Examining the Function of Problem Behavior in Fragile X Syndrome. A Preliminary Experimental Analysis.

Abstract

Fragile X syndrome (FXS) is the primary inherited cause of intellectual and developmental disability. The influence of environmental variables on behaviors associated with the syndrome has received only scant attention. The current study aimed to explore the function served by problem behavior in FXS by employing experimental functional analysis methodology with 8 children with FXS. No child met criteria for attention-maintained problem behavior, five children met criteria for escape-maintained problem behavior and four children met criteria for tangible-maintained problem behavior. Results are discussed in the light of previous findings on the function of problem behavior in FXS and implications for intervention are discussed. It is noted that the external validity of these findings is limited by the small sample size.

Fragile X syndrome (FXS) is the primary inherited cause of intellectual and developmental disability occurring in some 1 in 4,000 males and 1 in 8,000 females (Turner, Webb, Wake, & Robinson, 1996). The genetic basis of FXS lies on a single gene on the X chromosome known as the Fragile X Mental Retardation 1 (FMR1) gene. An individual is considered to have the full fragile X mutation when the number of trinucleotide repeats of cytosine-guanine-guanine (or CGG) within the promoter region of the FMR1 gene exceeds 200, which leads to hypermethylation of the cytosines and ultimately prevents the transcription of the FRM1 gene into mRNA and the translation of the Fragile X Mental Retardation Protein (FMRP).

Problem behaviors appear to be relatively prevalent in FXS, particularly in males with the syndrome (e.g., Hatton et al., 2002; Hessl et al., 2008). For example, Hessl et al (2008) found that some 79% of boys with FXS were reported to have recently displayed self-injurious behavior, 75% aggressive behaviors and 98% stereotypic behaviors. Certain forms of problem behavior, such as hand- or finger-biting appear to be especially common in this population (e.g., Symons, Clark, Hatton, Skinner, & Bailey, 2003), although many children with FXS present with multiple topographies of problem behavior (Hessl et al., 2008). There are few areas of the child's quality of life that such behaviors do not negatively impinge upon. Such behaviors are frequently cited by families as a great source of stress and can severely impair family functioning (Wheeler, Skinner, & Bailey, 2008). Under such circumstances, children who display problem behavior may be placed in relatively restrictive settings, sometimes a considerable distance from the family home (McGill, Tennyson, & Cooper, 2006).

Problem behavior associated with neurodevelopmental disorders, such as FXS, has been traditionally conceptualized as biologically driven. However, a number of studies have demonstrated that problem behavior associated with a range of different syndromes, including Lesch-Nyhan (Anderson, Dancis, & Alpert, 1978; Hall, Oliver, & Murphy, 2001), Smith-Magenis (Taylor & Oliver, 2008), and Cornelia De Lange syndrome (Sloneem, Arron, Hall, & Oliver, 2009) are open to environmental influence and frequently serve an operant function. Studies relating specifically to FXS have noted that environmental input can influence problem behaviors associated with the syndrome (Hessl et al., 2001) and that behaviors considered phenotypic of the syndrome, such as gaze avoidance, can be altered according to basic operant principles (Hall, Maynes, & Reiss, 2009). There is only a limited literature to help guide efforts at the early intervention and prevention of problem behaviors associated with FXS (Hall, 2009) and to some extent this may be a corollary of the historical focus on biological mechanisms in accounting for the behavior of children with FXS. It seems important therefore that research also examine environmental influences to help inform the development of intervention efforts for this group.

There is a growing body of evidence to suggest that children with FXS may be more likely to display problem behaviors that serve particular functions. A number of studies have noted high levels of ‘anxiety’ and minor problem behaviors in individuals with FXS when in situations characterised by high social or performance-related demands (Hall, DeBernadis, & Reiss, 2006; Hessl, Glaser, Dyer-Friedman, & Reiss, 2006; Kau et al., 2004; Lesniak-Karpiak, Mazzocco, & Ross, 2003). If relatively minor topographies of problem behavior are not effective in removing such demands then individuals with FXS may allocate their responses to potentially more costly forms of problem behavior (e.g., Lalli et al., 1995, Harding et al., 2001). Indeed, other studies have adopted indirect measures of behavioral function to examine such problem behaviors more explicitly (CITATION DELETED FOR REVIEW; Symons, Clark, Hatton, Skinner, & Bailey, 2003; Woodcock, Oliver, & Humphreys, 2009). In a postal survey study which adopted the *Functional Assessment Interview* (O'Neil, Horner, Albin, Storey, & Sprague, 1990) as a measure of behavioral function, Symons et al found that parents reported 87% of boys with FXS displayed self-injurious behaviors in response to routine changes, and 65% in response to task demands. In contrast only 3% were reported to display such behaviors to access attention. In a recent study, CITATION DELETED FOR REVIEW extended this line of work by examining within- and between-syndrome differences in the function of problem behavior using the *Questions About Behavioral Function* scale (QABF, Matson & Vollmer, 1995). Children with FXS were significantly less likely to be reported to display attention-maintained problem behaviors than they were tangible- or escape-maintained behaviors. In comparison to children with Smith-Magenis syndrome and mixed-etiology controls, children with FXS were also significantly less likely to display attention-maintained problem behaviors.

Findings from a number of different studies suggest that children with FXS may be especially likely to display problem behaviors that serve escape or tangible functions. To date, however, no study has examined the function of problem behavior in FXS using experimental functional analysis methodology. Functional analysis represents the 'gold standard' of functional assessment (Hanley, Iwata, & McCord, 2003) and the level of experimental control afforded by the explicit manipulation of antecedent and consequent variables holds many advantages over alternative methodologies (Iwata & Dozier, 2008), providing a believable demonstration of the function served by problem behavior. The current study, therefore, aimed to extend existing literature on problem behavior in FXS by adopting experimental functional analysis methodology to examine the function of problem behavior in a small group of boys with FXS. This is the first study of which we are aware to have used such methods to explicitly examine such relations in FXS.

Methodology

Participants

A total of 8 participants took part in the current study. All participants were male and had a diagnosis of FXS as confirmed by genetic testing and were selected primarily according to their geographical proximity to the study base (Canterbury, United Kingdom). One participant (Abe) also had a confirmed diagnosis of autism. Table 1 presents demographic information for each participant. Chronological ages ranged from 8 years to 15 years 10 months. Age equivalent scores on the Vineland (Sparrow, Balla, & Cicchetti, 1984) ranged from 1yr 3mths-5yrs 5mths for the communication sub-domain, from 1yr to 8yrs 4mths for the daily living skills sub domain and from 6mths to 6yrs 9mths for the socialization sub domain. The Aberrant Behavior Checklist- Community Version (Aman, Singh, Stewart, & Field, 1985) was used as a proxy measure of the severity of each child's problem behavior, with scores ranging from 39 - 128.

Participants were recruited from a prior study, conducted by the authors, which had used questionnaire-based methods to examine problem behavior in FXS (CITATION DELETED FOR REVIEW). Participants from this original study had been recruited via a UK-based parental support group for families of a child with FXS. All participants from this original sample were reported to display at least one topography of problem behavior.

To ensure the participants were representative of the original sample, categorical data from the QABF for the 8 children with FXS were compared against the remainder of the FXS group from the original study (N=26). A function was deemed to be present if the individual scored 10 or more for a given subscale. Using a significance level of $p = 0.05$, a series of chi-square analyses revealed no significant differences between the two sub groups for any scale across any topographical class (self-injurious behavior, aggressive behavior and property destruction), suggesting that the participants from the current study were representative of the original sample in terms of the potential function served by problem behaviors.

