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A Comparison of Traditional Aggregated Data to a Comprehensive Second-by-Second Data Depiction in Functional Analysis Graphs

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A COMPARISON OF TRADITIONAL AGGREGATED DATA TO A COMPREHENSIVE SECOND-BY-SECOND DATA DEPICTION IN FUNCTIONAL ANALYSIS GRAPHS

By

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Abstract

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Functional analyses (FAs) are an important component of treatment and the data gathered from FAs are often graphed in an aggregate or summary format, such as mean rate per session. Given the prevalence of undifferentiated analyses, it may be that this common method of data depiction is incomplete. In this paper, we compare the traditional aggregate method to a comprehensive second-by-second demonstration of the data including all appropriate and inappropriate responses emitted, as well as programmed and accidental antecedent and consequent variables, which may help further clarify the results of a functional analysis. We compared the functional analysis results of two participants when the data were depicted using the traditional rate aggregate method and depicted using a comprehensive second-by-second method. Although both rate and comprehensive second-by-second data depiction resulted in similar conclusions regarding the maintaining variables for the participants, comprehensive second-by-second data depiction allowed us to draw the conclusions in less time. Additional advantages and disadvantages of each method as it relates to efficiency, therapeutic risk and safety, and practicality are also discussed.

Keywords: efficiency, functional analysis, problem behavior, safety, within-session second-by-second analysis

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CHAPTER 1: INTRODUCTION

Origins of Behavior Analytic Data Collection Methods

In his first book, *The Behavior of Organisms* (1938), B.F. Skinner introduced a science of behavior distinct from the popular (at the time) conceptions of the mind. These conceptions of the mind, such as drive or motivation, ostensibly explained behavior but could not be tested. His goal was to describe a scientific system for understanding behavior, similar to those described by physicists, which explained the orderly relations between an organism's behavior and its environment (i.e., a set of scientific laws) through systematic experimentation rather than *a priori* hypothesizing (Skinner, 1938). Additionally, Skinner was adamant that a science of behavior should include both behaviors and the environmental variables influencing those behaviors, all of which should be observable and manipulatable (Skinner, 1938). Direct observation of behavior was therefore an essential feature of his data collection method. One of Skinner's major discoveries was operant behavior, defined as observable behaviors that are evoked by antecedent variables and are either strengthened or weakened by the consequences that immediately follow them (Skinner, 1938). Operant behavior and operant learning are major components of applied behavior analysis (Morris et al., 2005).

Skinner was not looking for operant learning when he was conducting his initial experiments, rather he was expecting to learn more about respondent learning (Vargas, 2004). It was not until Skinner developed an apparatus that recorded the exact moment a response was emitted that he was able to notice an important facet of operant responding, namely that antecedent and consequent variables had a direct effect on the occurrence of the target behavior (Vargas, 2004). During an experiment in which a rat pressed a lever to release food, a lever got stuck and stopped the food from reaching the rat (Vargas, 2004). This prompted a variation in the rat's responding and produced a data curve that was unlike the patterns Skinner had previously noted during his experiments on respondent learning (Vargas, 2004). Because Skinner was collecting second-by-second data, he was able to see exactly when the new pattern began. He noted that the rat was no longer being fed every time the lever was pressed, and this led to a change in the rat's pattern of responding (Vargas, 2004).

The change in data patterns led Skinner to experiment with manipulating antecedent variables such as a light, click, or buzz to signal when food would be available versus unavailable as well as consequences by releasing food or delivering shock at different intervals or following a certain amount of responding (lever pressing) (Skinner, 1938). He used second-by-second data collection to analyze the change in patterns of responding and the exact moments the change occurred in relation to the manipulation of antecedent and consequent variables. By doing so, Skinner discovered operant conditioning (Vargas, 2004) and the importance of functional relations between behavior and environmental variables. Skinner used the term functional analysis to describe the functional relations between behavior and the environmental conditions which evoke and maintain that behavior (Skinner, 1953). He described the relations as "cause-and-effect" (p. 35), in that the relevant environmental variables directly control the occurrence of the responses. He also showed that this control can be demonstrated repeatedly and with precision to predict future responses (Skinner, 1953).

As described above, we now know that the basic reinforcement contingency includes antecedent stimuli that evoke the target response in a particular moment, and consequent stimuli that reinforce and increase the future probability of that response. Michael (1993) further expanded on this topic by dividing antecedent stimuli into establishing operations (EO) and discriminative stimuli (SD). Michael defined EOs as changes in the environment that have two effects. The first effect is reinforcer establishing, which means that the introduction of the EO increases the value of the reinforcer following a response (Michael, 1993). The second effect is evocative, meaning that the introduction of the EO evokes a response (Michael, 1993). Therefore, when a relevant EO is present there is an immediate increase in the occurrence of the target response. Reinforcers also have two effects, both on the target response. The long-term effect of a reinforcer is an increase in the future probability of the target response. The immediate effect of a reinforcer, however, is a momentary cessation of responding that produced that reinforcer. This may be due to either an abolishing effect in that each delivery of reinforcement may in turn reduce the momentary value of that reinforcer, or it may be due to the occurrence of competing consumption responses (e.g., eating the food) that momentarily result in the non-occurrence of the target response. Thus, a full understanding of functional relations between the relevant environmental variables and the behaviors they control requires an intimate analysis of both immediate and long-term effects of these variables on the behavior of interest.

Functional Analysis of Problem Behavior: Applied Implications

The field of applied behavior analysis (ABA) was formally described by Baer et al. in 1968. Baer et al. identified seven dimensions of behavior analysis: behavioral, analytic, applied, technological, conceptual systems, effective, and generality. The analytic dimension requires that the variables responsible for behaviors occurring or not occurring be experimentally demonstrated. Despite Baer et al.'s paper, prior to the introduction of the functional analysis method developed by Iwata et al. in 1982, many practitioners were using behavior modification practices, relying on high value arbitrary reinforcers and punishers to decrease challenging behaviors rather than identifying the functionally related variables (Mace, 1994). Concerns surrounding the generality, safety, social validity, and long terms effects of behavior modification methods led to the shift to a functional approach (Hagopian et al., 2013; Mace, 1994). The functional approach focuses on weakening the relation between the reinforcer and challenging behaviors, and strengthening, or establishing, the relation between the reinforcer and adaptive behaviors (Mace, 1994). This approach can be done in many ways, meaning that the treatment developed based on the results of a functional analysis can be individualized (Mace, 1994). The increased usage of functional approaches to treat problem behavior also resulted in decreased use of punishment-only based treatments (Pelios et al., 1999).

Experimental analyses are used to identify the variables maintaining an individual's behavior. Functional analyses of problem behavior are experimental analyses that often focus on the variables specifically maintaining problem behavior (Lovaas et al., 1965). One of the earliest examples of using a functional analysis for problem behavior was conducted by Lovaas et al. in 1965. Lovaas et al. demonstrated functional control of three children's self-injurious behavior through the contingent presentation and removal of attention. They found that when they manipulated the EO (i.e., removed and delivered attention) self-injury occurred at a higher rate when attention was removed and decreased when attention was delivered contingent on the occurrence of problem behavior (Lovaas et al., 1965). They demonstrated that self-injurious behavior could be an operant behavior and that attention was functionally related to a high rate of the target behavior, both of which contradicted the belief at the time that these behaviors were organic or automatic (Lovaas et al., 1965). However, their functional analyses also took between 30 and 41 days to complete. Carr et al. (1976) conducted a study which demonstrated functional control of self-injurious behavior through the presentation and removal of demands; however, their functional analysis took approximately 21 days with 2 sessions occurring per day, 5 days a week. Neither of these functional analyses would be considered practical or ethical by today's standards (Professional and Ethical Compliance Code for Behavior Analysts 2.09c, 3.01a; BACB, 2014).

To address issues of variability in methods and length of functional analyses, Iwata et al. (1982/1994) combined the various procedures into a standard comprehensive assessment aimed at identifying the main effects of the common generic classes of reinforcement. In the standard functional analysis, multiple test conditions in which an isolated consequent variable (e.g., attention, escape, tangible) is presented or removed contingent on the occurrence of target behavior and is compared to an omnibus control condition in which all potential reinforcers are freely available (Iwata et al., 1982/1994). The specific test conditions include: attention, in which all vocal and physical attention are withheld and brief statements of disapproval or physical contact are delivered contingent on problem behavior; escape, in which academic demands are delivered and briefly removed contingent on problem behavior; unstructured play, in which toys are freely available, no academic demands are delivered, and attention is delivered contingent on the absence of problem behavior and served as the control condition; and an alone condition, in which the participant is placed in the observation room alone without any access to toys or materials to test for automatic function. A tangible condition, in which preferred items are withheld and delivered contingent on problem behavior is also typically included in functional analyses based on Iwata et al. (Beavers et al., 2013). This model has become the standard model for functional analysis of problem behavior and has been replicated over 350 times in published literature (Beavers et al., 2013; Hanley et al., 2003). Iwata et al.'s functional analysis (1982/1994) has also been extended to incorporate other topographies of problem behavior including aggression, property destruction, and inappropriate vocalizations; and other populations (Beavers et al., 2013; Hanley et al., 2003). To increase the efficiency of functional analyses, variations have been made to the original model. These variations include decreasing the length of sessions (Northup et al., 1991; Wallace & Iwata, 1999), using a different experimental design (Vollmer et al., 1993), using different methods of data collection and presentation (Thomason-Sassi et al., 2011), conducting only one session per condition (Northup et al., 1991), ending sessions following the first instance of problem behavior (Thomason-Sassi et al., 2011), using a pairwise experimental design (Iwata et al., 1994), and synthesizing conditions (Hanley et al., 2014).

Traditional Data Analysis and Presentation During Functional Analyses

The way in which functional analysis data is presented is important because decisions about the most appropriate treatment are typically based on visual analysis of the graphed data. The most common depiction of data is rate (Beavers et al., 2013). Skinner (1976) discussed his concerns regarding the shift from second-by-second data depiction in the form of a cumulative record to aggregate data depiction. He noted the importance of the depiction of steady rates in aggregate data depiction but expressed concern that important momentary changes in behavior would be lost through this method (Skinner, 1976). Generally, the only data presented in functional analyses represent the target problem behaviors and all topographies of the target problem behaviors are aggregated into a single data point per session (Hagopian et al., 2013; Hanley et al., 2014; Iwata et al., 1982/1994; Jessel et al., 2016; Northup et al., 1991; Thomason-Sassi et al., 2011). Thus, during visual analysis, it is unclear whether the response was mild, moderate, or severe, or served as a precursor behavior to more severe problem behavior. In addition to aggregating all topographies of problem behavior, many variables and behaviors are not reported, including appropriate behaviors and implementer behaviors; also missing is information about whether the behaviors are occurring during the reinforcement or EO interval and whether any unprogrammed variables occurred during the session. Given all of the information excluded from a typical functional analysis graph, it is possible that conclusions are being drawn from a very limited picture of what is actually occurring in the environment.

