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A Clinical Trial of an Electronic Monitoring System with a Deaf Child with an Autism Spectrum Disorder

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Abstract

Aggressive, dangerous and self-injurious behaviours also referred to as disruptive behaviours are commonly experienced by deaf children with Autism Spectrum Disorders (ASD). These behaviours pose a problem because they inhibit a child from meaningfully engaging in their learning and peer interactions and occur without any obvious cause. The current study was a clinical trial of an advanced electronic monitoring system. The purpose of this study was to test the efficacy of the system in identifying triggers to the participant's disruptive behaviour. The participant was a deaf child (male) aged 12 with an ASD. Audio, visual, temperature and humidity information of the participant's home environment was collected for a total of 12 hours. Analysis of the environmental data revealed the successful identification of an audio trigger that preceded the participant's disruptive behaviour. Environmental modifications based on the identified trigger can be made to the participant's home and potentially reduce or eliminate the disruptive behaviour. The limitations and practical implications for future research are discussed.

A Clinical Trial of an Electronic Monitoring System with a Deaf Child with an Autism Spectrum Disorder

Disruptive behaviours are a common characteristic observed in children with an Autism Spectrum Disorder (ASD) **(**Buschbacher & Fox, 2003). These behaviours include acts of aggression, crying and tantrums as well as self-injurious behaviours (Neitzel, 2010). For children who are both deaf and have a comorbid diagnosis of an ASD these behaviours are further exacerbated due to their communication and language difficulties (Conroy, Asmus, Boyd, Ladwig, & Sellers, 2007). The disruptive behaviours interfere with and inhibit a child from meaningfully participating in their learning and social environments (Neitzel, 2010).

Current research has primarily focused on the internal motivations a hearing child may have for engaging in disruptive behaviours such as gaining attention, reinforcement or escaping aversive situations (Buschbacher & Fox, 2003). Very little research to date has focused on external environmental factors that may provoke a child who has an ASD to engage in disruptive behaviour (Hanley, Iwata, & McCord, 2003). Even less research has specifically focused on deaf children with an ASD who remain a marginalized, under studied and under reported subset of children (Chovaz, Anderson, & Goldstein, 2011). The goal of the present study was to identify potential environmental triggers to the disruptive behaviour of a deaf child with an ASD using an advanced electronic monitoring system. This study builds upon earlier research projects with similar goals of identifying environmental stimuli; however this study functioned as the first clinical trial of the improved device. This paper introduces the topics of Autism Spectrum Disorders, deafness in general, Autism Spectrum Disorders together with deafness, disruptive behaviours and methods of assessment of disruptive behaviours.

Autism Spectrum Disorders

Autism Spectrum Disorders (ASD) are a group of neurodevelopmental disorders that are characterized by persistent impairments in social communication and interaction and repetitive and stereotyped behavior and interests (American Psychiatric Association., 2013). The prevalence rate of Autism according to the U.S Centres for Disease Control and Prevention (2007) is that of 1 in 110 children experiencing an ASD diagnosis. Each child with an ASD experiences the disorder differently, no two children experience the same symptoms or severity of the disorder. However, there are common characteristics that are observed among all children with an ASD including difficulties with social interaction and the use of language for communication and social purposes, resistance to change, absence of facial expression and eye contact and difficulties with make believe play. These characteristics disrupt a child's daily living and combine together to result in generalized difficulties for the child to engage and actively participate in the world around them (Szymanski & Brice, 2008).

The difficulties with language and communication that are common for children with an ASD are proposed to be caused by the child's delay in language development, coupled with their lack of eye contact in social situations and minimal desire to engage in social dialogue. A language delay inhibits a child from having a meaningful use of language and complicates their ability to inform caregivers and teachers of their distress (Neitzel, 2010). Sensitivities to various stimuli also cause concerns for children with an ASD as they experience hyper or hypo responses to auditory, visual, vestibular, olfactory, gustatory, and tactile stimuli (Chovaz et al. 2011). The reaction of a child with an ASD to certain stimuli may appear to be an over or under responsivity to the stimuli. Their responses can also be observed as disruptive behaviours such as screaming, crying and head banging (Talay-Ongan, & Wood, 2000). These reactions can interfere with the child's ability to actively participate in their environment.