Response Measurement and Inter-Observer Agreement

Target behaviors included *self-injurious behaviors, aggressive behaviors* and *destructive behaviors.* Response definitions were developed on an individual basis following direct observation and discussion with parents. A total of 7 participants presented with at least one form of self-injurious behavior (including finger-biting, hand-biting, arm biting, head slapping, forcibly rubbing head against surfaces, banging head against surfaces), 8 participants presented with at least one form of aggression (including kicking, pulled punching, slapping, pinching, head hitting, spitting, pulling, hitting, scratching, grabbing, pushing) and 8 participants presented with at least one form of destructive behavior (including object throwing, object banging, kicking surfaces, object ripping, stamping feet, punching surfaces, spitting and spraying water). All participants presented with multiple topographies of problem behavior (range = 3–8). Target behaviors for each of the participants are shown in Table 1.

All sessions were videotaped to facilitate data collection and inter-observer agreement (IOA) checks. A 10-s partial-interval method was used to code the data for all participants. All target behaviors were collapsed and coded according to their response class (i.e., behaviors were aggregated if different topographies occurred at high rates in the same experimental conditions).

A second observer recorded participant behavior for between 29% - 41.6% of functional analysis sessions for each participant. The percentage of IOA was calculated using the exact agreement method. Agreement was defined as both observers agreeing on the occurrence and/or non-occurrence of the target behavior(s) in any given interval. Disagreement was scored as any discrepancy between the observers in any given interval. The number of agreements was divided by the number of agreements plus disagreements, and the resulting value was multiplied by 100 and reported as a percentage. Overall IOA for all intervals ranged from 97.8% - 100%, for scored intervals ranged from 87.5% to 100% and for non-scored intervals ranged from 97.1% to 100%. Kappa scores were also calculated for each response class to account for chance agreements, which ranged from 0.93 to 1.0. Table 2 shows all IOA data for all participants and response classes.

Experimental Design

Experimental conditions were implemented using a multi-element design. Participants were exposed to up to six different experimental conditions, which were implemented in a randomised fashion.

General Procedure

Functional analyses were conducted over a maximum of four visits to either the child's home or school with each visit lasting up to a total of 90 minutes. Each participant was exposed to a maximum of six different experimental conditions, and, with the exception of the No Interaction condition, there were a minimum of 3 replications of each condition and a maximum of 7 repetitions. Each session lasted 5 minutes. The number of visits made to each participant's home or school were negotiated with key stakeholders. Due to varying levels of availability this resulted in some differences between participants in the number of sessions that could be conducted. For Abe there were a total of 24 sessions, for Calum there were 25 sessions, for Greg there were 21 sessions, for Richard there were 15 sessions, for Jacob there were 27 sessions, for Luke there were 26 sessions, for Theo there were 25 sessions, and for John there were 22 sessions.

Functional analyses were conducted in rooms in each child's natural settings. For seven participants (Abe, Calum, Greg, Jacob, John, Richard and Theo) functional analyses were conducted in a suitable room in the child's house (either the living room or child's bedroom). All rooms were quiet and contained only the participant, the experimenter and a person who operated the video camera who provided no interaction with the participant in any condition. Rooms were selected based on the extent to which potentially reinforcing stimuli (e.g., toys) could be removed and replaced accordingly for each condition. For one participant (Luke) the functional analysis was conducted at school. Due to difficulties in room scheduling, the functional analysis conditions were conducted either in a partitioned area of the classroom or in a specially designated therapy room. This varied by way of a naturally occurring ABAB reversal design conducted over four separate visits. The classroom contained a partitioned area in which the functional analysis was conducted. Although the classroom contained other children and teachers, Luke was regularly asked to work in this area when conducting school work with his teacher. The therapy room was a large, unoccupied room furnished with tables and chairs and soft cushions.

The experimental functional analysis conditions were conducted using a procedure similar to that reported by Iwata et al (1982/1994), with each condition differing in terms of the programmed antecedents and consequences available for challenging behavior. The following experimental conditions were included in the analysis*:*

1) *Attention.* The participant was asked to play with some toys. The experimenter then pretended to read a book and stated that he was going to do some work. Attention was given for 10s contingent on each occurrence of problem behavior and took the form of statements of concern and mild disapproval paired with non-punitive physical contact, whilst the child was redirected to his toys. All other responses were ignored.
2) *Academic demand.* Educational activities were selected following discussion with informants and direct observation. Completion of tasks was judged to have a low probability of occurrence and never occurred spontaneously. Learning trials were presented to the participant using a three-prompt procedure (verbal request, modeling, and physical guidance). If the child did not respond to the demand after 5 seconds the experimenter gave a gestural or model prompt indicating the correct response. If the participant still did not respond a physical prompt was used. Social praise was given contingent on the successful completion of the learning trial, except on those occasions in which physical guidance was

required for task completion. Academic demands were removed for 10s contingent on target behaviors.

3) *Unstructured play*. The child had access to preferred toys (as determined by caregiver report and direct observation), whilst the experimenter delivered social praise at least every 15s following the first 5s period in which problem behaviors had not occurred. All target behaviors were ignored and the experimenter provided no demands on the child.
4) *No interaction.* The experimenter turned his back to the child and provided no interaction contingent on any behavior. The child had no access to toys. This condition aimed to test whether target behaviors were maintained by their non-social consequences.
5) *Social avoidance*. The child was provided with preferred toys and asked to play with them. The experimenter provided continuous attention by talking with the child and commenting on their play. If problem behaviors occurred then attention was removed for approximately 10s (cf., Hagopian, Wilson, & Wilder, 2001).
6) *Tangible.* In the tangible condition, toys or food items, identified as highly preferred, were placed in sight but out of reach of the child. The experimenter delivered the tangible for approximately 10s contingent on the occurrence of target behaviors or the child was given access to food on a FR-1 schedule.

As functional analyses were conducted in natural settings and some rooms contained multiple doorways it was not always possible to prevent the child from eloping and communicating with his caregivers when conducting the No Interaction condition. For this reason this condition was excluded from the analysis for 2 participants (Abe and Richard) and curtailed after a single session for 2 participants (Greg and Jacob). Variations were also made to the Demand condition for one participant (John). This specific condition was run by his mother, who was trained by the experimenter to run the condition, and the demand was combined with restricted tangibles to better reflect the contingencies reported to evoke problem behavior in his natural environment. Conditions for all other participants were run in accordance with the above protocol and were conducted by the first author. Items used in the tangible condition included preferred toys/activities for Abe (penguin toy), Greg (access to TV), Richard (access to video game). Food was used as the preferred tangible for Calum (cookies), Theo (potato chips) and Luke (potato chips). Both toys and sweets were used in the tangible condition for Jacob.

Data Analysis

In order to overcome some of the problems of relying solely upon visual analysis a modified version (see Martin, Gaffan, & Wiliams, 1999) of the Hagopian et al (1997) criteria for differentiation was used to ascribe behavioral function.

Using the modified Hagopian et al method a condition is considered differentiated when at least 50% of the data points for one condition falls 1 standard deviation (SD) above the mean of the play condition. In situations where levels of responding in the play condition are near zero the criterion is set at a minimum of 0.5 responses per minute (in the current study this meant the criterion being set at a minimum of 8.33% of intervals). The criterion line (CL) is marked at the relevant position on figures 1-9 for each participant. Hagopian et al also propose criteria for the interpretation of unusual data paths and the rules for low rate behaviors (see Hagopian et al., 1997, p. 325) were used to interpret functional analyses for Greg (aggression) and John. The data for all other participants were analysed using the standard protocol.

Results

Of the 8 participants, 4 displayed at least one response class of problem behavior that met the Hagopian et al criteria for tangible-maintained behavior, 5 displayed at least one response class of problem behavior that met the criteria for negatively-reinforced problem behavior either by the removal of demands or social attention. No participants displayed any behaviors that met the criteria for attention-maintained problem behavior.