The notion of within-session analysis of functional analyses is not new (Northup et al., 1991; Roane et al., 1999; Vollmer et al., 1993). Roane et al. (1999) conducted functional analyses based on Iwata et al. (1982/1994) where they divided the test sessions into reinforcement present and reinforcement absent intervals and noted during which interval the target behaviors were occurring (Roane et al., 1999). By closely examining whether target behaviors occurred in reinforcement present or absent intervals, they were able to expand and clarify the conclusions of the functional analysis, in particular in the case of seemingly undifferentiated results. These authors suggested that within session analyses, particularly when comparing reinforcer present and reinforcer absent intervals, may be a useful tool worthy of additional research. Northup et al. (1991) conducted brief functional analyses and then did a within session analysis of a contingency reversal in which manding was reinforced. They divided the sessions into 1-min intervals and reported the number of 6-sec intervals in which target behavior occurred. They found that within the sessions, there was an increase in responding as the session went on. Vollmer et al. (1993) conducted functional analyses based on Iwata et al. (1982/1994) and analyzed within session responding. They divided the sessions into 1-min intervals and recorded the number of responses that occurred within each minute (Vollmer et al., 1993). They found that by using within session analysis they were able to identify sensitive responding to particular contingencies (Vollmer et al., 1993). It is unclear, however, in both Northup et al. and Vollmer et al. whether the behaviors were occurring in reinforcement present or reinforcement absent intervals. This information can be particularly useful if the results of functional analyses are undifferentiated.

Current Problems with Functional Analyses

Despite the evidence that functional analyses lead to more efficacious treatments (Campbell, 2003), many practicing behavior analysts do not conduct functional analyses (Oliver et al., 2015; Roscoe et al., 2015). Among surveyed behavior analysts who stated they did not conduct functional analyses in their practices, the most frequently cited reason was a lack of time (Oliver et al., 2015). This is not a trivial concern when we consider the length of time of the functional analysis method first described by Iwata et al. (1982/1994). Though the current most popular length of sessions is 10 min, in these functional analyses, test and control sessions lasted 15 minutes, with approximately 8 sessions per day; sessions continued until responding was stable, unstable across all conditions for 5 days or until 12 days of sessions were completed. Thus, if functional analyses are conducted exactly as described by Iwata et al., a single functional analysis would take a minimum of 3 hours across 1.5 days and a maximum of 24 hours across 12 days, without guarantees of clearly differentiated results (e.g., Beavers et al., 2013; Hagopian et al., 2013; Hanley et al., 2003). Therefore, although the functional analysis is (and should remain) the gold standard of assessment procedures, the way in which functional analysis data are collected and depicted warrants investigation.

Reviews of the published functional analysis literature and consecutive case series have shown that undifferentiation, particularly during an initial functional analysis, is a common occurrence (Beavers et al., 2013; Hagopian et al., 2013; Hanley et al., 2003). Although Hanley et al. (2003) found approximately 4% of functional analyses in the literature were undifferentiated and Beavers et al. (2013) found that the number of undifferentiated functional analyses doubled within the 10 years to approximately 8%, these low percentages can be misleading. These low percentages do not account for modifications and changes made to a substantial number of undifferentiated functional analyses in order to obtain clear patterns (Hanley et al., 2003). Although clearly, modifications and changes that result in a re-do of a functional analysis will add additional time to the assessment phase, and re-expose the individual to these assessment conditions, the exact cost in terms of time and resources is unknown. Hagopian et al. (2013) demonstrated that undifferentiation is actually a common occurrence and highlighted the need for modifications to current analyses of functional analysis data. They analyzed consecutive case series in which all functional analyses conducted with patients at an inpatient treatment center were reviewed. This is different than a typical single subject design as all consecutive participant data, differentiated or not, were published. They found that only 47% of functional analyses were initially differentiated. They were able to increase differentiation to 87% of the functional analyses conducted by making up to two modifications (e.g., changing antecedent conditions, changing consequent variables, changing the design) to the analyses (Hagopian et al., 2013). Additionally, Slaton et al. (2017) conducted a consecutive case series in and found that with Iwata et al. (1982/1994) type functional analyses, only 4 of their 9 functional analyses were initially differentiated (Slaton et al., 2017). Thus, a publication bias may exist, such that researchers fail to report undifferentiated results, modify their analyses until there are undifferentiated results, submit for publication only studies with clear results, or are unable to get their studies showing undifferentiated results accepted for publication (Hanley, 2012; Tincani & Travers; 2019). Rosenthal (1979) coined the term “file drawer problem” which refers to the idea that only a small number of studies conducted make it into journals; these studies tend to be the ones with significant results, even though these studies tend to be in the minority of all studies conducted. Unfortunately, this gives us a skewed view of the meaningfulness of certain types of data.

We ought to be concerned about the proportion of functional analyses that are likely to end with undifferentiated results. Every time an additional session or a new functional analysis must be conducted, we are both exposing the individual to a context that is potentially dangerous and they are practicing inappropriate behaviors. Moreover, published functional analyses are typically conducted by expert researchers in highly controlled settings and yet they still show some level of undifferentiation; this does not bode well for the average clinician who may need to conduct sessions in the home or community where there are many extraneous and competing variables. In addition to time and a lack of differentiated results, almost a quarter of surveyed behavior analysts indicated that there was a lack of approval from administration and families for conducting functional analyses (Oliver et al., 2015). It is possible that a lack of approval from families stems from not only the time it takes to conduct a functional analysis, but also the potential for harm and concerns for the safety of the individual during the functional analysis. Hanley (2012) described that not conducting a functional analysis is more dangerous than conducting one because regardless of a functional analysis the behaviors are occurring in the natural environment. Reaching an understanding about the contextual variables that evoke and support these dangerous forms of behavior are in fact necessary and the safest option for treating such behaviors. However, concerns for safety and feasibility of conducting a functional analysis in a variety of setting deserve further consideration and may require further modifications to the traditional arrangement of the conditions of a functional analysis (Hanley, 2012). Direct observation of the target behavior is necessary when conducting a functional analysis (Hanley et al., 2003) and traditionally there has been a requirement to observe the individual engage in severe and dangerous forms of problem behavior. This means that the direct observation of the individual is occurring throughout the entire functional analysis. A functional analysis that is lengthy or inconclusive repeatedly puts the individual and the implementers in a dangerous situation for a prolonged time and can produce little useful data. Time and safety are important ethical and safety considerations when conducting functional analyses (Iwata & Dozier, 2008) and therefore the time spent actively conducting functional analyses should be minimized for the client first and foremost, but also for the implementers (Iwata & Dozier, 2008; Oliver et al., 2015).

Previous Attempts to Address Practical Barriers of Traditional Functional Analyses Procedures

Various strategies have been recommended to decrease time spent actively conducting functional analyses and increase safety (Hanley, 2012; Iwata & Dozier, 2008). These strategies include decreasing the number of sessions required for a functional analysis (Northup et al., 1991), decreasing the length of sessions (Wallace & Iwata, 1999), conducting latency-based sessions (Thomason-Sassi et al., 2011), and the Interview Informed Synthesized Contingency Analysis (IISCA; Hanley et al., 2014). Northup et al. (1991) developed the brief functional analysis to decrease time spent actively conducting functional analyses with individuals who engaged in severe aggression. The brief functional analysis is based on Iwata et al. (1982/1994) where within each of the conditions, variables are presented or removed repeatedly contingent on target responding. It is a brief functional analysis because it requires only one session for each condition and sessions are no longer than 10 min (Northup et al., 1991). They found that they were able to determine the variables that were maintaining problem behavior while minimizing the number of sessions in which the participants were exposed to the EO (Northup et al., 1991).

Another method to decrease time spent exposing individuals to EOs, is to decrease session duration (Wallace & Iwata, 1999). For example, Wallace & Iwata (1999) shortened sessions to 5 min and their data were similar to those found when conducting the 15 min sessions (Iwata et al. 1982/1994).

Iwata et al. (1994) introduced using a pairwise design for functional analyses as opposed to the multielement design as described in Iwata et al. (1982/1994). This was in response to concerns regarding undifferentiation when typical multielement designs were used and the potential inefficiency reversal design as it required more sessions to demonstrate a pattern of responding than multielement (Iwata et al., 1994). They found that for 2 of their 5 participants, the results of the pairwise design matched that of the multielement design. For the other 3 participants who had unclear results when a multielement design was used, 2 had clearer results with the pairwise design (Iwata et al., 1994). However, this iteration of the pairwise design required more sessions than the typical multielement design and was therefore only recommended when results were undifferentiated or if the alternative design was a reversal (Iwata et al., 1994).

To further decrease the likelihood of undifferentiation during functional analyses, Hanley (2012) recommended eliminating the use of generic contingencies, and instead using a detailed open-ended interview and a brief observation as the first step in the assessment process to individualize the contingencies tested in a functional analysis. He also recommended the use of a pairwise design (Hanley, 2012). This process was further evaluated by Hanley, et al. (2014) in which an open-ended interview and a brief observation were used to design individualized test and control conditions leading to effective and socially validated functional communication training (FCT) treatments for three children. Although not all researchers agree (Fisher et al., 2016), the IISCA has been evaluated as a practical and efficient functional analysis model for designing efficacious and socially valid treatments of severe problem behavior (Beaulieu et al., 2018; Coffey et al., 2019; Ghaemmaghami et al., 2016; Ghaemmaghami et al., 2018; Jessel et al., 2018; Slaton et al., 2017; Taylor et al., 2018).

However, despite these modifications, some practitioners were still concerned about the social validity and safety of repeated exposure to EOs and the requirement that individuals repeatedly engage in potentially dangerous behaviors. In response, Thomason-Sassi et al. (2011) developed a functional analysis in which the sessions were terminated following the first instance of target behavior. They measured response latency and found that they were able to determine the variables maintaining responding by only evoking the problem behavior once (Thomason-Sassi et al., 2011).

Strategies such as shortening the number of sessions and session duration and terminating following the first instance of a target behavior can decrease time actively conducting functional analyses. However, if the results of the functional analysis are undifferentiated, the functional analysis must be continued, possibly with modifications. As Hagopian et al. (2013) and Slaton et al. (2017) demonstrated, often the first iteration of standard functional analyses (based on the methods described by Iwata et al.,1928/1994) required multiple modifications before differentiated results were obtained. Additionally, Jessel et al. (2016) showed that undifferentiation and modification are also common for synthesized functional analyses (based on the methods of Hanley et al., 2014). Even with these modifications, there are still instances in which the results remain undifferentiated (Hanley et al., 2003; Slaton et al., 2013). It is possible, however, that before additional sessions or analyses are conducted a more intimate look at the data can be done to replace the need to actively conduct more sessions.

An Alternative Comprehensive Second-by-Second Within-Session Depiction of Data

One alternative to aggregate data depiction is a comprehensive second-by-second data depiction method which includes a more intimate depiction of behaviors emitted during the analysis. Comprehensive second-by-second data depiction has three main components. First, it requires displaying each occurrence of the response at the moment of its occurrence and separate depiction of all topographies of problem behavior. Second, this comprehensive method calls for measuring additional behaviors and variables including appropriate behavior (e.g., compliance, communication, engagement) emitted by the participant, as well as all implementer behaviors such as introduction and removal of EOs and reinforcers (whether programmed or accidental). Third, a post hoc analysis is necessary to identify all relevant responses and variables. By using a more intimate and comprehensive depiction of the responses and environmental factors present during an analysis, we may be able to determine the relevant variables maintaining problem behavior more quickly, thereby eliminating the need for additional functional analyses or sessions, a question that we attempt to answer in this study.

Data Point Depiction Using Second-by-Second Within-Session Analysis

Comprehensive second-by-second data depiction requires each data point to be shown in real time as it occurs in relation to the introduction and removal of EOs. This means that each behavior and variable is depicted independently at the moment that it occurred within the session. This is important as it allows for a clear picture of the relation between the suspected maintaining variables and the target behaviors.