(O'Donnell, Deitz, Kartin, Nalty, & Dawson, 2012). The characteristics and behaviours children with an ASD express are inappropriate for their age and impact all aspects of their life, specifically, their perception, thought and attention (Chovaz et al. 2011).

Deafness

An additional complication to the already perplexing issue of an ASD is the added diagnosis of deafness. A child is considered to be deaf when they have little to no functional hearing and rely on visual communication aids such as signing and speech reading. Deaf children may also use hearing aids to assist them in communicating with others. Children who use hearing aids can theoretically hear some pitches of sound despite their deafness as the hearing aids assist them in orientating to conversations and sounds around them. The severity of the hearing loss also has a role. Hearing loss severity can range from mild hearing loss to moderate, moderately severe, severe and profound hearing loss (du Feu & Chovaz, 2014). Children who are deaf experience the world very differently from hearing children including their interpretation and perception of the world around them (Chovaz et al. 2011).

Language development is a crucial concern for these children as various issues can arise if an accessible language is not obtained early on. If deaf children do not obtain an accessible language, verbal or signing, during the critical period for language development they can experience a delay in their language development and lack the social and communicative use of language that hearing children have. This can potentially lead to the child becoming language impoverished (Szymanski &Brice, 2008). A basic need for a deaf child who uses sign language to communicate is the use of eye contact; eye contact allows the child to acquire language, develop social skills and to learn in general (Morton,

2008). The child must be able to see other individuals speaking or signing in order to effectively communicate with them.

Deafness and Autism Spectrum Disorders

Currently very little research exists that examines the co-occurrence of deafness and ASDs together. Much of the research examines each as a separate entity and not together as a comorbid diagnosis. According to data from the Gallaudet Research Institute's 2009-2010 Annual Survey of Deaf and Hard of Hearing Children and Youth, 1 in 53 deaf children have a comorbid diagnosis of an ASD. School administrators provided information for a total of 32, 334 children, 611 of those children were reported to have a dual diagnosis of deafness and an ASD. This prevalence rate represents a substantial increase of ASD diagnoses in deaf children from the 1 in 104 prevalence rate that was reported in 2004-2005. The rates of Autism in the deaf population are considerably higher and increasing faster than the prevalence rates of Autism experienced by those without a hearing loss. In comparing the prevalence rates of Autism in hearing children and deaf children it can be seen that ASDs are reported more in deaf children than in hearing children (Szymanski, Brice, Lam, & Hotto, 2012).

The troubling aspect of a dual diagnosis of both deafness and an ASD is the compounding effect each separate condition has on the child's quality of life. Combined, deafness and ASDs can be extremely debilitating for a child. A child's social and communicative use of language is affected due to the impairments associated with Autism and additional communication difficulties are experienced due to the language barrier associated with being deaf and being unable to communicate in the same language as others. Additionally, a specific concern for deaf children with an ASD is the lack of eye contact that is characteristic of a child with an ASD. The need for eye contact for a deaf child to acquire language, learn

and interact with others is severely compromised in deaf children with an ASD as it is common for them to make little to no eye contact with others, specifically lacking in the case of communication purposes (Morton, 2008). This creates a barrier for the deaf child in acquiring language, developing social skills and learning in general.

Should the deaf child with an ASD not receive an accessible language or miss the critical period to learn a language, they can grow up linguistically, communicatively, socially and emotionally isolated from their world. Furthermore this increasing the difficulty for the child to communicate their thoughts, feelings and concerns with other people (Morton, 2008). This results in more complications for caregivers and others to understand the children and results in a misunderstanding of their communication and behaviours.

Disruptive Behaviours

Children who are deaf and have an ASD frequently engage in challenging behaviours that interfere with their attention and participation with the environment around them. These behaviours are broken down into two categories; repetitive and stereotypical behaviours such as rocking back and forth and collecting specific items as well as disruptive behaviours such as acts of aggression and self-injurious behaviours (Neitzel, 2010). Of concern for the present study were the second of the two categories, the disruptive behaviours that are commonly observed in this population. Disruptive behaviours include acts of aggression such as screaming, kicking and punching, tantrums, crying and also self-injurious behaviours such as head banging, scratching and biting. Disruptive behaviours are not considered a diagnostic criteria for deafness or Autism but are frequently observed in children who are both deaf and have an ASD.