Figures 1-9 depict the results of the functional analyses for all response classes displayed by all participants, with the exception of finger-biting displayed by Abe which occurred primarily in the Play condition and as such could not be interpreted using the Hagopian et al criteria. Anecdotally, this behavior appeared to occur in response to sounds emitted by a toy train with which Abe interacted primarily during the Play condition (data available from the first author) and as such may have been automatically reinforced (see Van Camp et al., 2000 for example).

Figures 1-4 present summary data for four participants with FXS, for whom at least one response class of problem behavior was positively reinforced by the contingent provision of tangible items. For Abe, as shown in Figure 1, there were heightened rates of problem behavior in the tangible condition of the functional analysis (M= 9.3; range= 0 - 16.6). There were low or zero levels of problem behavior in the demand (M = 2; range = 0 - 10), attention (M= .83; range = 0 – 3.3), play (M= 0; range = 0) and social avoidance (M= 0; range = 0) conditions. For Calum, as shown in Figure 2, there were elevated rates of problem behaviors occurring in each tangible condition (M = 43.85; range = 13.3 - 86.6). There were low rates of problem behavior in the demand (M = .83; range = 0 – 3.3), social avoidance (M = .83; range = 0 - 3.3) and no interaction (M = 2.2; range = 0 - 6.6) conditions of the functional analysis. There were zero rates of challenging behaviour in the play and attention conditions of the functional analysis. For Greg, as shown in Figure 3, there were elevated rates of 'other' problem behaviors solely in the tangible condition (M = 45.8; range = 33.3 – 53.3). There were zero occurrences of problem behavior in all other conditions. For Richard, as shown in Figure 4, there were elevated rates of problem behaviors occurring in each of the three tangible conditions (M = 64.4; range = 36.6 - 93.3). There were slightly elevated rates of problem behavior in two of the three demand conditions (M = 9.96.; range = 0 – 23.3). There were zero occurrences of problem behavior in the play, attention, and social avoidance conditions of the functional analysis.

Figures 5-9 present data from the functional analyses for those participants who displayed at least one topography of problem behavior that appeared to be negatively reinforced by the removal of aversive stimuli, such as attention or demands. For Jacob, as shown in Figure 5, problem behaviors occurred exclusively in the demand condition of the functional analysis (M = 13.9; range = 0-30). For Luke, as shown in Figure 6, there were high rates of problem behavior in all but two of the demand conditions (M = 27.2; range = 0 - 50). There were also relatively high levels of problem behavior in two of the five tangible conditions (M = 11.98; range = 0 - 30) and attention conditions (M=13.3; range = 0 - 30). Problem behavior occurred in two of the four no interaction (M = 9.97; range = 0 – 36.6) and play (M = 10; range = 0 – 33.3) conditions and one of the three social avoidance conditions (M = 12.2; range = 0 - 36.6). As at least 50% of scores for the demand condition lay above the CL, the data met the criterion for escape-maintained problem behavior. Despite the observed variability no other condition met this criterion. As shown in Figure 7, Theo displayed high rates of problem behavior in three of the five demand conditions (M = 24.7; range = 0 – 53.3). There were also elevated levels of challenging problem behavior in two of the five social avoidance conditions (M = 6; range = 0 - 26.6). There were zero to low rates of problem behavior in all other conditions (*Play*, M = .83; range = 0 - 3.3: *Attention*, M = 0: *Tangible*, M = 0: *No Interaction*, M = 0). Figure 8 shows that John displayed elevated levels of problem behavior in three of the seven demand conditions (M = 3.31; range = 0 – 13.3). Problem behavior occurred at low rates in the play (M= 2.2; range = 0 - 6.6), social avoidance (M = 1.1; range = 0 – 3.3) and no interaction conditions (M = 2.2; range = 0 – 3.3) of the functional analysis. There were zero rates of problem behavior in the tangible and attention conditions of the functional analysis. Finally, as displayed in Figure 9, Greg showed elevated rates of aggression in the social avoidance condition (M = 6.63; range = 0 - 16.6) and to a lesser extent the play condition (M = .83; range = 0 – 3.3) and demand condition (M = .83; range = 0 – 3.3) of the functional analysis. There were zero occurrences of aggression in attention, tangible and no interaction conditions.

Parents of all the participants who took part in the current study completed the QABF as part of a related study (CITATION DELETED FOR REVIEW). Table 3 presents the correspondence between the results of the QABF and the functional analysis results from the current study. The correspondence between the two different methodologies was somewhat mixed. There was no agreement between the QABF and functional analysis for 1 participant (Calum). There was partial agreement for 4 participants (Abe, Greg, Luke, John). Functional analyses were successful in identifying a behavioural function for 3 participants (Richard, Theo, Jacob) for whom the QABF had been unable to ascribe a function.

Discussion

The current study employed experimental functional analysis methodology to extend current understanding of the function served by problem behavior in FXS, finding low levels of attention-maintained problem behavior in a group of children with FXS in comparison to escape- or tangible-motivated problem behavior. Indeed, no child displayed any behavior that met the criteria for attention-maintained behavior. These data contrast with the findings of a related study conducted by the authors in which 4 out of 6 participants with Smith-Magenis syndrome (SMS) met the Hagopian et al criteria for attention-maintained problem behavior (CITATION DELETED FOR REVIEW).

This is the first study to have used functional analysis methodology to examine the within-syndrome profile of behavioral function associated with FXS. Unlike alternative functional assessment methodologies, experimental functional analysis provides a ‘believable demonstration’ of the variables that evoke and maintain problem behavior, and as such the current study represents a methodological advancement over indirect or descriptive alternatives that have been used in prior research on FXS. These findings suggest that interventions for problem behaviors associated with FXS should aim to modify the environmental context in which those behaviors take place.

There are striking consistencies between the findings of the current study and others to have examined the function of problem behavior in FXS (CITATION DELETED FOR REVIEW; Symons, Clark, Hatton, Skinner, & Bailey, 2003; Woodcock, Oliver, & Humphreys, 2009). CITATION DELETED FOR REVIEW, using the QABF, noted similar within-group differences in relation to attention-maintained problem behavior, with children with FXS being significantly less likely to display attention maintained problem behaviors than other functions. The authors also reported between-group differences in regards to attention-maintained problem behavior, with children with FXS scoring significantly lower on attention-maintained problem behaviors than comparison groups. The consistency in the findings between studies that have used such diverse methodologies appears to add to the robustness of the current findings.

When considered in the light of these previous findings, it may be that children with FXS are less likely to present with attention-maintained problem behavior than would be typically expected. It should be noted that such relations are probabilistic and it seems likely that some children with FXS will present with attention-maintained behaviors. That said, it may be that aspects of certain syndromes, such as FXS, influence the motivation for some of the social consequences that commonly maintain problem behavior (e.g., Langthorne & McGill, 2008; Kennedy, Caruso & Thompson, 2000; Oliver, 1993) and it seems important that further work along these lines be conducted. Such relations would have notable implications for efforts directed at the prevention of problem behavior in this group. For example, if children with FXS were found to be more likely to develop problem behaviors that served specific functions then early communication training could emphasize the development of alternative behavioral repertoires at a time before problem behaviors begin to emerge. Further research should explicitly examine this hypothesis in FXS.