Inclusion of All Behaviors and Environmental Events During the Analysis

When using comprehensive second-by-second data depiction, we can measure and report on behaviors and variables other than the target problem behaviors. These behaviors and variables include appropriate behaviors, problem behaviors not originally defined as belonging to the target response class, implementer behaviors such as EO and reinforcement delivery or prompting, and emotional and collateral responses. Second-by-second data depictions illustrate the many things occurring within the functional analysis at the moment they occur and provide more detailed or differentiated information about the functional relation between the behaviors and maintaining variables. For example, if there is latency in target responding after the introduction of the EO, second-by-second data depiction can capture what is occurring during that time. It is possible that the individual is engaging in alternative or less severe problem behaviors or has some tolerance to the EO and is engaging in appropriate behaviors such as functional communication or compliance. There is some precedence of reporting appropriate responding, such as mands (Ghaemmaghami et al., 2016; Harding et al., 2009), however these data are aggregated and therefore it is not clear as to whether or not these responses are occurring during reinforcement present or absent intervals, or if these responses are occurring in relation to the introduction or removal of EOs and reinforcers.

Additionally, published functional analyses typically focus on the behaviors of the target individual and do not consider the behaviors of the implementer (Hagopian et al., 2013; Hanley et al., 2014; Iwata et al., 1982/1994; Jessel et al., 2016; Northup et al., 1991; Thomason-Sassi et al., 2011). By measuring implementer behavior, comprehensive second-by-second data depiction may capture situations such as delays delivering reinforcement following the first instance of target behavior which may result in higher rates of responding. These additional variables may create a clearer picture of what is occurring within a functional analysis that could potentially lead to more accurate findings regarding which variables are maintaining problem behavior.

Post-Hoc Analysis of Unprogrammed and Additional Variables

Other variables potentially functionally related to the target behavior often cannot be predicted prior to establishing the target behavior of interest in a functional analysis. This makes post-hoc analyses necessary, especially if the results of a functional analysis are undifferentiated. In order to do this, the functional analysis sessions must be video recorded to allow for analyzing data post-hoc. Although this used to be a barrier (Kahng & Iwata, 1998), advances in technology such as access to portable devices that record in high quality are widely available (e.g., the smart phone), thus effectively removing this barrier. Having a reliable way to record sessions to conduct post-hoc analyses also means that a second person may not be required to collect *in vivo* data, thus effectively eliminating what used to be another barrier to this type of data collection.

Skinner (1953) noted that behavior does not occur in a vacuum and that an organism will react and behave differently to features of even an empty box. Functional analyses are typically conducted in rooms that have even more features than an empty box. Therefore, despite best efforts to control for extraneous variables, there may be unprogrammed environmental variables having an effect on behavior that are occurring simultaneously with the programmed variables. These extraneous variables may not be noticed until the functional analysis is being actively conducted and may be difficult to control or predict. Similar to the inductive method of research that Skinner originally used in his experiments, by using a post-hoc analysis the analyst can identify potential unprogrammed variables that may have had an effect on responding without having to conduct additional functional analyses. This approach has the potential advantage of being safer for the client as it limits the opportunities to engage in potentially dangerous responses as well as decreasing overall time by not having to conduct additional functional analysis sessions.

The current method of aggregate data depiction is generally less arduous to code and graph than second-by-second data. Because the exact moment the behavior occurs is not important for graphing aggregated data, the data collector need only record either the number of occurrences of the target behavior or the percentage of intervals within the session that the target behavior occurred (Fiske & Delmolino, 2012). One advantage of this method is that it allows a single practitioner to both collect the data and conduct the functional analysis at the same time. However, as Skinner (1953) explained, the purpose of a functional analysis is to see the direct relation between behaviors and environmental variables. By aggregating data, this relation can be lost, as it is not necessarily clear when the behaviors are occurring in relation to the change of the environmental variables.

Second-by-second data depiction requires video recording the functional analysis and coding it afterwards. Although this might initially increase the necessary time and resources, the time spent coding might yield advantages over aggerated data collection and depiction. First, real time functional relations between the target behavior and the environmental variables might be more apparent. Because the exact moments behaviors occur are being recorded, we can more easily observe if they are occurring while reinforcers are present or absent. This can show whether the manipulation of the environmental variables had a direct effect on responding thus potentially decreasing the amount of time needed to actively be conducting a functional analysis. Additionally, because individual occurrences of the behavior are not aggregated, we might more readily see responding that occurs in bursts or clusters and precursors to the target behavior. Comprehensive second-by-second data depiction, while possibly requiring more time and resources at the start, has the potential to minimize overall time spent actively conducting functional analyses.

Purpose

Functional analyses are experimental arrangements in which variables evoking and maintaining behaviors are identified. Aggregate depictions of functional analysis data are the most commonly used depictions. However, aggregating data may result in certain patterns of behavior or environmental variables being overlooked. The first purpose of this study was to examine whether use of comprehensive second-by-second data depiction provides a clearer relation between the manipulation of environmental variables and responding, particularly with undifferentiated analyses. The second purpose was to see if use of comprehensive second-by-second data depiction decreases time spent actively conducting functional analyses therefore decreasing the individual/client's time in assessment as well as increasing safety. Finally, we examined whether measuring and depicting each topography of problem behavior, appropriate behavior, implementer behavior, and EOs separately reveals any additional effects of the EO or reinforcement. These questions were answered through a comparison of functional analyses depicted by the current most common method, rate (Beavers, 2013), and comprehensive second-by-second data depiction.

CHAPTER 2: METHODS

Participants and Setting

Two children participated in this study. John was a 6-year old Caucasian boy who lived in his family home with his mother and father. He had a diagnosis of autism and had a stroke at birth limiting his mobility on one side. He engaged in aggression, property destruction, and self-injurious behavior. He did not engage in vocal language but used a picture exchange system that his mother developed in the home and at school. Miguel was a 6-year-old Latino boy. He and his sister lived part time with his mother and part time with his father. Both households spoke English and Spanish. Miguel had a diagnosis of autism. He engaged in disruptive tantrums that involved flopping and crying. He had limited vocal language skills and had access to a picture exchange communication system at school.

Sessions were conducted in English in treatment rooms on a university campus that were equipped with audio and video equipment, a one-way mirror, child-sized table and chairs, and play materials. 3 to 6 sessions were conducted per visit 2 to 4 times per week based on participant availability. Sessions were 5 min in duration. Sessions would have been terminated if there were 3 mins of severe problem behavior or if blood had been drawn. This did not occur during any sessions.

Measurement and Interobserver Agreement (IOA)

All sessions were video recorded allowing for post-hoc collection and analysis of data. Trained observers used Countee, a smartphone app, to record second-by-second data on participant and implementer behaviors including manipulation of relevant contextual variables. In addition to pre-selected variables measured, observers noted and subsequently collected data on any additional responses and unprogrammed environmental events (e.g., presence of a wrist-brace which may have functioned as an unprogrammed EO) that occurred. For one analysis, the time required to conduct the post-hoc analysis was calculated to provide an estimate of the additional time required to review the analysis and identify variables and behaviors that were not pre-selected and to measure these additional behaviors and variables.

Table 1 outlines the responses recorded for both participants. John's behaviors in the contingency class (i.e., the behaviors that signaled the start of the reinforcement period) included aggression, self-injurious behavior, and property destruction, all of which were measured as frequency counts. Problem behaviors that were not included in the contingency class for John included flopping, whining, and crying, and these responses were measured in duration. Functional behaviors that were not included in the contingency class for John were measured in frequency and included functional communication. Additionally, the duration of an unprogrammed EO, having a wrist brace on, was also recorded.

Problem behaviors included in the contingency class for Miguel, measured as frequencies, included aggression and property destruction; problem behaviors included in the contingency class measured in duration were screaming and flopping. Problem behaviors that were not included in the contingency class for Miguel which were measured in duration included crying, whining, and non-compliance (i.e., completing a demand with a physical prompt). Functional behaviors not included in the contingency class for Miguel included functional communication which was measured as a frequency, and independent compliance (i.e., completing a demand with either a vocal, model, or gestural prompt) which was measured in duration. Implementer behaviors recorded during Miguel's functional analyses included demand delivery which was measured in frequency and the presentation of reinforcement was recorded in duration.

Table 1

Environmental Events and Various Topographies of Behavior Measured and Depicted for Each Participant

Participant	Problem Behaviors in contingency class	Problem behaviors not in contingency class	Appropriate behaviors
John	Aggression: Hitting, kicking, biting others, throwing items within 2 ft of a person Property Destruction: swiping items off surface, throwing items Self-Injurious behavior: biting right hand	Flopping*, whining*, crying*	Mands: Picture exchange
Miguel	Aggression: Hitting, kicking, biting others, throwing items within 2 ft of a person Property Destruction: swiping items off surface, throwing items Screaming Flopping*	Crying* Whining* Non-compliance: requiring physical prompting*	Mands: Vocal, picture exchange Compliance*

Note : indicates measurement in duration*

For both participants, data were collected on the duration of the presence of three possible EOs: escape EO (considered present when the implementer vocally indicated it was time to sit at the work station, when academic materials were in front of the participant, and when verbal demands were being delivered), tangible EO (considered present when preferred items were visible but out of reach), and attention EO (considered present when implementer was turned or walked away from the participant and ignored any mands for attention and excluded when attention was delivered as part of a prompt). All EOs started when the implementer vocally indicated that it was time to go to the workstation and removed access to the preferred items and attention and ended when the implementer vocally indicated that the reinforcers were available and started to re-deliver the items (e.g., “Okay, you can have your toys” while turning to deliver the toys).

Interobserver Agreement (IOA) was calculated by having a second observer collect all data independently for a minimum of 20% of sessions per condition for each functional analysis. Data was compared on an interval-by-interval basis using 10s intervals. Percentage of agreement was calculated by dividing the smaller number of responses in each interval by the larger number multiplied by 100. IOA for John was an average of 98% (Range 96% - 100%). IOA for Miguel was an average of 98% (Range 97% - 98%).

Design and Data Analysis

A multielement design was used to demonstrate the effects of a reinforcement contingency on problem behavior. Data from each functional analysis were graphed in two ways: rate of responding across test and control sessions (the traditional aggregate method) and as second-by-second within session (comprehensive second-by-second data depiction) frequency or duration of responding across EO (test) and reinforcement (control) intervals. Aggregate depiction of data included only rate of target problem behavior as traditionally used to evaluate the effects of the reinforcement contingency, while the second-by-second comprehensive analysis included all appropriate and inappropriate behavior outside of the contingency classes

Functional Assessment Process

Open-Ended Functional Assessment Interview (OEFAI) and Interactive Observation

An approximately 45 min open-ended interview (Hanley, 2012) was conducted with each participant's mother. Questions were asked about problem behavior of concern including ranges of intensity and topography and any precursor behavior, contexts in which these behaviors were more likely and less likely to occur, and typical responses to these behaviors. In addition, the mothers were asked to describe the participant's current language, motor, and play or leisure skills including preferred items and activities.

Next, a brief 20 to 40 min interactive observation was conducted with the participants and their mothers in the relevant contexts described during the interview. The participants' mothers were asked to present the potential evocative contexts and relevant consequences described during the interview. Qualitative details regarding the manner of the presentation of the potential evocative context, the delivery of the reinforcers, and the form and severity of any problem behavior and precursors, as well as the participant's motor, imitation, and visual skills were noted. The information gathered during the interview and observation informed the conditions of the functional analyses, and further refined the operational definitions of the target topographies of problem behavior and precursors

Preference Assessment

Following the observation, a modified multiple-stimulus without replacement preference assessment was conducted (Ghaemmaghami et al., 2016). Ten preferred and non-preferred (i.e., demand) items and were used during this assessment. John's mother identified 5 items and activities and Miguel's mother identified 4 items and activities. Other items included in the assessment were nominated by the research team as developmentally appropriate. All items and activities were presented simultaneously and placed randomly on two tables. The analyst identified each item by touching each one and describing it, and then the participant was allowed to walk around and briefly manipulate the items. The analyst then prompted the participant to choose three to five items to bring into the session room. The analyst also picked one to three items that were not chosen by the participant to be used as demand or alternate activity materials. The items chosen remained the same across the functional analysis conditions. Additionally, the participants chose the same items before each analysis.