Hattier, Matson, Belva, and Horovitz (2011) compared a group of children with ASD diagnoses to other children of atypical development (non ASD children). It was found that both groups of children exhibited similar behavioural concerns but the children with an ASD exhibited a higher percentage of challenging behaviours, displayed more aggression and self-injurious behaviours and overall had more frequent behaviour than the other atypically developing children. Similar results have been observed in regards to the disruptive behaviour of deaf children. Stevenson, McCann, Watkin, Wordsfold and Kennedy (2010) examined the differences in behavioural problems of deaf children and hearing children. Children with hearing loss and poor language competence were found to have a greater risk for displaying disruptive behaviours. Behaviour problems were more common in deaf children and included more conduct and hyperactivity problems as compared to hearing children. These studies indicate that behaviour problems are highest amongst those with hearing loss and those lacking effective language ability, such as would be expected in deaf children with a diagnosis of an ASD **(**Buschbacher, & Fox, 2003).

Disruptive behaviours are a problem for this population of children because the behaviours can negatively impact the child's ability to learn and socialize in the world, inhibiting them from meaningfully engaging in their academic activities and also impacting the learning of others around them **(**Buschbacher, & Fox, 2003). The behaviour of a deaf child with an ASD is very chronic and can be a cause of distress for caregivers and teachers who report feelings of stress, frustration and emotional burn out. Disruptive behaviour is often the reason why caregivers seek referrals for interventions (Ashburner, Ziviani, & Rodger, 2008; Lecavalier, Leone, & Wiltz, 2006; Hastings, & Brown, 2002). The reason these behaviours cause such an issue, is not simply that they occur, but that the underlying causes for why the behaviours occur are unknown (Chovaz et al. 2011). Deaf children

with an ASD are especially sensitive to their environments and it may be this sensitivity that triggers their disruptive behaviours. However, deaf children with an ASD typically struggle to effectively communicate to caregivers what is causing their distress. This unfortunately results in caregivers having very little knowledge as to how to assist these children and remove the triggers to reduce the likelihood of the behaviour reoccurring.

Of concern is the ability to accurately identify these environmental triggers and make the necessary changes to the environment to reduce the likelihood of future occurrence. A device that is able to identify what stimuli within the environment is functioning as a trigger for a deaf child with an ASD would potentially greatly impact the life of the child, enabling him or her to more adaptively participate in the world. It would also assist caregivers and teachers in understanding and interacting with the child.

Methods to Assess and Reduce Behaviours

Functional Behavioural Analysis is the predominant method used to assess a child's behaviour and determine the reinforcements a child may gain from engaging in such behaviour. Both the child's internal motivations and the child's environment are considered in the assessment process to uncover what may be influencing, reinforcing and maintaining the behaviour (Chovaz et al. 2011). Applied Behavioural Analysis is a strategy that is used to reduce the occurrence of problem behavior with a focus on understanding the behaviour and how the environment affects it. Behaviour is explained in terms of external events that can then be manipulated by researchers rather than internal constructs that cannot be observed or controlled by researchers (Zane, Carlson, Estep, & Quinn, 2014). Positive Behaviour Support is used to promote the ideal environment within which a child may interact and learn

(Neitzel, 2010). Behavior Tracking is an additional method used with individuals who are deaf and have an ASD to assess what the child may gain from engaging in the behaviour. It involves collecting information on the patterns of the child's behaviour and examining the antecedents to and consequences of the behaviour (Chovaz et al. 2011). All assessment methods examine the expressed behaviour for elements that influence and reinforce the behaviour consisting of either the child's internal motivations or external stimuli in the physical environment. These methods of behaviour assessment are conducted in person and typically require that a clinician or trained individual observe the child naturalistically. Human observation and the use of paper and pencil methods of behaviour assessment have inherent error and biases associated with the reliance on the individual's memory and the assumptions the individual may have for the cause of the behaviour. In this study, the goal was to focus on and examine the external, physical environment that the child is in to observe and uncover environmental triggers to disruptive behaviour. This would be executed with the use of an electronic monitoring system that would record the environment autonomously.