Previous studies have not allowed for a clear examination of the role played by social attention in problem behavior in FXS. In their study, for example, Hall et al (2006) were unable to determine whether problem behaviors in children with FXS occurred to escape from demands or social attention. In the current study, only one child displayed differentially high levels of problem behavior in the social avoidance condition of the functional analysis. This suggests that social contact did not function as an aversive stimulus for the other 7 children in the FXS group. Coupled with the low levels of problem behavior in the attention condition of the functional analysis for all children with FXS, this would seem to support the hypothesis that the value of attention as a type of reinforcement may be abolished in this particular group, as opposed to functioning as an aversive stimulus. There may be neurobiological pathways involved in some of the relations described above and further research is required to begin to examine this in FXS. As we have described elsewhere (CITATION DELETED FOR REVIEW), FXS has been associated with the impaired functioning of the limbic-hypothalamic-pituitary-adrenal (L-HPA) axis, which plays an important role in the mediation of the human stress response. It has been suggested that the L-HPA axis may influence the occurrence of problem behavior in FXS. Indeed positive correlations have been reported between levels of cortisol (an indicator of the functioning of the L-HPA axis) and parental report of behavioral problems (Hessl et al., 2002). Hypothetically, changes in brain circuitry that result from the mutation on the FMR1 gene that causes FXS, may lead to the altered functioning of the L-HPA axis. The onset of an environmental ‘stressor’, such as a demand, may lead to an exaggerated physiological stress response in children with FXS. This would be expected to enduringly heighten the child’s ‘motivation’ to escape from such aversive stimuli and may explain the relatively high levels of negatively reinforced problem behavior observed in this group. One would also expect children with FXS to show a diminished ‘motivation’ for stimuli correlated with the onset of demands, such as attention, perhaps accounting for the low levels of attention-maintained problem behavior observed for this group. Whilst purely hypothetical, such postulations require empirical examination.

There are a number of limitations in the current study, which are now discussed. First, the 'no interaction' condition may not have provided the most optimal of tests for automatically reinforced problem behavior. In this condition, the establishing operation (EO) for attention (i.e., deprivation of attention) is present, as are salient discriminative stimuli for attention (i.e., the presence of the 'therapist'). Recent work on the evocative effect of the EO (e.g., O'Reilly et al., 2006) suggests that high levels of problem behavior occurring in this condition could potentially be indicative of an attention rather than an automatic function. That said, this interpretation could equally apply to the standard alone condition of a functional analysis (which also contains the EO for attention). Second, the correspondence between the results of the functional analyses and the QABF were somewhat mixed. However, to a certain degree the two methods measure different things and prior studies have reported variable correspondence between indirect and experimental functional assessment methodologies (e.g., Hall, 2005; Toogood & Timlin, 1996). Despite this, no child was reported to display attention-maintained problem behavior using the QABF, which corresponds to the findings for each functional analysis. Third, there remains the possibility that the functions identified in the current study were an artifact of the assessment methodology used. That is, the delivery of certain consequences may have led to a 'false positive' result within the functional analysis (Shirley, Iwata, & Kahng, 1999). As with all functional analyses that involve the manipulation of potentially reinforcing consequences, it remains difficult to rule out this interpretation in the absence of intervention data. Fourth, for a number of participants there was considerable variability in the occurrence of problem behavior across replications of the same experimental condition. The current study controlled the immediate antecedents and consequences of the functional analysis, although no fidelity data were collected to demonstrate the extent to which this was achieved. It also remains possible that other sources of variability which were not controlled, such as the level of pre-session access to tangible items or attention, influenced rates of responding. Part of Luke's functional analysis, for example, was conducted in natural classroom settings, where there may have been more uncontrolled sources of variability, perhaps accounting for the undifferentiated pattern of responding during those sessions conducted in the classroom. Fifth, due to practical constraints it was not always possible to run sessions until stable rates of responding were apparent, meaning that functional analyses were in some cases curtailed prematurely. In spite of this limitation, all participants did meet the Hagopian et al criteria for differentiation. Sixth, three participants (Abe, John and Greg's aggression) showed low rates of responding during the functional analysis relative to others in the sample, which may have restricted the extent to which target behaviors came into contact with the contingencies of the functional analysis. The fact that a function was identified for each of these participants, however, suggests that the functional analysis was sufficiently sensitive to detect the function of each participant's behavior. Seventh, the data in the current study were collected using partial interval recording procedures. However, the methods for establishing differentiation reported by Hagopian et al (1997) and Martin et al (1999) both relied on event data; as such, the use of this methodology in the current study represents a somewhat unorthodox application of this approach. Finally, the external validity of the study is hampered by the low number of participants and reliance on convenience sampling. Generalization of the findings to other children with FXS who present with problem behavior should, therefore, be undertaken only with considerable caution.

Studies are needed that begin to examine the effectiveness of environmentally-based interventions that are matched to the function of problem behavior for children with a diagnosis of FXS. It should now be a priority for studies to examine the effectiveness of behavioral interventions for problem behavior in FXS (see Hall, 2009, for example). Previous indirect studies (e.g., Symons et al., 2003) have indicated the potential relevance of transitions on problem behavior in FXS and future research could examine this explicitly using the methodology proposed by McCord, Thomson and Iwata (2001). As already noted, future research should also begin to examine the relationship between the L-HPA axis and the function of problem behavior in FXS. Finally, large-scale studies that allow for statistical comparison are required to further investigate both within- and between-syndrome differences in behavioral function at an epidemiological level. The findings of the current study suggest that such an endeavor, whilst costly, may be merited.

The current study has extended the existing literature on problem behavior in FXS and has provided further evidence that problem behaviors in children with FXS are sensitive to environmental influence. Further research is required, which explores the specificity of such influences and examines the effectiveness of interventions derived from this understanding of behavioral function for children with FXS.

References

Aman, M. G., Singh, N. N., Stewart, A. W., & Field, C. J. (1985). The Aberrant Behavior Checklist - a behavior rating scale for the assessment of treatment effects. *American Journal of Mental Deficiency, 89,* 485-491.

Anderson, L., Dancis, J., & Alpert, M. (1978). Behavioral contingencies and self-mutilation in Lesch-Nyhan disease. *Journal of Consulting and Clinical Psychology, 46,* 529-536.

Hagopian, L. P., Fisher, W. W., Thompson, R. H., Owen-DeSchryver, J., Iwata, B. A., & Wacker, D. P. (1997). Toward the development of structured criteria for interpretation of functional analysis data. *Journal of Applied Behavior Analysis, 30*, 313-326.

Hagopian, L. P., Wilson, D. M., & Wilder, D. A. (2001). Assessment and treatment of problem behavior maintained by escape from attention and access to tangible items. *Journal of Applied Behavior Analysis, 34*, 229-232.

Hall, S. S. (2009). Treatments for Fragile X Syndrome: a Closer Look at the Data. *Developmental Disabilities Research Reviews, 15*, 353-360.

Hall, S. S. (2005). Comparing descriptive, experimental and informant-based assessments of problem behaviors. *Research in Developmental Disabilities, 26*, 514-526.

Hall, S., DeBernadis, M., & Reiss, A. (2006). Social escape behaviors in children with fragile X syndrome. *Journal of Autism and Developmental Disorders, 36*, 935-947.

Hall, S., Maynes, N. P., & Reiss, A. L. (2009). Using percentile schedules to increase eye contact in children with fragile X syndrome. *Journal of Applied Behavior Analysis, 42*, 171-176.

Hall, S., Oliver, C., & Murphy, G. (2001). Self-injurious behaviour in young children with Lesch-Nyhan syndrome. *Developmental Medicine & Child Neurology, 43,* 745-749.

Hanley, G. P., Iwata, B. A., & McCord, B. E. (2003). Functional analysis of problem behavior a review. *Journal of Applied Behavior Analysis, 36*, 147-185.

Hatton, D. D., Hooper, S. R., Bailey, D. B., Skinner, M. L., Sullivan, K. M., & Wheeler, A. (2002). Problem behavior in boys with fragile X syndrome. *American Journal of Medical Genetics, 108,* 105-116.