Functional Analyses

Based on the results of the interview and observation, pairwise functional analyses using single test and matched control conditions were designed to test the relevance of the suggested contingencies on problem behavior. The functional analysis involved a rapid alternation of 5 min test and control conditions with a 1 min break between conditions. The functional analyses always started with a matched control condition in which the suspected reinforcer(s) were freely available and there were no programmed consequences for problem behavior. In the test condition, the suspected reinforcer(s) were withheld and returned for 30 s contingent on problem behavior.

John

The results of the OEFAI and brief observation for John suggested that his problem behavior was evoked by restricted access to a preferred item or activity, when he was asked to transition from a preferred activity to a lesser preferred activity, and when demands to engage in less preferred activities were presented. These potential functions were identified by John's mother when she described situations in which he engaged in problem behavior when toys or activities were not available or when he needed to stop playing with preferred toys. Additionally, she indicated that John enjoyed playing with adults and would engage in problem behavior if the adults refused or if John had to wait. During the preference assessment, John chose sound books and a bubble machine as his preferred items.

Three pairwise analyses were designed for John. The first analysis tested the hypothesis that his problem behavior was maintained by escape to preferred tangibles. In the control condition, John had free and continuous access to his preferred items, no demands were delivered, and attention was withheld throughout. In the test condition, the analyst restricted physical and vocal attention, moved preferred items to be visible but unavailable, and delivered academic demands (e.g., tracing and coloring worksheets). To promote compliance with the demands, a three-step prompting hierarchy was used. If John complied, the analyst delivered praise in a neutral tone. If John engaged in problem behavior the analyst continued to restrict attention but returned preferred items and stopped delivering demands for 30 sec. Following the 30 sec of withheld attention, the evocative context was reimplemented. Contingencies regarding escape or access to tangible items were not evaluated in isolation because the interview suggested that they typically occur simultaneously.

A second functional analysis was conducted for John due to parental report that challenging behaviors often occurred when attention was restricted in the family home. Attention was tested in isolation because John's mother indicated that he would engage in challenging behavior even when he had preferred items and there were no demands. In the control condition the analyst continually delivered vocal and physical attention, but restricted access to preferred items and delivered academic demands. Due to high levels of problem behavior occurring in the control condition a test condition was not completed. However, the test condition would have had the analyst restrict physical and vocal attention, while restricting access to preferred items and delivering academic demands. If John had engaged in problem behavior vocal and physical attention would have been delivered for 30 seconds while the preferred items remained visible but unavailable and demands continued to be delivered.

John's final functional analysis, to test the hypothesis that escape from demands to preferred items and attention was maintaining problem behavior, was conducted due to low rates of responding in the initial functional analysis and to try to identify a more reinforcing context from which to implement intervention. In the control condition, the analyst delivered vocal and physical attention and did not deliver academic demands. John also had continuous access to preferred items. During the test condition the analyst restricted vocal and physical attention, moved preferred items to be visible but unavailable and delivered academic demands. If John engaged in problem behavior, the analyst would deliver physical and vocal attention, return access to preferred items, and stop delivering academic demands. Following 30 seconds, the evocative context was reimplemented.

Miguel

The results of the OEFAI and brief observation for Miguel suggested that his problem behavior was evoked when access to a preferred item was restricted and to escape demands. During the interview, Miguel's mother explained that she observed problem behavior when Miguel was asked to stop playing toys or when his toys stopped working (e.g., batteries died). Additionally, during the observation, Miguel was observed engaging in some whining and grabbing when his mother told him he was all done with his toys. During the preference assessment before the first functional analysis, Miguel chose toy cars, and a bubble machine as his preferred items. During the preference assessment before the second functional analysis, Miguel chose a Nintendo Switch as his preferred item.

Miguel's first functional analysis tested the hypothesis that his problem behavior was maintained by access to tangibles. During the control condition, Miguel's preferred items were available, but the analyst restricted attention and delivered academic demands (e.g., tracing and counting worksheets). To promote compliance with the demands, a three-step prompting hierarchy was used. If Miguel complied, the analyst delivered praise in a neutral tone. During the test condition the analyst moved the low-technology toys to be visible but unavailable and continued delivering demands while restricting attention. If Miguel engaged in problem behavior the analyst returned preferred items, but continued to deliver demands, and restrict attention. Following 30 seconds, the evocative context was reimplemented.

Due to a lack of problem behavior in the initial functional analysis, a second functional analysis was conducted to test the hypothesis that Miguel's problem behavior was maintained by access to electronic toys, specifically a handheld video game (i.e., Nintendo Switch). This was because Miguel's mother told the analyst that this was the item that seemed to evoke the most problem behavior at home, but she had forgotten to bring it for the first functional analysis. The test and control conditions were identical to the initial functional analysis, the only change being the video game as the preferred tangible.

CHAPTER 3: RESULTS

Data Depiction

The data are depicted by both a rate and a comprehensive second-by-second graph. The rate graph shows sessions on the x-axis and rate of responding in responses per minute on the y-axis. The open symbols on the rate graph denote control conditions and the closed symbols denote test conditions. The comprehensive second-by-second graph shows each session as a panel, moving chronologically from top to bottom. Each panel corresponds with an aggregate session data point on the rate graph. Seconds are shown on the x-axis, and each recorded behavior and EO are shown on the y-axis. Behaviors that were recorded as frequency are denoted by symbols at the second that they occurred in the session. Behaviors and EOs that were recorded as duration are denoted as lines that that span from the second they began to the second they ended during the session.

When the data were depicted by rate, decisions regarding the variables maintaining problem behavior were based on the visual comparison of the rate of responding in the test conditions versus the control conditions. When the data were depicted by comprehensive second-by-second, decisions were based on the visual comparison of occurrence of responding during EO present and EO absent intervals.

John

The results of John's first functional analysis are depicted as rate (Figure 1) and as second-by-second individual data points (Figure 2). When depicted as rate (Figure 1), there is differentiated responding between the test and control conditions suggesting that John's problem behavior is maintained by a context involving escape from demands to a preferred item. The rate of responding in the test conditions, however, occurred at an average of 1.1 times per minute. This rate is approximately half of what would be expected had John engaged in target behavior immediately upon introduction of the EOs and ceased engaging in target behavior immediately upon introduction of the reinforcers. The results of the second-by-second analysis (Figure 2) also show that John's problem behavior is maintained by a context involving escape from demands to preferred items. Importantly, the second-by-second data showed that the low rate of responding was due to a delay between the introduction of the EOs and the behaviors in the contingency class. The post-hoc analysis also allowed us to observe that John engaged in a host of less severe problem behaviors, such as flopping (John was engaging in high levels of flopping before engaging in property destruction or self-injurious behavior). Additionally, we were able to observe the relation between the introduction of the EO and John's problem behavior within the sessions when using second-by-second data depiction. This means that we were able to observe the same pattern of responding demonstrating that a context involving escape to tangibles was maintaining John's problem behavior in a single 5 min session. Moreover, it was found that despite having the picture exchange communication freely available, John did not engage in functional communication.

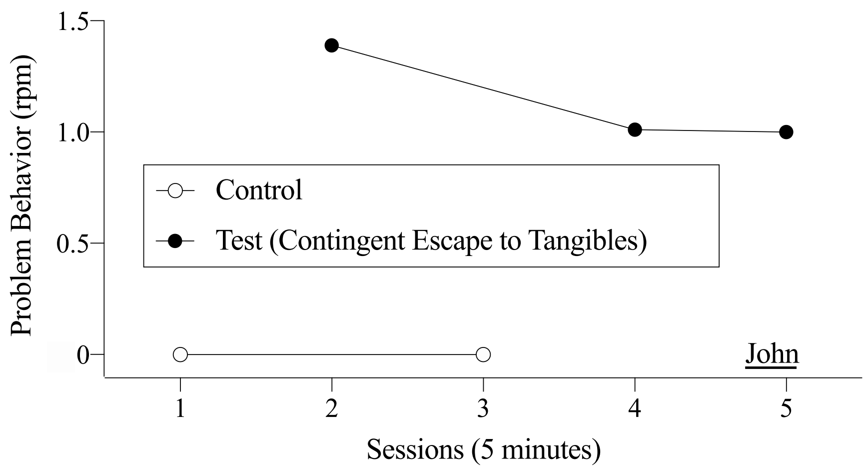

Figure 1. Results of John's escape to tangibles functional analysis depicted by rate. In the control conditions, John had free and continuous access to his preferred items, no demands were delivered, and attention was withheld throughout. In the test conditions, the analyst restricted physical and vocal attention, moved preferred items to be visible but unavailable, and delivered academic demands.

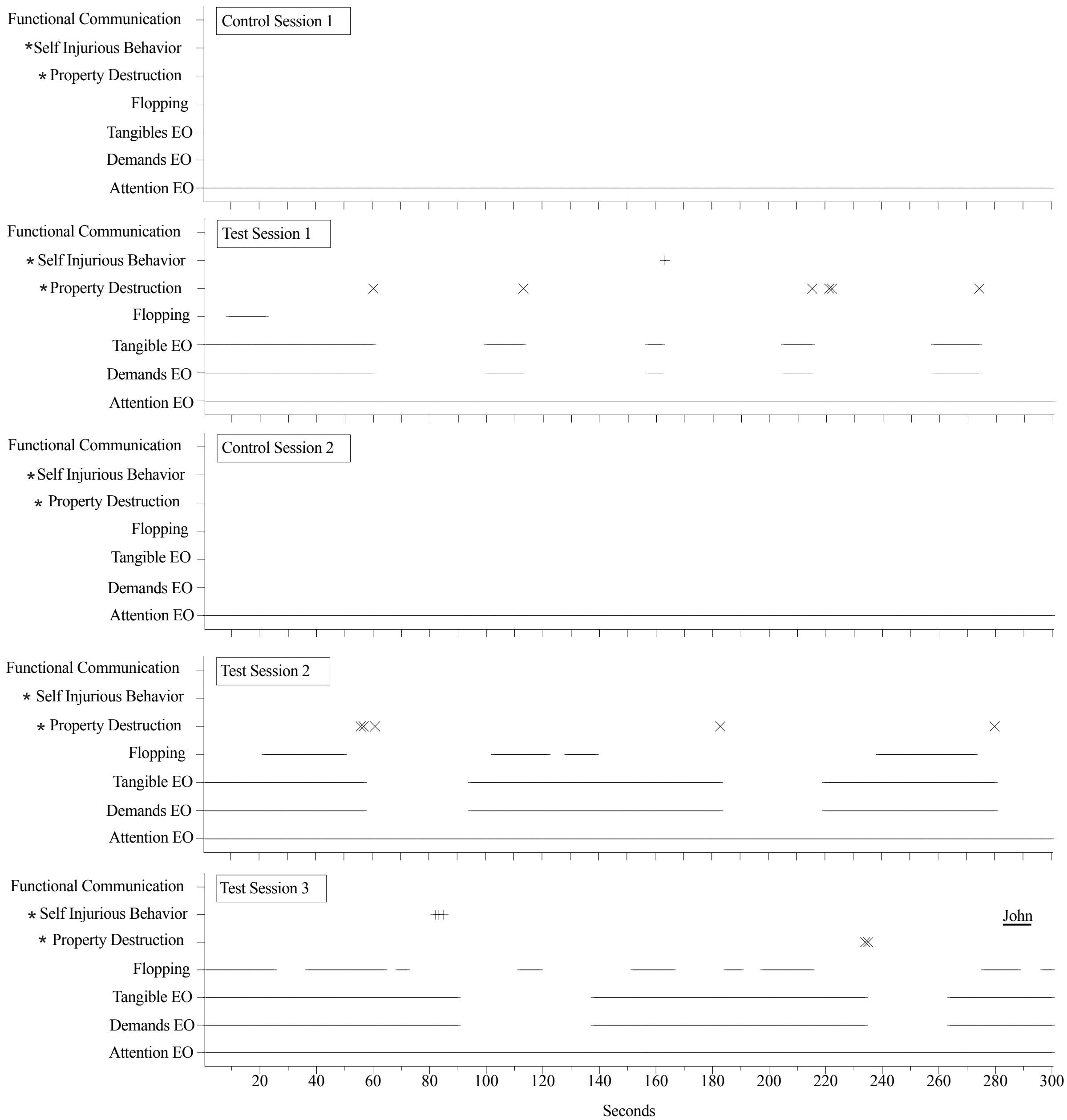

Figure 2. Results of John's escape to tangibles functional analysis depicted second-by-second. Asterisks denote behaviors in the contingency class.