Past Projects

The current study built upon previous projects that were completed as earlier trials of a similar device for the same larger study (Gardener, 2013; Cota, 2013). In the past, researchers used a device that was worn by a teacher in a classroom that recorded the duration and frequency of behaviour experienced by a deaf child with an ASD. The teacher was required to wear the device and initiate a timer when the behaviour was observed. Results indicated high risk time periods when behaviour was most likely to occur and a diversion was later provided to the child during those high risk times to reduce the possibility of the child experiencing disruptive behaviour (Gardener, 2013). There were many issues with the device malfunctioning and a loss of data with this study. It was also onerous on the

teacher to initiate the timer and record when the child engaged in behaviour while also teaching a class of students. It was learned that a more sophisticated device was needed in order to identify the environmental stimuli across multiple sensory domains that triggers behaviour in deaf children with an ASD.

In an attempt to use a more advanced device to capture the environmental stimuli across multiple sensory domains, another researcher completed a project that required a teacher to wear a device that recorded data on the behaviour of the deaf child with an ASD. Audio, visual, temperature, humidity and GPS data as well as frequency and duration of the behaviour was collected (Cota, 2013). It was intended that the device would capture as many environmental factors as possible that could be understood to be triggers. A small armband camera was worn by the deaf child with an ASD to record snapshots of the environment around the student for evidence of antecedent stimuli to the disruptive behaviour. Results indicated that the student did not like wearing the device and it proved difficult to obtain accurate data from both the student and the teacher as the device was not consistently initiated when behaviour was experienced and the initiation of the timer was once again onerous on the teacher (Cota, 2013). A more sophisticated monitoring system that does not require an individual to initiate recording at each occurrence of behaviour and does not require the teacher or child to wear the device is needed in order to collect accurate data of triggers to disruptive behaviours.

The Current Study

The current study tested the effectiveness of an electronic monitoring system to identify environmental triggers to disruptive behaviour for a deaf child with an ASD. A more sophisticated system was used in the current study that built upon earlier models. The goal was to identify stimuli

within the child's home environment that could be potential triggers to their disruptive behaviour. The monitoring system collected audio, visual, temperature and humidity data of the environment around the child. Examples of triggers could include a ceiling fan blowing air on the child and the child being sensitive to the air on their body, a high pitch sound bothering the child or perhaps a specific object needing to be near them.

The hypotheses of the current study were predominately exploratory to examine the efficacy of the system to accurately identify triggers in the environment of a deaf child with an ASD. It was hypothesized that the electronic monitoring system would capture more of the child's environment compared to earlier projects and would successfully identify potential environmental triggers. This study was a logical next step from earlier projects and for the progression of the larger research study. This study also contributes to the limited research that is currently available concerning disruptive behaviours in deaf children with an ASD.

Method

Participants

The participant in the current study was a deaf child (male) 12 years of age with an Autism Spectrum Disorder diagnosis who experienced disruptive behaviour. The participant was diagnosed with an ASD at 18 months of age and had a diagnosis of Global Developmental Delay. At the time of the study the participant functioned at the chronological age of three years old. The participant had a Bone Anchored Hearing Aid (BAHA) and communicated via American Sign Language, communicating in one to two sign phrases. The participant was recruited through research postings from Autism Ontario and was not

compensated for their participation. Ethics approval was obtained from The Research Ethic Review Committee at King's University College at Western University.

Materials

An electronic monitoring system was used to record environmental information of the participant's home environment. The electronic monitoring system was developed by the Deaf Autism Research lab with Dr. Ken McIsaac and Dr. Cathy Chovaz at Western University and was used to identify environmental triggers to the participant's disruptive behaviour. The monitoring system consisted of three small cameras that recorded video footage and a tablet and a sensor tag that recorded audio, temperature and humidity information of the participant's home environment. The collected data was saved to the recording system's DVR and the tablet and was downloaded off of the devices to conduct analyzes.

Procedure

An informed consent form was provided to the participant's mother regarding the study requirements. Due to the participant functioning below his chronological age and because he could not comprehend the details of the study, the informed consent was obtained from his mother. If the guardian or child wished to end their participation, they were free to do so at any time.

The monitoring system was set-up in the home of the participant. The living room was chosen as that was where the participant spent most of his time outside of his bedroom. To respect the participant's privacy, no cameras were set-up in his bedroom. Three cameras were used and taped to wooden drink coasters and placed in inconspicuous locations around the room. The first camera was positioned to face the couch and seating area where the participant liked to sit. The second camera was placed to capture footage of the TV, seating area and some of the kitchen. The last camera was positioned to capture the

hallway leading away from the living room and a larger view of the kitchen. See Figure 1 for a map of the camera set-up.