Hessl, D., Dyer- Friedman, J., Glaser, B., Wisbeck, J., Barajas, R. G., Taylor, A., et al. (2001). The influence of environmental and genetic factors on behavior problems and autistic symptoms in boys and girls with fragile X syndrome. *Pediatrics, 108*, 88-97.

Hessl, D., Glaser, B., Dyer- Friedman, J., Blasey, C., Hastie, T., Gunnar, M., et al. (2002). Cortisol and behavior in fragile X syndrome. *Psychoneuroendocrinology, 27*, 855-872.

Hessl, D., Glaser, B., Dyer-Friedman, J., & Reiss, A. (2006). Social behavior and cortisol reactivity in children with fragile X syndrome. *Journal of Child Psychology and Psychiatry, 47*, 602-610.

Hessl, D., Tassone, F., Cordeiro, L., Koldewyn, K., McCormick, C., Green, C., et al. (2008). Brief Report: Aggression and stereotypic behavior in males with fragile X syndrome- moderating secondary genes in a 'single gene' disorder. *Journal of Autism and Developmental Disorders, 38*, 184-189.

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*, 197-209.

Iwata, B. A., & Dozier, C. L. (2008). Clinical application of functional analysis methodology. *Behavior Analysis in Practice, 1*, 3-9.

Kau, A. S. M., Tierney, E., Bukelis, I., Stump, M. H., Kates, W. R., Trescher, W. H., et al. (2004). Social behavior profile in young males with fragile X syndrome: Characteristics and specificity. *American Journal of Medical Genetics Part A, 126A*, 9-17.

Kennedy, C. H., Caruso, M., & Thompson, T. (2001). Experimental analyses of gene-brain-behavior relations: Some notes on their application. *Journal of Applied Behavior Analysis*, *34*, 539-549.

Langthorne, P., & McGill, P. (2008). A functional analysis of the early development of self-injurious behavior: Incorporating gene-environment interactions. *American Journal on Mental Retardation*, *113*, 403-417.

CITATION DELETED FOR REVIEW

CITATION DELETED FOR REVIEW

Lesniak-Karpiak, K., Mazzocco, M. M. M., & Ross, J. L. (2003). Behavioral assessment of social anxiety in females with Turner or fragile X syndrome. *Journal of Autism and Developmental Disorders, 33*, 55-67.

McCord, B. E., Thomson, R. J., & Iwata, B. A. (2001). Functional analysis and treatment of self-injury associated with transitions. *Journal of Applied Behavior Analysis, 34*, 195-210.

Martin, N., Gaffan, E. A., & Wiliams, T. (1999). Experimental functional analyses for challenging behavior: A study of validity and reliability. *Research in Developmental Disabilities, 20*, 125-146.

Matson, J. L., & Vollmer, T. R. (1995). *User's Guide: Questions About Behavioral Function (QABF).* Baton Rouge, LA: Scientific Publishers Inc.

CITATION DELETED FOR REVIEW

McGill, P., Tennyson, A., & Cooper, V. (2006). Parents whose children with learning disabilities and challenging behaviour attend 52-week residential schools: Their perceptions of services received and expectations of the future. *British Journal of Social Work, 36, 597-616*

O'Reilly, M. F., Sigafoos, J., Edrisinha, C., Lancioni, G., Cannella, H., Choi, H. Y., et al. (2006). A preliminary examination of the evocative effects of the establishing operation. *Journal of Applied Behavior Analysis, 39*, 239-242.

O'Neil, R. E., Horner, R. H., Albin, R. W., Storey, K., & Sprague, J. R. (1990). *Analysis of Problem Behavior: A Practical Assessment Guide*. Sycamore, IL: Sycamore.

Richman, D. (2008). Early intervention and prevention of self-injurious behavior exhibited by young children with severe developmental delays. *Journal of Intellectual Disability Research, 5*, 3-17.

Rutter, M., Moffitt, T. E., & Caspi, A. (2006). Gene-environment interplay and psychopathology: multiple varieties but real effects. *Child Psychology and Psychiatry, 47*, 226-261.

Shirley, M. J., Iwata, B. A., & Kahng, S. W. (1999). False-positive maintenance of self-injurious behavior by access to tangible reinforcers. *Journal of Applied Behavior Analysis, 32,* 201-204.

Sloneem, J., Arron, K., Hall, S., & Oliver, C. (2009). Self-injurious behavior in Cornelia de Lange syndrome: 2. Association with environmental events. *Journal of Intellectual Disability Research, 53*, 590-603.

Sparrow, S., Balla, D., & Cicchetti, D. (1984). *Vineland adaptive behavior scales. Expanded form manual.* . Circle Pines, MN: American Guidance Service.

Symons, F. J., Clark, R. D., Hatton, D. D., Skinner, M., & Bailey, D. B. (2003). Self-injurious behavior in young boys with fragile X syndrome. *American Journal of Medical Genetics, 118A*, 115-121.

Taylor, L., & Oliver, C. (2008). The behavioural phenotype of Smith-Magenis syndrome: evidence for a gene-environment interaction. *Journal of Intellectual Disability Research, 52*, 830-841.

Toogood, S., & Timlin, K. (1996). The functional assessment of challenging behaviour: A comparison of informant-based, experimental and descriptive methods. *Journal of Applied Research in Intellectual Disabilities*, 9, 206-222.

Turner, G., Webb, T., Wake, S., & Robinson, H. (1996). Prevalence of fragile X syndrome. *American Journal of Medical Genetics, 64*, 196-197.

Van camp, C. M., Lerman, D. C., Kelley, M. E., Roane, H. S., Contrucci, S. A. & Vorndran, C. M. (2000) Further analysis of idiosyncratic antecedent influences during the assessment and treatment of problem behavior. *Journal of Applied Behavior Analysis*, 33**,** 207-221.

Wheeler, A. C., Skinner, D. G., & Bailey, D. B. (2008). Perceived quality of life in mothers of children with fragile X syndrome. *American Journal on Mental Retardation, 113*, 159-177.

Woodcock, K., Oliver, C., & Humphreys, G. (2009). Associations between repetitive questioning, resistance to change, temper outbursts and anxiety in Prader-Willi and Fragile X syndromes. *Journal of Intellectual Disability Research, 53*, 265-278.

Figure Captions

Figure 1. Abe. Percentage of intervals with problem behavior during functional analysis.

Figure 2. Calum. Percentage of intervals with problem behavior during functional analysis.

Figure 3. Greg. Percentage of intervals with other problem behavior during functional analysis.

Figure 4. Richard. Percentage of intervals with problem behavior during functional analysis.

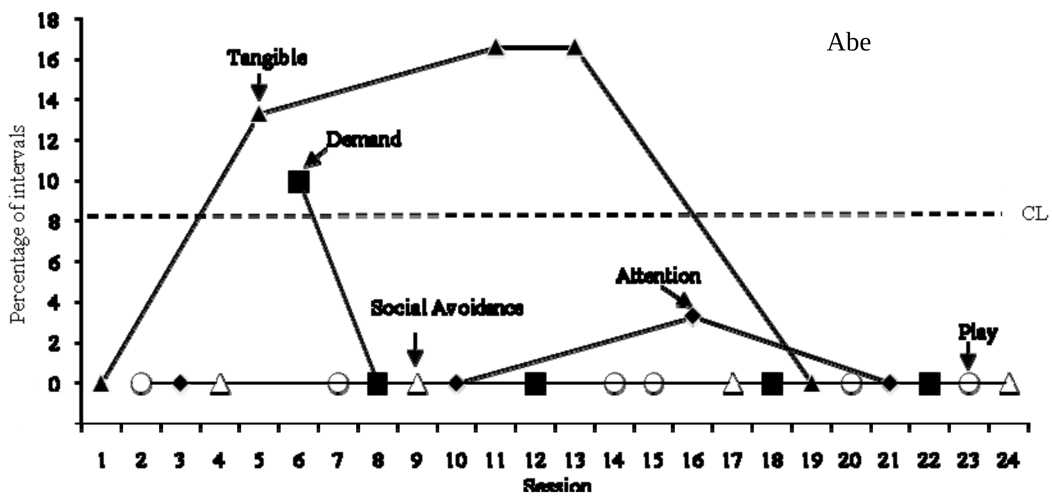
Figure 5. Jacob. Percentage of intervals with problem behavior during functional analysis.