Due to high levels of self-injurious behavior during the first control condition of John's second functional analysis, this functional analysis was terminated. The results of John's second functional analysis are depicted as rate of problem behavior per session (Figure 3), as within session second-by-second individual data points (Figure 4), and as a cumulative record (Figure 5). Figure 3 depicts the results of the control session showing problem behavior occurring at a rate of 3.6 times per minute. By contrast, the second-by-second depiction (Figure 4) and the cumulative record (Figure 5) reveals a pattern of responding similar to that of an extinction burst as the rate of responding increases within the session while all other variables remain constant. Second-by-second data depiction allowed us to see from one 5 min session that attention alone was not a sufficient reinforcer that would result in a cessation of problem behavior. Had this functional analysis been analyzed solely by rate, it would have required at minimum two additional control sessions and two test conditions for a total additional 20 min of exposing John to the evocative context to conclude that attention is not maintaining problem behavior.

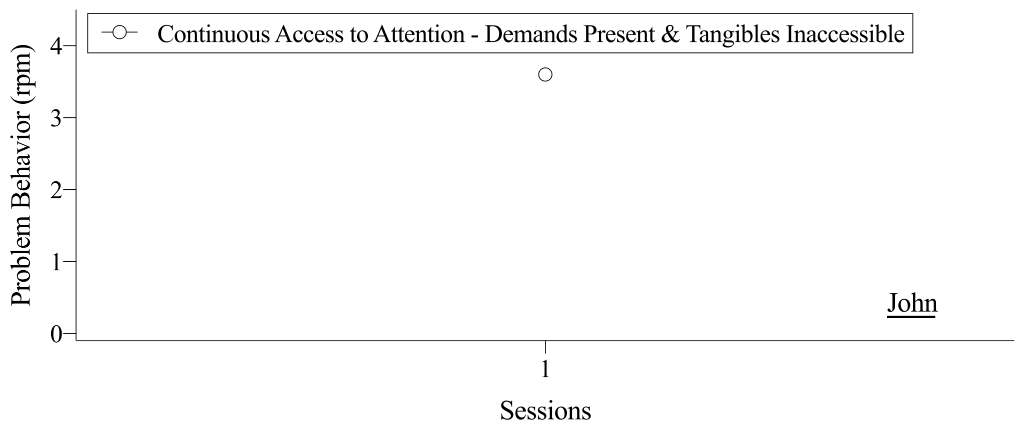

Figure 3. Results of John's access to attention functional analysis depicted by rate. In the control condition the analyst continually delivered vocal and physical attention, but restricted access to preferred items and delivered academic demands. Due to high levels of problem behavior occurring in the control condition a test condition was not completed. However, the test condition would have had the analyst restrict physical and vocal attention, while restricting access to preferred items and delivering academic demands.

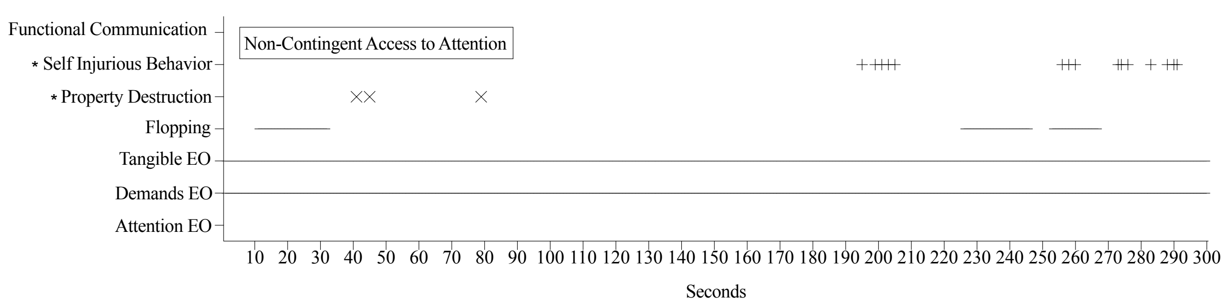

Figure 4. Results of John's access to attention functional analysis depicted second-by-second. Asterisks denote behaviors in the contingency class.

Figure 5. Results of John's access to attention functional analysis depicted by a cumulative record.

The results of John's final functional analysis depicted as rate (Figure 6) and second-by-second individual data points (Figure 7). When the data were depicted as rate (Figure 6) there was responding in the test sessions occurring at 0.4 and 0.8 times per minute respectively and in the control at 0 and 0.2 times per minute respectively. When these data were depicted second-by-second (Figure 7), there were longer latencies to respond and fewer occurrences of problem behavior. Additionally, by conducting a post-hoc analysis, we were able to identify an unprogrammed EO, the accidental inclusion of a wrist brace John was wearing that seemed to be an aversive stimulus. During the functional analysis, John engaged in one instance of self-injurious behavior when the wrist brace was on and when the wrist brace was removed during the second control condition, John ceased engaging in self-injurious behavior.

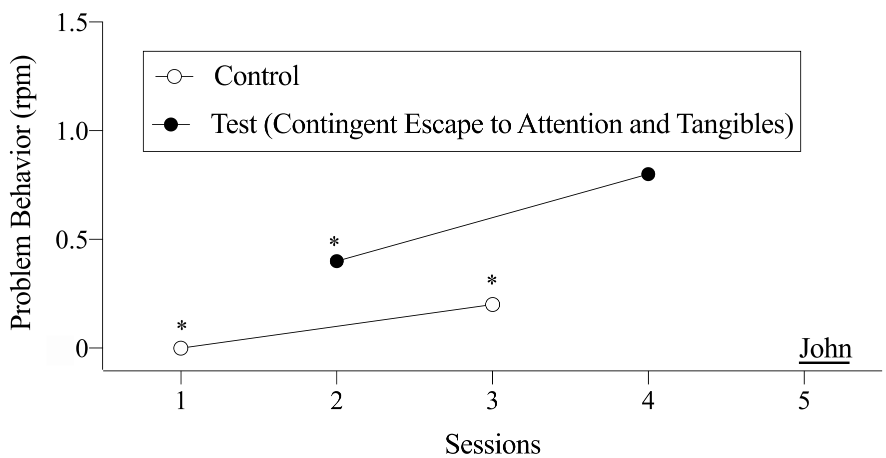

Figure 6. Results of John's escape to attention and tangibles functional analysis depicted by rate. Asteriks denote sessions in which John was wearing a wrist brace. In the control condition, the analyst delivered vocal and physical attention and did not deliver academic demands. John also had continuous access to preferred items. During the test condition the analyst restricted vocal and physical attention, moved preferred items to be visible but unavailable and delivered academic demands.

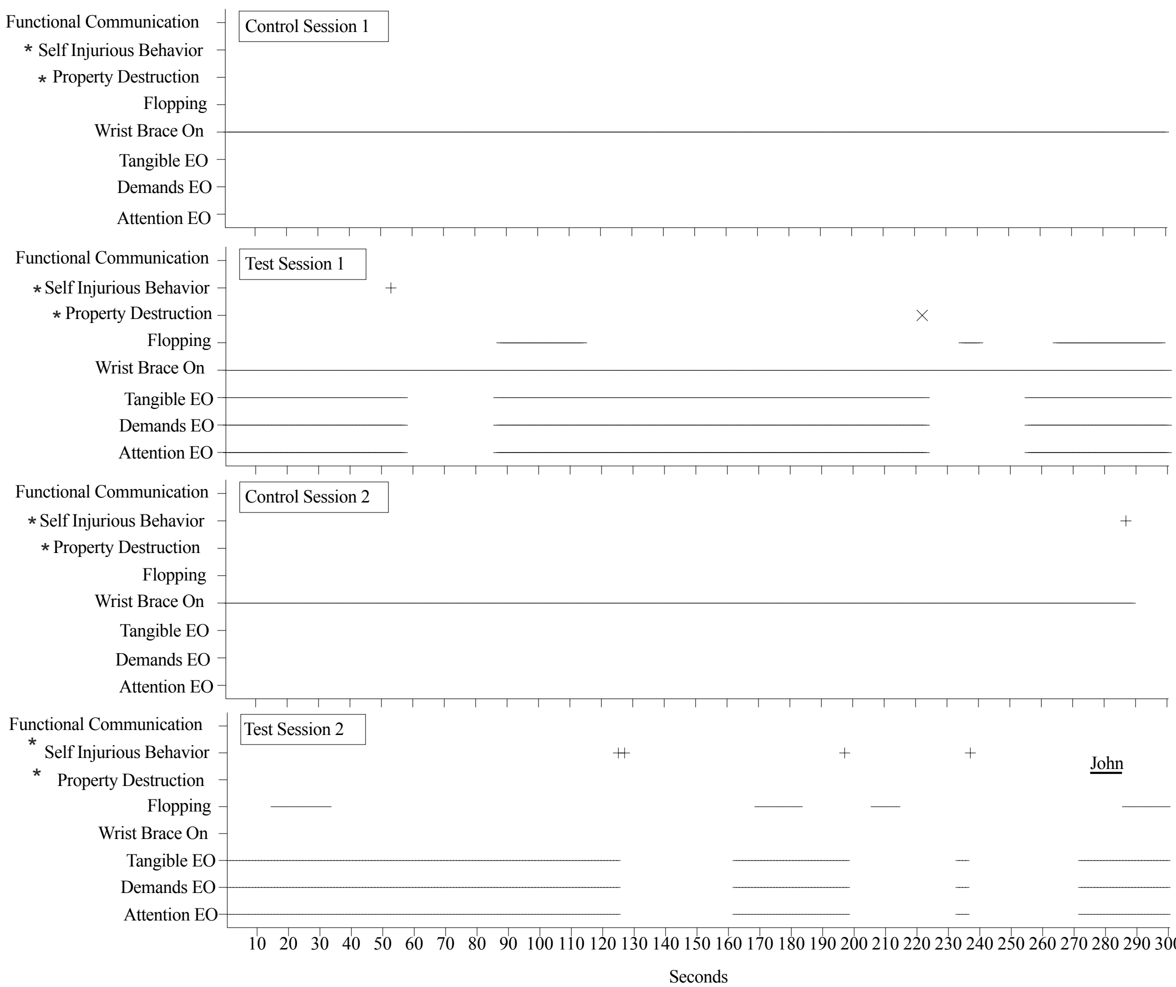

Figure 7. Results of John's escape to attention and tangibles functional analysis depicted second-by-second. Asterisks denote behaviors in the contingency class.

