 0.55, 0.45).
Figure 7

*Precursor functional analysis for Jon*

*Figure 7: Precursor Functional Analysis for Jon*

![Graph showing precursor behaviors over sessions](image)

*Note.* Figure 7 displays the results of the precursor functional analysis for Jon. The precursor functional analysis initially identified tangible as the primary variable maintaining the precursors, but due to a new therapist running the functional analysis, the participant started to display different precursor behaviors not previously observed in the precursor assessment. When the new potential precursors were assessed, they met criteria for inclusion in the functional analysis, so the precursor behaviors were redefined for sessions 17-22. After redefining the precursor behaviors, the escape condition showed the highest rate of precursors. Jon’s precursor behaviors are likely maintained by escape from demands, but may also be sensitive to tangible access.
Figure 8

Lag-sequential Analysis for Jon

Note. Figure 8 illustrates the lag-sequential analysis of heart rate during the 60s before and after the first occurrence of the precursor during the functional analysis for Jon. Heart rate was on average 96 bpm one minute before the occurrence of the first precursor, 94.6 bpm during the first precursor, and 93.4 bpm one minute after the precursor. There was a 1.4-bpm decrease in heart rate from the one minute before to the first occurrence of the precursor, and an additional reduction from the precursor to the one minute following the occurrence (1.2 bpm). Jon’s heart rate during calm play was 94 bpm, active play was 105 bpm, and topographically similar activity was 110 bpm. The average heart rate during the first precursor was 0.6 bpm higher than calm play, 10.4 bpm lower than active play, and 15.4 bpm lower than the topographically similar activity.
Figure 9

Precursor functional analysis for Camilla

Figure 9: Precursor Functional Analysis for Camilla

Note. Figure 9 displays the results of the precursor functional analysis for Camilla. The precursor functional analysis yielded differentiated results and identified escape from demands as the function of the precursor (disruptions) for Camilla.
**Figure 10**

*Lag-sequential Analysis for Camilla*

*Figure 9: Lag-Sequential Analysis of Heart Rate During First Precursor (Camilla)*

*Note.* Figure 9 illustrates the lag-sequential analysis conducted with Camilla for the first occurrence of the precursor during the functional analysis. Heart rate for Camilla showed a decrease in the 6 seconds immediately preceding the precursor from 109 bpm (lag -6) in Escape session 4, and 92 bpm (lag -6) in Escape 9 and 14 to 105 bpm, 89 bpm, and 90 bpm (lag 0) respectively. Following the occurrence of the precursor, heart rate continued to decrease until lag (17) in which heart rate increased in all sessions. For Escape 9, there was an additional reduction in heart rate from lag (48) to lag (60).
**Figure 11**

*Precursor functional analysis for Teddy*

Figure 11: Precursor Functional Analysis for Teddy

![Graph of precursor behaviors](image)

Note. Figure 11 displays the results of the precursor functional analysis for Teddy. There was a rapid increase early on in precursor behaviors in the attention condition, however behaviors subsided to near zero levels following this. Access to tangibles was the most stable condition which appears to be the primary maintaining variable, but these behaviors may also be sensitive to escape from demands, and on occasion attention.
Note. Figure 12 displays the lag-sequential analysis conducted with Teddy for the first occurrence of the precursor during the functional analysis. Heart rate showed an increase from the one minute before the precursor (87.8 bpm) to the precursor (96 bpm), and an additional increase from heart rate during the precursor behavior to the one minute following (103.4 bpm). There was a 8.2-bpm increase from the one minute preceding to the occurrence of the first precursor, and an additional 7.4 bpm increase from the precursor to one minute after the precursor. Teddy’s heart rate during the precursor behavior was lower than calm play (100 bpm), active play (106 bpm), and a topographically similar activity (97 bpm). Overall, there was an increasing trend starting from the one minute preceding the precursor until the one minute after the precursor.
Social Validity Survey

1. Do you feel like this research study was relevant for your client?
   1  2  3  4  5
   Not at all  Very

2. Were you comfortable with the procedures used in this study?
   1  2  3  4  5
   Not at all  Very

3. Do you feel there were enough safeguards in place in this study?
   1  2  3  4  5
   Not at all  Very

4. Do you feel like the outcome of this study provided more information about your client’s problem behavior (aggression and/or disruptions)?
   1  2  3  4  5
   Not at all  Very

5. Did the outcome of this study provided any clinical benefit?
   1  2  3  4  5
   Not at all  Somewhat  Very

6. Would you recommend this study to others with similar behavior concerns? Why or why not? __________________________________________________________

7. Is there any other feedback you would like to share about the study?
   _________________________________________________________________