Figure 6. Luke. Percentage of intervals with problem behavior during functional analysis.

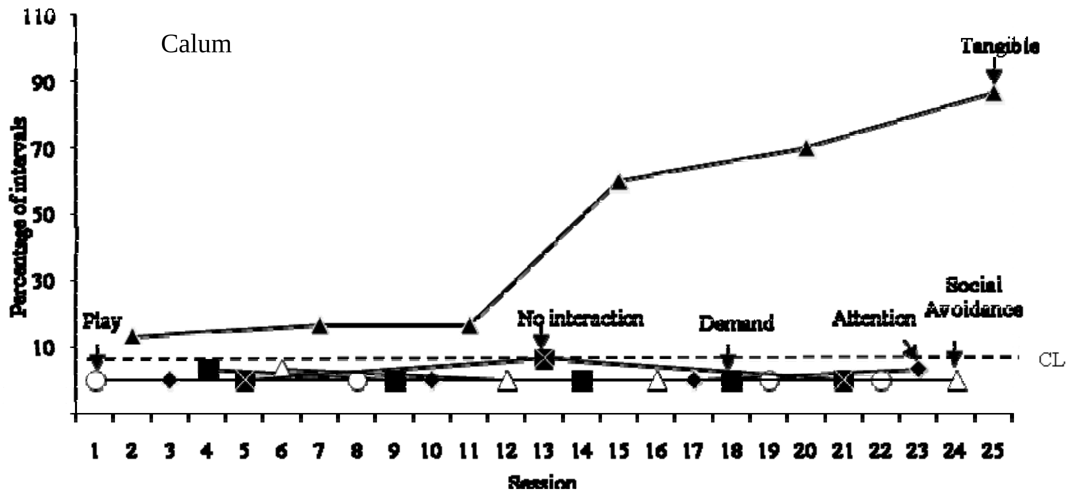
Figure 7. Theo. Percentage of intervals with problem behavior during functional analysis.

Figure 8. John. Percentage of intervals with problem behavior during functional analysis.

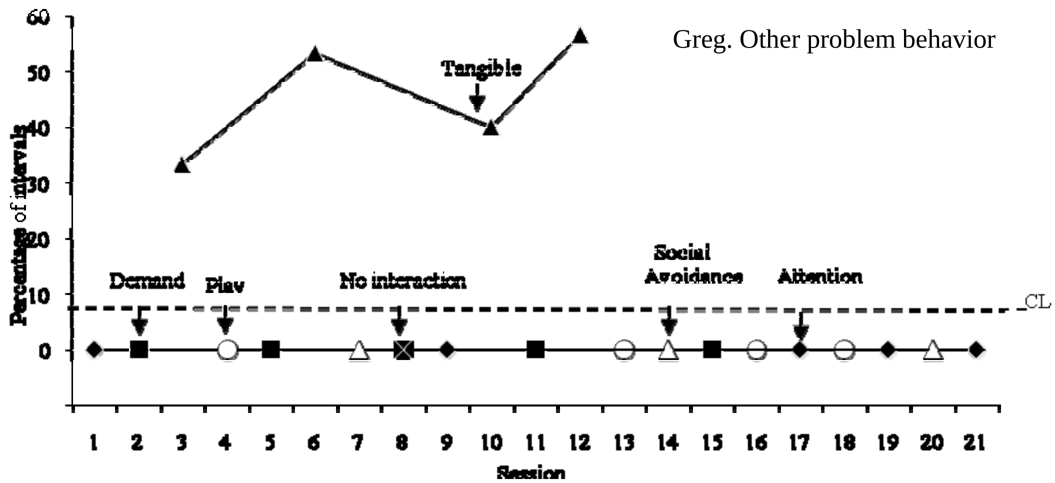
Figure 9. Greg. Percentage of intervals with aggression during functional analysis.

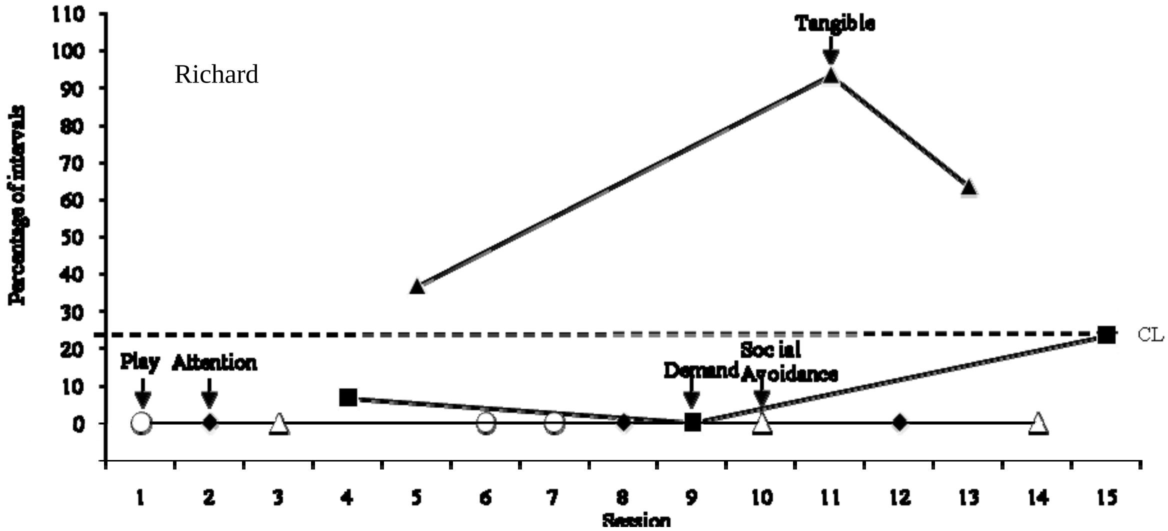


Abe
Tangible
Demand
CL
Attention
Social Avoidance
Play
Percentage of intervals
0
2
4
6
8
10
12
14
16
18
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Session



Calum
Tangible
Play
No interaction
Demand
Attention
Social
Avoidance
CL
Percentage of intervals
110
90
70
50
30
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Session


Greg. Other problem behavior
Percentage of intervals
Session
Tangible
Demand
Play
No interaction
Social
Avoidance
Attention
CL
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21