Miguel

The results of Miguel's first functional analysis are depicted as rate (Figure 8) and second-by-second individual data points (Figure 9). When the data were depicted as rate (Figure 8), there was no responding in either test or control conditions. When depicted second-by-second (Figure 9), we identified compliance to demands as another important behavior. Miguel was observed complying to all demands without engaging in any problem behavior; this important behavior is unlikely to be depicted in the typical functional analysis graph.

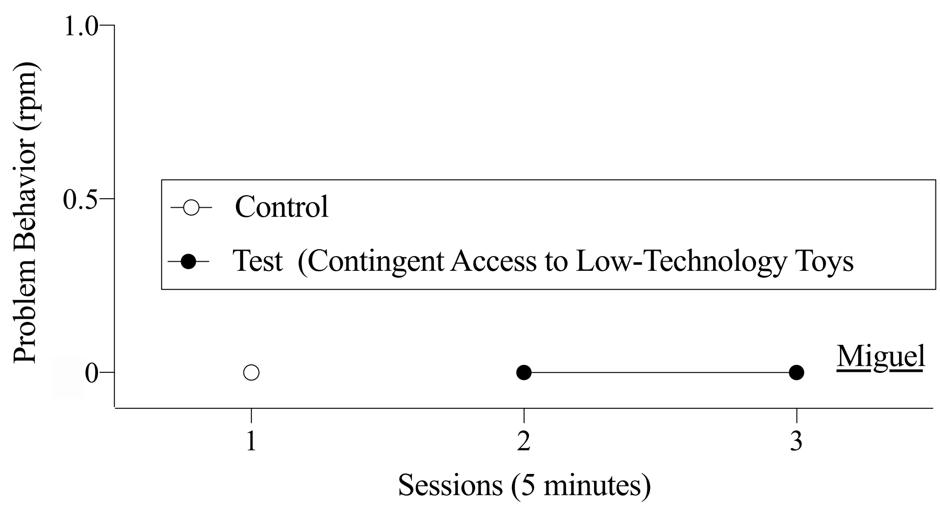

Figure 8. Results of Miguel's access to low-technology toys functional analysis depicted by rate. During the control condition, Miguel's preferred items were available, but the analyst restricted attention and delivered academic demands. During the test condition the analyst moved the low-technology toys to be visible but unavailable and continued delivering demands while restricting attention.

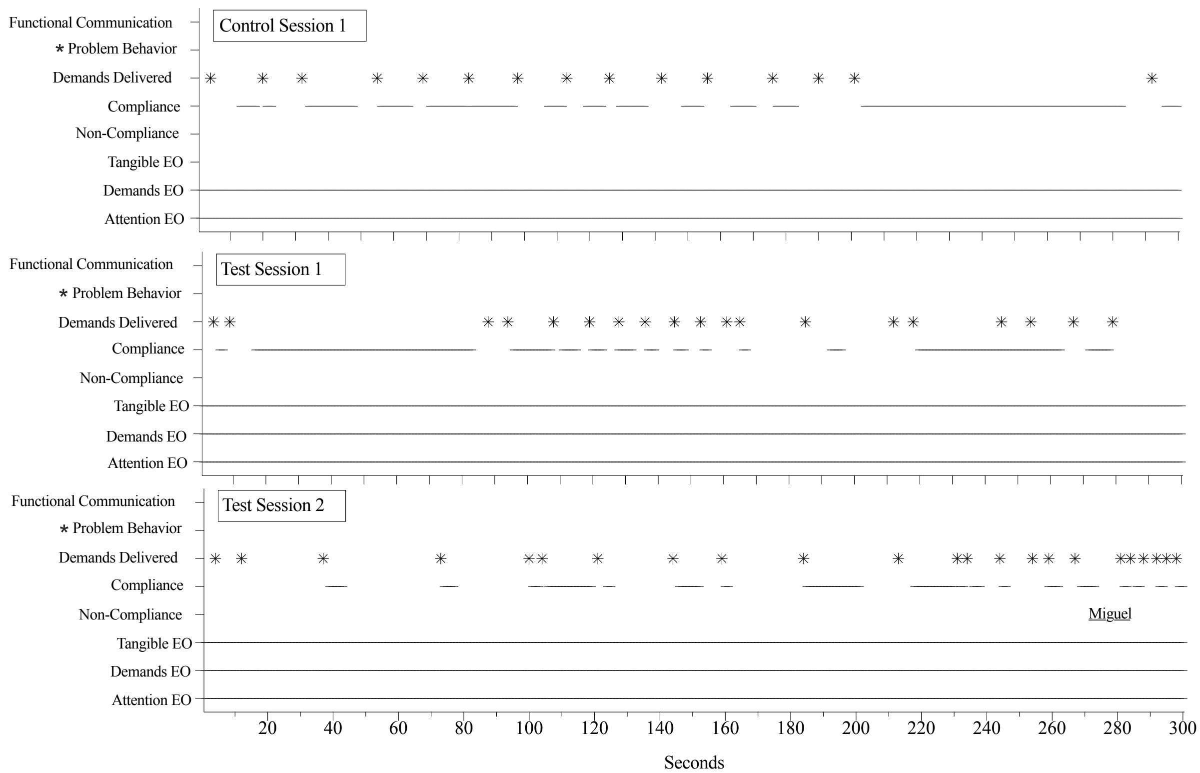

Figure 9. Results of Miguel's access to low-technology toys functional analysis depicted second-by-second. Low technology toys included toy cars and a bubble machine that were chosen during the preference assessment. Asterisks denote behaviors in the contingency class.

The results of Miguel's second functional analysis are shown in rate (Figure 10) and second-by-second (Figure 11). Miguel did not engage in problem behavior during either the test or control conditions (Figure 10). However, using post-hoc second-by-second analysis, we observed that Miguel required more prompting to comply during the second test condition compared to the first test and control conditions, i.e., a reduction in compliance (Figure 11).

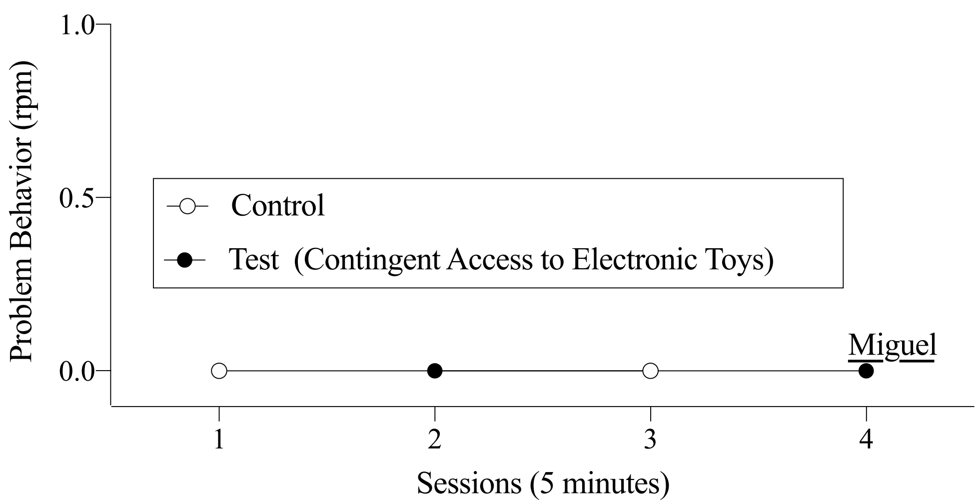

Figure 10. Results of Miguel's access to electronic toys functional analysis depicted by rate. During the control condition, Miguel's preferred items were available, but the analyst restricted attention and delivered academic demands. During the test condition the analyst moved the electronic toys to be visible but unavailable and continued delivering demands while restricting attention.

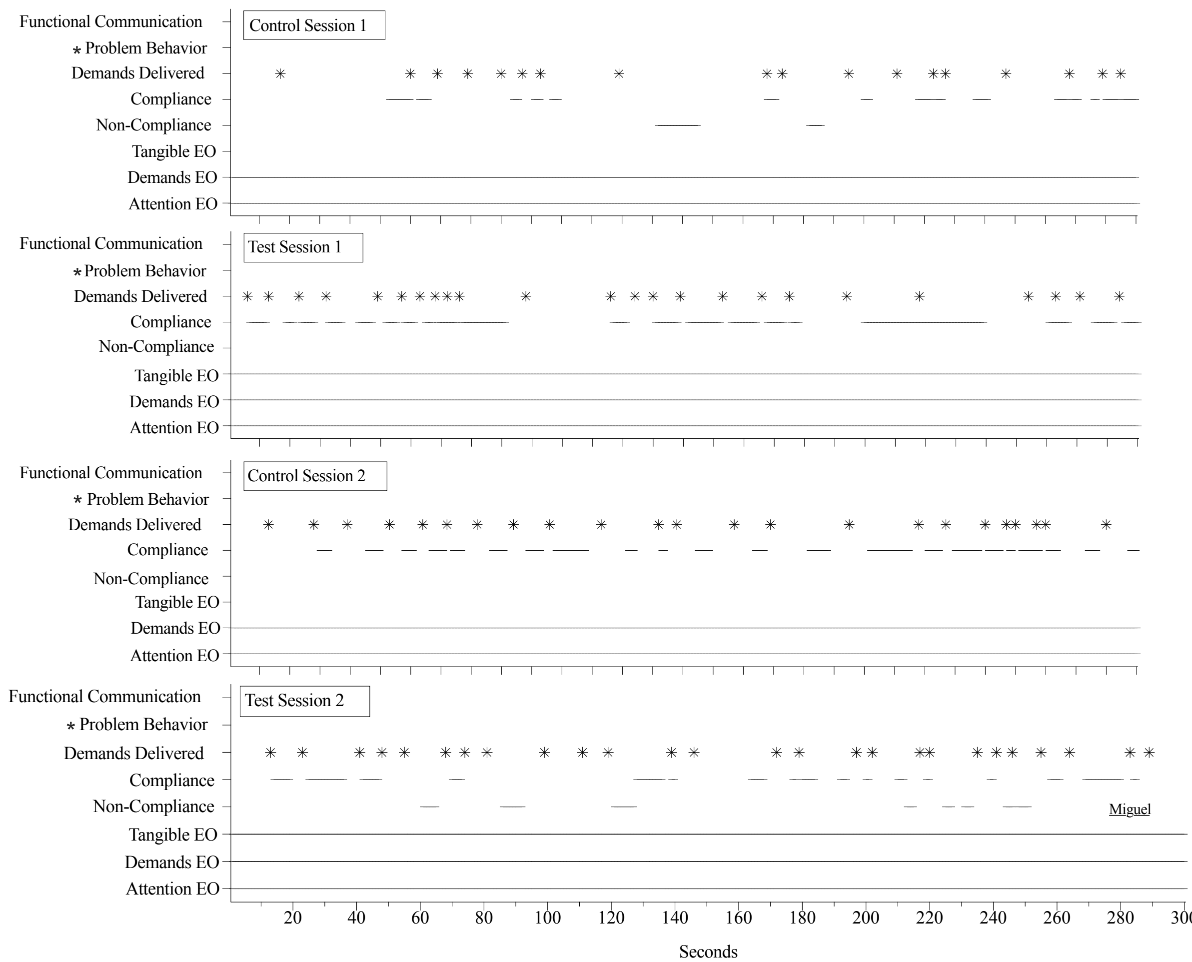

Figure 11. Results of Miguel's access to electronic toys functional analysis depicted second-by-second. Electronic toy was a Nintendo Switch chosen during the preference assessment. Asterisks denote behaviors in the contingency class.