Richard
Tangible
Play
Attention
Demand
Social Avoidance
CL
Percentage of intervals
Session
110
100
90
80
70
60
50
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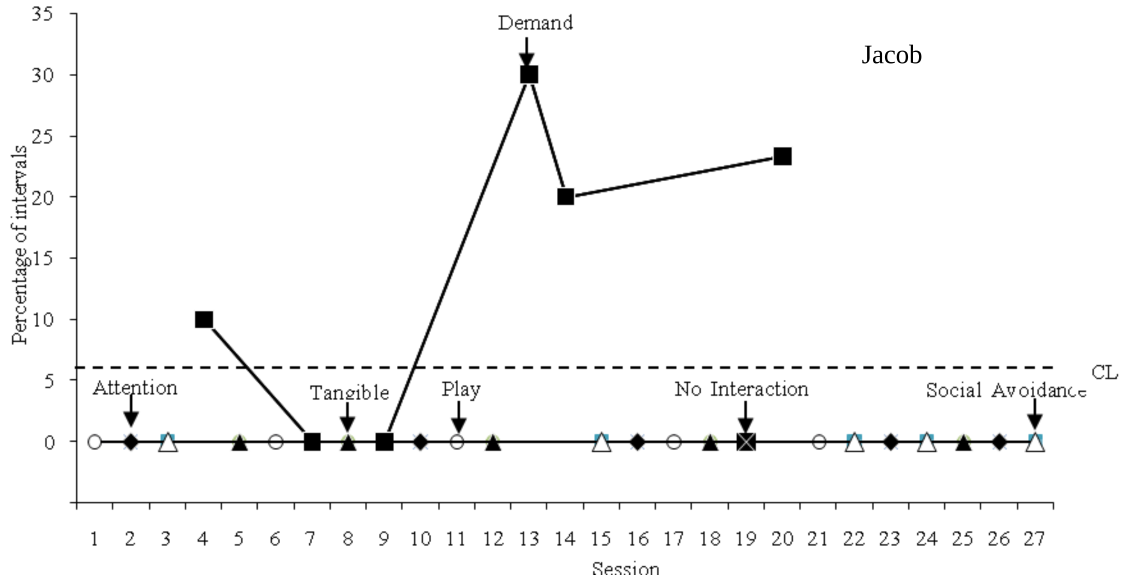
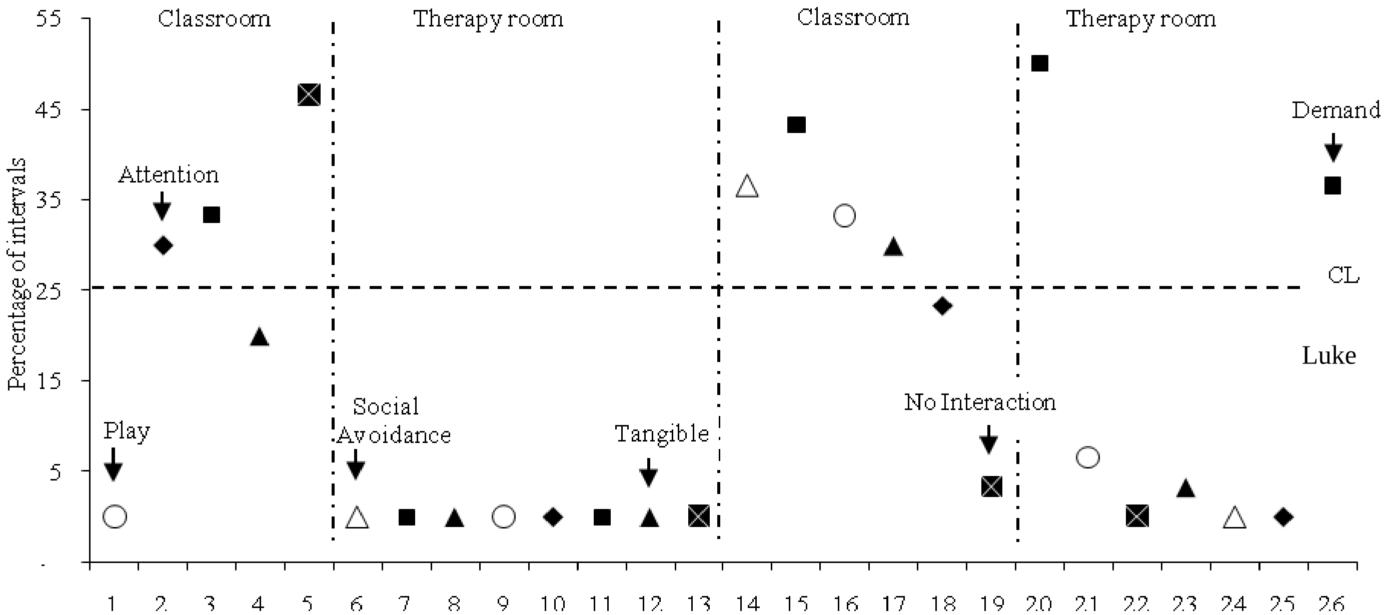
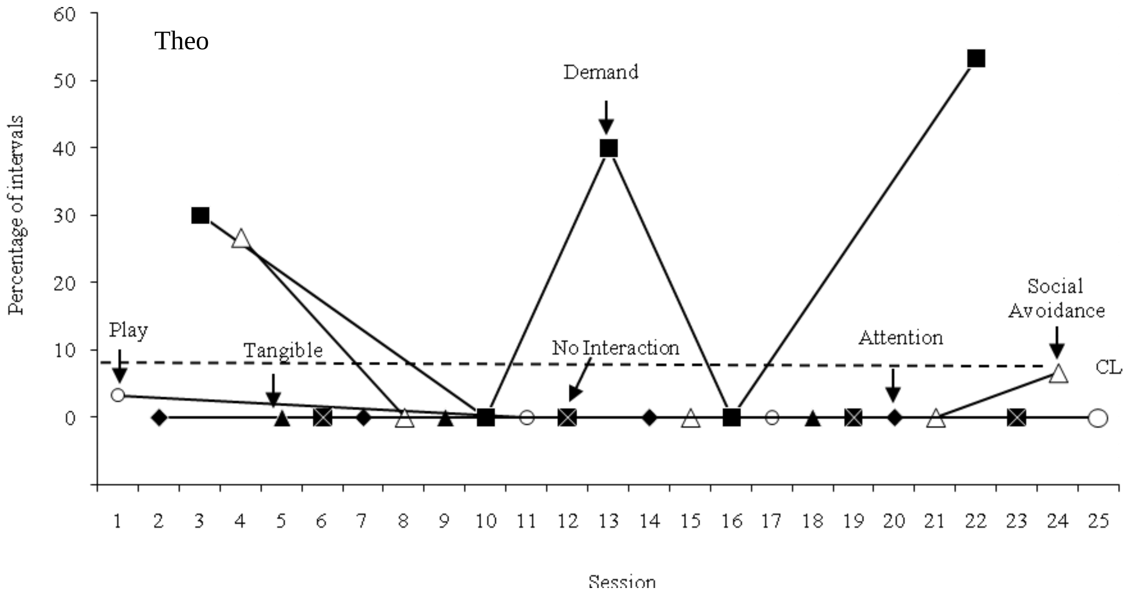
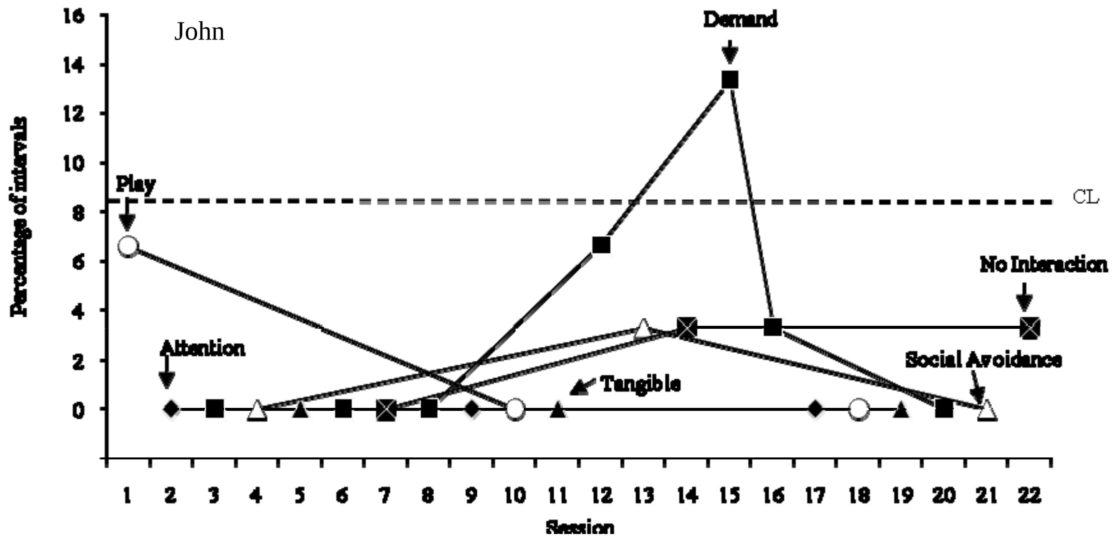
11
12
13
14
15


Jacob
Demand
Attention
Tangible
Play
No Interaction
Social Avoidance
CL
Percentage of intervals
Session
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27



Classroom
Therapy room
Classroom
Therapy room
Percentage of intervals
55
45
35
25
15
5
Attention
Play
Social
Avoidance
Tangible
No Interaction
Demand
CL
Luke
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26


Theo
Demand
Play
Tangible
No Interaction
Attention
Social Avoidance
CL
Percentage of intervals
Session
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25


John
Demand
Play
CL
No Interaction
Attention
Social Avoidance
Tangible
Percentage of intervals
Session
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

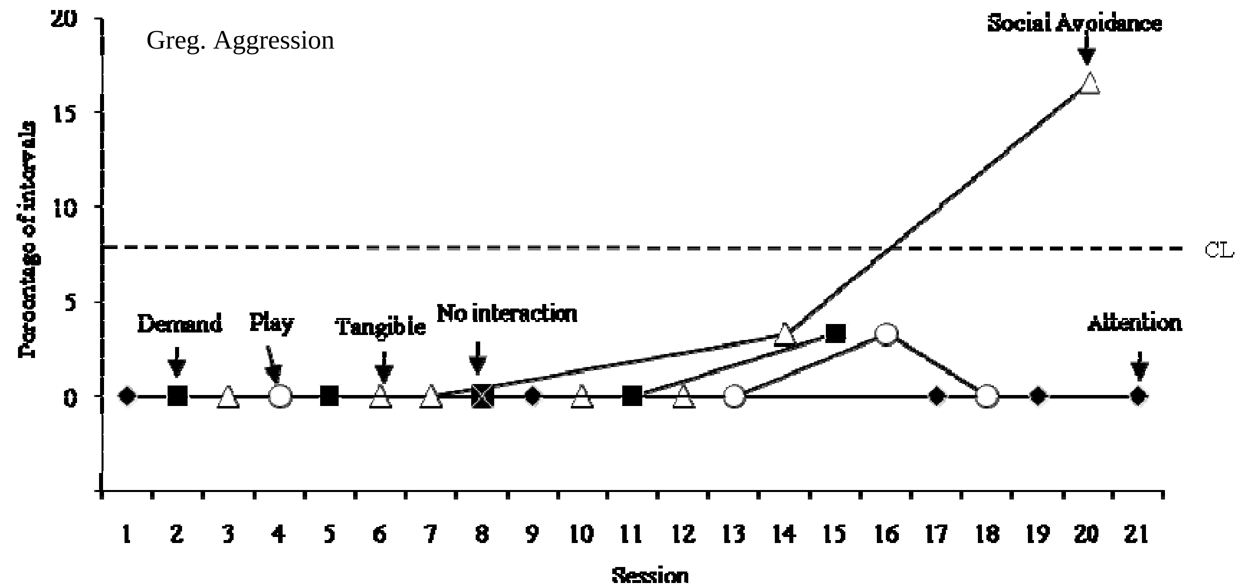

Greg. Aggression
Social Avoidance
CL
Demand
Play
Tangible
No interaction
Attention
Percentage of intervals
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Session

Table 1. *Participant Characteristics.*

Participant	Age	Aberrant Behavior Checklist (Total Score)	Age Equivalent (Vineland Sub-domains)			Behavioral Topographies
			Communication	Daily Living	Socialization	
Abe	9yrs 8mths	108	1yr 9mths	1yrs	2yrs	*Self-injurious behaviors*: Finger-biting, hand-biting. *Aggressive behaviors*: kicking, pulled punch, slapping, pinching. *Destructive behaviors*: object throwing.
Greg	9yrs 8mths	112	3yrs 1mth	2yrs	2yr 1mth	*Self-injurious behaviors*: N/A. *Aggressive behaviors*: head hitting, spitting. *Destructive behaviors*: object banging.
Jacob	8yrs	51	4yrs 1mth	4yrs2mths	5yrs 5mths	*Self-injurious behaviors*: arm biting, head slapping, forcibly rubbing head against surfaces. *Aggressive behaviors*: hitting. *Destructive*

						behaviors: object throwing, object banging, kicking surfaces.
Luke	15yrs 10mths	59	1yr 3mths	1yr 1mth	0yrs 6mths	*Self-injurious behaviors*: hand-biting. *Aggressive behaviors*: pulling, hitting, scratching. *Destructive behaviors*: object throwing and ripping, stamping feet.
Theo	10yrs 4mths	39	3yrs 1mth	2yrs 8mths	6yrs 9mths	*Self-injurious behaviors*: finger-biting *Aggressive behaviors*: hitting. *Destructive behaviors*: object ripping.
John	13yrs	128	2yrs 2mths	2yrs 3mths	3yrs 1mth	*Self-injurious behaviors:* finger-biting. *Aggressive behaviors*: hitting. *Destructive behaviors:* object throwing, foot stamping.
Calum	15yrs 1mth	80	5yrs 3mths	8yrs 4mths	5yrs 7mths	*Self-injurious behaviors*: banging head against surfaces . *Aggressive*

						behaviors: grabbing. *Destructive behaviors*: object throwing and punching surfaces.
Richard	11yrs 7mths	47	5yrs 5mths	3yrs 1mth	4yrs 10mths	*Self-injurious behaviors*: finger-biting. *Aggressive behaviors*: kicking, hitting, pushing,. *Destructive behavior*: Object throwing and ripping, spitting and spraying water.

Table 2. *Inter-observer agreement data*.

Participant	Response class	Percentage agreement Total	Percentage agreement (Scored Intervals)	Percentage agreement (Unscored Intervals)	Kappa
Abe	Other challenging behaviors	99.3%	87.5%	99.3%	.93
Greg	Head-hitting	100%	100%	100%	1.0
	Other challenging behaviors	99.1%	95.4%	98.9%	.97
Jacob	All challenging behaviors	99.2%	87.5%	99.1%	.93
Luke	All challenging behaviors	97.8%	90.9%	97.1%	.94
Theo	All challenging behaviors	99.3%	89.5%	99.2%	.94
John	All challenging behaviors	99.6%	87.5%	99.6%	.93
Calum	All challenging behaviors	99.7%	97.9%	99.6%	.99
Richard	All challenging behaviors	99%	96%	99%	.97

Table 3. *Correspondence Between Results of Indirect Functional Assessment and Experimental Functional Analysis Methodologies*.

Participant	QABF*	Experimental functional analysis**
Abe	Tangible, Escape, Automatic	Tangible
Greg	Escape, Automatic	Escape (social avoidance), Tangible
Jacob	Function not identified	Escape (demand)
Luke	Escape, Tangible	Escape (demand)
Theo	Function not identified	Escape (demand)
John	Escape, Tangible, Automatic	Escape (demand)
Calum	Escape, Automatic	Tangible
Richard	Function not identified	Tangible

* For a function to be ascribed using the QABF there had to be a score of 10 or more on the relevant subscale (necessitating that 4 of the 5 items for the particular subscale be endorsed). Data from the Physical discomfort related subscale were excluded as this function was not assessed in the experimental functional analyses. **As there is no specific social avoidance subscale on the QABF, social avoidance and demand functions identified via experimental functional analyses were collapsed into the category ‘Escape’.