Time Spent on Post-Hoc Analysis

The post-hoc analysis for John's third functional analysis was recorded. A second observer spent 27 min reviewing the functional analysis to note any additional behaviors and variables that were not determined prior to the analysis. It took them approximately 5 min to update their Countee app to include the new variables. They then spent 28 min recording these behaviors. In total, the post-hoc analysis took 1 hour and 1 min. This means that the post-hoc analysis requires at least two times the original time spent actively conducting the functional analysis.

CHAPTER 4: DISCUSSION

The purpose of this study was to evaluate the use of a comprehensive second-by-second data depiction and compare it against the more typical depiction of aggregated rate of problem behavior data during an analysis. We found that comprehensive second-by-second data depiction provided a clearer picture between various antecedent and consequent variables and problem behavior. Because of this, we were able to make conclusions regarding the maintaining variables in fewer sessions. Practically speaking, this means that had we conducted post-hoc analyses of the videos and second-by-second data depiction, we could have decreased the total amount of time spent actively conducting the functional analyses, which is beneficial to the client. Additionally, we obtained useful information regarding non-target problem behaviors and functional skills when conducting a post-hoc analysis of the data for comprehensive second-by-second data depiction. These less severe problem behaviors and functional skills are not typically measured or depicted as part of the functional analysis data.

Benefits and Limitations of Second-by-Second Analyses

Maintaining Variables Identified in Fewer Sessions

By using comprehensive second-by-second data depiction, we were able to draw conclusions regarding the variables maintaining problem behavior in fewer sessions compared to aggregate data depicted by rate. Though the conclusions regarding which variables were maintaining problem behavior were consistent across the two methods, the direct relation between the environmental variables that were being manipulated and problem behaviors was more immediately apparent when depicted second-by-second; therefore, fewer sessions were needed to demonstrate the same functional relation. Because many clinicians report they do not conduct functional analyses because of a lack of social approval of its safety (Oliver et al., 2015), the fact that second by second data analyses allowed us to draw the same conclusion within fewer sessions is important. For example, by using comprehensive second-by-second data depiction during the first test session in John's first functional analysis, we were able to determine in a single 5 min session that a context involving escape from demands to a preferred item was maintain problem behavior. This is because when we compared EO present and EO absent intervals we were able to see a pattern of responding in which his engaged in the target problem behavior when the EO was present and did not engage in problem behavior when the EO was not present. When data were depicted solely by rate, the more typical format for depicting functional analysis data, we needed two controls and three tests to observe a trend in responding. This meant that we exposed John to a context that evoked problem behavior for an additional 20 min to determine the context that was maintaining his problem behavior. Decreasing the time spent actively conducting functional analyses may help in increasing the social validity of functional analyses. Almost half of the clinicians surveyed by Roscoe et al. (2015) named lack of support for functional analysis procedures as a barrier to conducting functional analyses. While participants who need functional analyses would already be engaging in problem behavior in their typical environment, it can be difficult to convince caregivers to agree to a functional analysis in which the problem behavior is being repeatedly evoked and reinforced (Hanley., 2012). Therefore, if researchers and clinicians can decrease the time spent exposing a participant to an evocative context by using comprehensive second-by-second data depiction, it could make it easier to convince caregivers to participate in this procedure. In addition to the need to consider social validity and feasibility of procedures, minimizing the time spent in assessment phase and in a condition that actively allows the individual to engage in serious problem behavior, and reducing the need for the most serious topography of problem behavior to occur repeatedly, and more quickly moving to a treatment context are not only best practice but also directly in line with our ethical guidelines and responsibilities (Professional and Ethical Compliance Code for Behavior Analysts, 2.09c, 3.01a&b; BACB, 2014).

Less Time Spent Conducting the FA but More Time Spent Coding the FA

Although second-by-second data depiction has the potential to decrease clinicians' and researchers' time spent actively conducting functional analyses and individuals' time being exposed to evocative contexts, it does require the clinician or researcher to spend more time coding and analyzing the data compared to the standard rate-based data depiction. When we timed the post-hoc analysis, it required approximately two times the time spent actively conducting the functional analysis. At a minimum, comprehensive second-by-second data depiction requires the functional analyses be filmed and then viewed at least twice. Once to identify all relevant behaviors and variables and a second time to collect the data on these behaviors and variables. However, it could also allow for clinicians to stop actively conducting the analysis after a single 5 min session and instead take approximately 10 min to review and analyze the session for a response trend or additional variable to include in the in the contingency class that may help more efficiently identify the controlling variables. Comprehensive second-by-second data depiction however may require more resources such as devices that can record video and sound in high quality, funding for the additional time to spend analyzing the data, and additional training for analysts on the comprehensive second-by-second data depiction method.

Comprehensive second-by-second data depiction may be more feasible for researchers than for clinicians, particularly because surveyed clinicians indicated that a lack of time and resources were two main reasons they do not conduct functional analyses (Oliver et al., 2015;

Roscoe et al., 2015). It is unclear, however, whether the time restrains identified in these surveys is direct client time or indirect time. Different considerations may need to be made depending on insurance and billing requirements. The additional post-hoc analysis time, however, may be more easily fulfilled by behavioral staff and BCaBAs that may also provide more flexibility to the clinical team. Given the significant advantages that comprehensive second-by-second data analyses offers in terms of decrease time spent actively conducting functional analyses, potential increases in buy-in and social validity, and overall safety, we highly recommend that clinicians consider this method when the target behaviors are severe and pose a safety concern (Professional and Ethical Compliance Code for Behavior Analysts 3.01a; BACB, 2014) or when results are undifferentiated. For these situations, time spent coding and analyzing the data would be time well spent.

Additional Meaningful Data Can Be Obtained

No problem behavior was recorded during Miguel's functional analyses. When the data were graphed as rate, we learned that the context was not sufficiently evocative to evoke problem behavior. Reviewing the videos (i.e., post-hoc review) allowed us to code data on prompts and compliance. While there were no instances of the target problem behaviors, we observed that Miguel did engage in more non-compliance (that fell outside of the original target behavior definition) when his video game was visible but unavailable. Additionally, non-compliance occurred at a higher rate during the final test condition which was after approximately 15 min of demands being delivered. This suggests that Miguel can tolerate academic demands for approximately 15 min. It could be beneficial to use this information to either teach him to ask for a break before he engages in non-compliance or to decrease the time when academic tasks are being delivered to approximately 15 min; this type of information would be beneficial to

Miguel's parents and teachers and perhaps creating a less aversive demand context for Miguel. Post hoc analyses and comprehensive second by second data depiction allowed us to focus on and identify both the problem behaviors and the appropriate behaviors and skills exhibited by Miguel, outside the target behaviors that were the original focus of the functional analysis, providing a much more comprehensive picture without any additional risk to the client. This information can be used as a baseline for skill building and acquisition, or to determine the appropriate supports for an individual.

Moreover, during John's functional analysis sessions, he was observed engaging in lower severity problem behaviors (i.e. flopping) that were not included in the contingency class. We cannot speak to the functional relation of the manipulated variables and flopping as we did not manipulate the variables in response to flopping and therefore, if we did want to know the functional relation, we would have to conduct a precursor functional analysis. At this stage, the data we collected on flopping could only be considered descriptive data. Thompson & Iwata (2007) found that when descriptive data alone was collected, the contingencies determined to be maintaining problem behavior did not consistently match that of the functional analysis. The descriptive data we collected, however, was within the context of a functional analysis and while consequences for flopping were not directly manipulated in response to this behavior, given that many antecedent and consequence variables were controlled, this descriptive assessment can be considered a structured observation which does allow for more conclusions to be drawn about the controlling variables for flopping. In this way, our confidence in identifying condition under which flopping is likely is increased. We can say that flopping consistently occurred prior to the target problem behavior and may be considered a reliable precursor, this information is very valuable for treatment. Analysts and clinicians can deliver reinforcement when precursor behaviors occur to remove the EO that maintains the target behaviors and potentially prevent more severe problem behaviors from occurring, thus increasing safety.

Limitations

Although the findings from this study are important, this study was not without limitations. One limitation of this study is that we only had two participants. We were able to glean important information regarding the time spent actively conducting a functional analysis with John and information regarding tolerance for compliance to academic demands with Miguel, but further research is recommended. Systematic replication is important to demonstrate the generality of the effects of an assessment or intervention (Horner et al., 2005). Horner et al. (2005) suggests that studies should be replicated at minimum three times across participants, settings, materials, and behaviors to improve external validity and demonstrate generality across participants. Therefore, as this study only included two participants, further replications of this study are recommended.

A second limitation of this study was our failure to extend our research to treatment. While both rate and comprehensive second-by-second data depiction resulted in determining the same maintaining variables for problem behavior, we did not extend this study to treatment to determine if the variables identified were actually the functionally related variables. Functional analyses are an important component of function-based treatments. Function-based behavioral treatments are efficacious treatments in which the reinforcement context evoking and maintaining problem behavior is identified through a functional behavior assessment, including a functional analysis (Ingram et al., 2005), and used in treatment. The superior efficacy of function-based treatments likely stems from the direct manipulation of relevant reinforcers and evocative contexts that maintain problem behavior (McKenna et al., 2015). The manipulation of relevant variables (e.g., withholding functional reinforcers, eliminating evocative contexts, teaching alternative means of accessing functional reinforcers) results in significant reductions in problem behavior without the use of punishment and other intrusive procedures (Campbell, 2002). Thus, future research ought to extend our study by conducting treatment analyses of the variables identified as functionally related to problem behavior. This will be particularly important if second-by-second data analyses identify other or different variables than the traditional data depiction methods. Additionally, although comprehensive second-by-second data analyses were shown to identify maintaining variables in a shorter amount of time, it remains to be seen if this method affects treatment (e.g., faster or slower acquisition of replacement skills) because fewer instances of the target behaviors are reinforced; this is another avenue for future research.

A third limitation is that we only conducted IISCA type functional analyses despite the majority of our arguments stemming from concerns regarding the standard functional analysis developed by Iwata et al. (1982/1994). The functional analyses included in this study were not conducted specifically for this study. The functional analyses were initially conducted as a part of a study that aimed to evaluate a specific procedure within functional communication training (FCT). The FCT study was abandoned due to COVID-19 and the functional analysis data that had been already collected were re-analyzed for the purpose of this study. Had we been able to conduct additional functional analyses and collect additional data, standard functional analyses would have been included as this type of functional analysis is the most commonly used (Beavers et al., 2013). Therefore, we recommend this study be extended to include standard functional analyses.

A fourth limitation is that we did not collect IOA data for 100% of the sessions. As the sessions were video recorded a second observer could have collected data for all of the sessions. Unfortunately, due to time constraints we were unable to do collect IOA for all sessions during this study. We recommend that future studies collect IOA data for 100% of sessions.

Finally, a fifth limitation is that this study did not explore the cost-benefit relationship of the use of comprehensive second-by-second data depiction. It has yet to be seen if the benefit of less time spent actively conducting functional analyses is enough to outweigh the cost of more time and resources required initially. It is possible that because less time actively engaging in functional analyses increases safety for participants and implementers that it is worth the additional time and resources, but that has yet to be examined. Therefore, we recommend further research on the cost-benefit relationship of comprehensive second-by-second data depiction.

Conclusion

There are two main advantages to using an alternative comprehensive second-by-second data depiction. The first is the potential to decrease time spent actively conducting functional analyses. This decrease in time increases safety for both the client and the implementer. The second advantage is that additional adaptive and maladaptive behavior that may be a part of the contingency or related contingencies can be identified and this information may lead to more effective treatments. This intimate and comprehensive analysis of all responses in relation to EOs and reinforcers may be particularly useful in clarifying undifferentiated results. Of course, these assertions are in early stages and need more extensive investigation and similar comparisons of both differentiated and undifferentiated analyses using synthesized and isolated contingencies. In addition, a cost-benefit analysis of advantages versus disadvantages of this method will further clarify its usefulness for widespread dissemination and feasibility as a tool to increase our understanding of contexts that evoke and eliminate problem behavior.

REFERENCES

Baer, D.M., Wolf, M.M., & Risley, T.R. (1968). Some Current Dimensions of Applied Behavior Analysis. *Journal of Applied Behavior Analysis, 1(1),* 91-97. https://doi.org/10.1901/jaba.1968.1-91

Beaulieu, L., Van Nostrand, M. E., Williams, A. L., & Herscovitch, B. (2018). Incorporating interview-informed functional analyses into practice. *Behavior Analysis in Practice, 11(4),* 385-389. https://doi.org/10.1007/s40617-018-0247-7

Beavers, G.A., Iwata, B.A., & Lerman, D.C. (2013). Thirty years of research on the functional analysis of problem behavior. *Journal of Applied Behavior Analysis, 46(1),* 1-21. https://doi.org/ 10.1002/jaba.30

Behavior Analyst Certification Board. (2014). *Professional and ethical compliance code for behavior analysts*. Littleton, CO: Author.

Campbell, J.M. (2002). Efficacy of behavioral interventions for reducing problem behavior in persons with autism: A quantitative synthesis of single-subject research. *Research in Developmental Disabilities, 24(2),* 120-138. https://doi.org/10.1016/S0891-4222(03)00014-3

Carr, E.G., Newsom, C.D., & Binkoff, J.A. (1976). Stimulus control of self-destructive behavior in a psychotic child. *Journal of Abnormal Child Psychology, 4,*139-153. https://doi.org/10.1007/BF00916518

Coffey, A. L., Shawler, L. A., Jessel, J., Nye, M. L., Bain, T. A., & Dorsey, M. F. (2019). Interview-informed synthesized contingency analysis (IISCA): novel interpretations and future directions. *Behavior Analysis in Practice*, *13(1),* 217-225. doi: 10.1007/s40617-019-00348-3.

Ferster, C.B., & Skinner, B.F. (1957). *Schedules of reinforcement*. Appleton, Century, Crofts. https://doi.org/10.1037/10627-000

Fisher, W.W., Greer, B.D., Romani, P.W., Zangrillo, A.N., & Owen, T.M. (2016). Comparisons of synthesized and individual reinforcement contingencies during functional analysis. *Journal of Applied Behavior Analysis, 49(3),* 596-616. Httpis://doi.org/ 10.1002/jaba.314

Fiske, K. & Delmolino, L. (2012). Use of discontinuous methods of data collection in behavioral intervention: Guidelines for practitioners. *Behavior Analysis in Practice, 5(2),* 77-81. https://doi.org/10.1007/BF03391826

Ghaemmaghami, M., Hanley, G.P., & Jessel, J. (2016). Contingencies promote delay tolerance. *Journal of Applied Behavior Analysis, 49(3)*, 548-575. https://doi.org/10.1002/jaba.333

Ghaemmaghami, M., Hanley, G. P., Jessel, J., & Landa, R. (2018). Shaping complex functional communication responses. *Journal of Applied Behavior Analysis*, *51(3)*, 502-520. https://doi.org/10.1002/jaba.468.

Hagopian, L.P, Dozier, C.L., Rooker, G.W., & Jones, B.A. (2013). Assessment and treatment of severe problem behavior. In G.J. Madden, *APA Handbook of Behavior Analysis: Vol 2. Translating Principles into Practice* (353-3620). https://doi.org/10.1037/13938-014

Hagopian, L.P., Rooker, G.W., Jessel, J., & DeLeon, I.G. (2013). Initial functional analysis outcomes and modifications in pursuit of differentiation: A summary of 176 inpatient cases. *Journal of Applied Behavior Analysis, 46(1)*, 88-100. https://doir.org/10.1002/jaba.25

Hanley, G.P. (2012). Functional assessment of problem behavior: dispelling myths, overcoming implementation obstacles, and developing new lore. *Behavior Analysis in Practice, 5(1),* 54-72. https://doi.org/10.1007/BF03391818

Hanley, G.P., Iwata, B.A., & McCord, B.E. (2003). Functional analysis of problem behavior: A review. *Journal of Applied Behavior Analysis, 36(2),* 147-185. Htpps://doi.org/10.1901/jaba.2003.36-147

Hanley, G.P., Jin, C.S., Vanselow, N.R., & Hanratty, L.A. (2014). Producing meaningful improvements in problem behavior of children with autism via synthesized analyses and treatments. *Journal of Applied Behavior Analysis, 47(1)*, 16-36. https://doi.org/10.1002/jaba.106

Harding, J.W., Wacker, D.P., Berg, W.K., Winborn-Kemmer, L., Lee, J.F., & Ibrahimovic, M. (2009). Analysis of multiple manding topographies during functional communication training. *Education and Treatment of Children, 32(1),* 21-36. https://doi.org/10.1353/etc.0.0045

Horner, R.H., Carr, E.G., Halle, J., McGee, G., Odom, S., & Wolery, M. (2005).The use of single-subject research to identify evidence-based practice in special education. *Exceptional Children, 71(2),* 165-179. https://doi.org/ 10.1177/001440290507100203

Ingram, K., Lewis-Palmer, T., Sugai, G. (2005). Function based intervention planning: Comparing the effectiveness of FBA function-based and non-function-based intervention plans. *Journal of Positive Behavior Interventions, 7(4),* 224-236. https://doi.org/10.1177/10983007050070040401

Iwata, B.A., Dorsey, M.F., Slifer, K.J., Bauman, K.E., & Richman, G.S. (1982/1994). Toward a functional analysis of self injury. *Journal of Applied Behavior Analysis, 27(2),* 197-209. https://doi.org/10.1901/jaba.1994.27-197

Iwata, B.A., & Dozier, C.L. (2008). Clinical application of functional analysis methodology. *Behavior Analysis in Practice, 1(1)*, 3-9. https://doi.org/10.1007/BF03391714

Jessel, J., Hanely, G.P., & Ghaemmaghami, M. (2016). Interview-informed synthesized contingency analyses: Thirty replications and reanalysis. *Journal of Applied Behavior Analysis, 49(3),* 576-595. https://doi.org/10.1002/jaba.316

Jessel, J., Ingvarsson, E. T., Metras, R., Kirk, H., & Whipple, R. (2018). Achieving socially significant reductions in problem behavior following the interview-informed synthesized contingency analysis: A summary of 25 outpatient applications. *Journal of Applied Behavior Analysis, 51(1)*, 130-157. https://doi.org/10.1002/jaba.436

Kahng, S., & Iwata, B.A. (1998). Computerized systems for collecting real-time observational data. *Journal of Applied Behavior Analysis, 31(2),* 253-261. https://doi.org/10.1901/jaba.1998.31-253

Lovaas, O.I., Freitag, G., Gold, V.J., & Kassorla, I.C. (1965). Experimental studies in childhood schizophrenia: Analysis of self-destructive behavior. *Journal of Experimental Child Psychology, 2(1),* 67-84. https://doi.org/10.1016/0022-0965(65)90016-0

Mace, F.C. (1994). The significance and future of functional analysis methodologies. *Journal of Applied Behavior Analysis, 27(2),* 385-392. https://doi.org/10.1901/jaba.1994.27-385

McKenna, J. W., Flower, A., Falcomata, T., Adamson, R. M. (2015). Function-based replacement behavior interventions for students with challenging behavior. *Behavioral Interventions, 32(4),* 379-398. https://doi.org/10.1002/bin.1484

Michael, J. (1993). Establishing operations. *The Behavior Analyst, 16(2),* 191-206. https://doi.org/10.1007/BF03392623

Morris, E.K., Smith, N.G., Altus, D.E. (2005). B.F. Skinner's Contributions to Applied Behavior Analysis. *The Behavior Analyst, 28(2),* 99-131. https://doi.org/10.1007/BF03392108

Northup, J., Wacker, D., Sasso, G., Steege, M., Cigrand, K., Cook, J., & DeRaad, A. (1991) A brief functional analysis of aggressive and alternative behavior in an outclinic setting. *Journal of Applied Behavior Analysis, 24(3),* 509-522. https://doi/org/10.1901/jaba.1991.24-509

Oliver, A.C., Pratt, L.A., & Normand, M.P. (2015). A survey of functional behavior assessment methods used by behavior analysts in practice. *Journal of Applied Behavior Analysis, 48(4),* 817-829. https://doi.org/10.1002/jaba.256

Pelios, L., Morren, J., Tesch, D., & Axelrod, S. (1999). The impact of functional analysis methodology on treatment choice for self-injurious and aggressive behavior. *Journal of Applied Behavior Analysis, 32(2),* 185-195. https://doi.org/10.1901/jaba.1999.32-185

Roscoe, E.M., Phillips, K.M., Kelly, M.A., Farber, R., & Dube, W.V. (2015). A statewide survey assessing practitioners' use and perceived utility of functional assessment. *Journal of Applied Behavior Analysis, 48(4),* 830-844. https://doi.org/10.1002/jaba.259

Rosenthal, R. (1979). The "file drawer problem" and tolerance for null results. *Psychological Bulletin, 86(3),* 638-641. https://doi.org/10.1037/0033-2909.86.3.638

Skinner, B.F. (1938). *Behavior of Organisms* (7th Printing). B.F. Skinner Foundation.

Skinner, B.F. (1953). *Science and Human Behavior*. Pearson Education Inc.

Skinner, B.F. (1976). Farewell, my lovely!. *Journal of the Experimental Analysis of Behavior, 25(2),*218. https://doi.org/ 10.1901/jeab.1976.25-218

Slaton, J.D., Hanley, G.P., & Raftery, K.J. (2017). Interview-informed functional analyses: A comparison of synthesized and isolated components. *Journal of Applied Behavior Analysis, 50(2),* 252-277. https://doi.org/10.1002/jaba.384

Taylor, S. A., Phillips, K. J., & Gertzog, M. G. (2018). Use of synthesized analysis and informed treatment to promote school reintegration. *Behavioral Interventions, 33(4)*, 364-379. https://doi.org/10.1002/bin.1640

Thomason-Sassi, J.L., Iwata, B.A., Neidert, P.L., & Roscoe, E.M. (2011). Response latency as an index of response strength during functional analyses of problem behavior. *Journal of Applied Behavior Analysis, 44(1),* 51-67. https://doi.org/10.1901/jaba.2011.44-51

Thompson, R.H., & Iwata, B.A. (2007). A comparison of outcomes from descriptive and functional analyses of problem behavior. *Journal of Applied Behavior Analysis, 40(2),* 333-338. https://doi.org/ 10.1901/jaba.2007.56-06

Tincani, M., & Travers, J. (2019). Replication research, publication bias, and applied behavior analysis. *Perspectives on Behavior Science, 42(1),* 59-75. https://doi.org/10.1007/s40614-019-00191-5

Wallace, M.D., & Iwata, B.A. (1999). Effects of session duration on functional analysis outcomes. *Journal of Applied Behavior Analysis, 32(2),* 175-183. https://doi.org/10.1901/jaba.1999.32-175

Vargas, J.S. (2004). Contingencies over B.F. Skinner's discovery of contingencies. *European Journal of Behavior Analysis, 5(2),* 137-142. https://doi.org/10.1080/15021149.2004.11434240

Vollmer, T.R., Iwata, B.A., Duncan, B.A., & Lerman, D.C. (1993). Extensions of multielement functional analyses using reversal-type designs. *Journal of Developmental and Physical Disabilities, 5(4),* 311-325. https://doi.org/10.1007/BF01046388