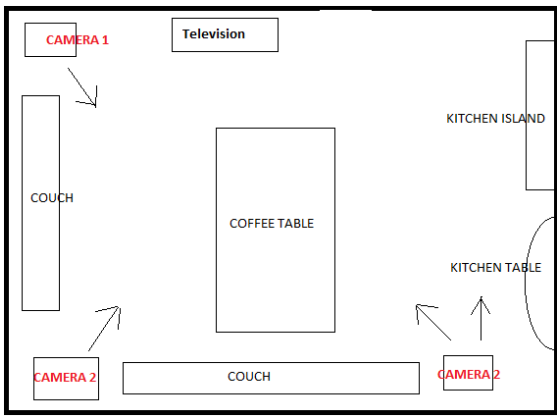

Figure 1. Map of the participant's living room and the position of each camera.

The participant was observed for a total of 12 hours across three weekdays, from 5:30am to 7:00am and 4:30pm to 7:30pm to accommodate the family's schedule. The recorded data was then downloaded from the DVR for analysis. Analyses were performed to identify potential environmental triggers to the participant's disruptive behaviour. Debriefing was provided to the participant's guardian following the completion of the study.

Design

The current study was designed as an exploratory descriptive clinical trial of an advanced electronic monitoring system.

Results

The current study examined the effectiveness of an electronic monitoring system to accurately identify environmental triggers to the disruptive behaviour of a deaf child with an ASD. The system was set-up

in the participant's home and recorded audio, visual, temperature and humidity information of the environment for 12 hours. The goal of this study was for the system to identify stimuli in the child's home that preceded his disruptive behaviour and could be understood as potential environmental triggers to the behaviour. Some of this data set was artificially created to allow researchers to better understand how we would analyze data in the larger study and also for the teaching purposes of this thesis.

Dr. Ken McIsaac at Western Engineering assisted the student researcher in understanding, interpreting and analyzing the data output to identify environmental triggers. Examination of the environmental information revealed minimal changes in the temperature and humidity of the home throughout the study period. This suggested that these environmental stimuli were likely not triggers to the participant's behaviour and were excluded from further analyses of potential environmental triggers. A visual scan of the room provided information of additional potential triggers aside from temperature and humidity. Researchers reviewed a small subset of the environmental data, observing the occurrences of disruptive behaviour in the video footage and noting the time stamp of the occurrences. We then hypothesized triggers based on the scan of the room and the stimuli that were present when the disruptive behaviour occurred. We hypothesized that noises from the kitchen such as, the microwave beeping, could be triggering the participant's behaviour. The hypothesized trigger was then isolated in the remainder of the environmental data. Cross correlations and automatic processing were conducted to investigate additional times the trigger occurred in the data set. A 10 second audio sample of the microwave beeping was isolated and processed through the data set. The video footage was reviewed again to examine the times when the hypothesized trigger was identified and to verify whether disruptive behaviour occurred. Analyses were performed to examine the similarity of the identified audio triggers to the original hypothesized audio trigger to investigate if the identified sounds were in fact the hypothesized audio trigger. The hypothesized audio trigger was successfully identified 30 times

within a three hour subset of the data. See Table 1 for an abbreviated example of the frequency and percentage of similarity that the identified triggers were found to have to the hypothesized trigger. Within the entire data set the audio trigger was identified 151 times with similarity to the original hypothesized trigger ranging from seven percent to 100 percent. The trigger was successful identified with above 90 percent similarity a total of 125 times. See Appendix A for the full output of the trigger analyses. See Figure 2 for a graph representation of the audio trigger across one minute.

The cross correlations and automatic processing procedures used to analyze the data set were effective in reducing the total length of time required for a researcher to examine the video footage and review the data. The system was able to autonomously identify the trigger without the need of human eyes to detect each occurrence.

Table 1.
Frequency and Timing of the Audio
Trigger for a 3 Hour Period March 10th

Recorded Time	Similarity to Hypothesized Trigger (%)
16:51:20	97.86
16:51:20	97.86
17:07:30	95.84
17:12:30	97.86
17:16:00	94.91
17:17:30	97.92
17:27:10	99.95
17:33:00	93.91
17:44:50	84.58
17:51:00	85.47
17:52:30	60.27
17:56:10	97.74
18:07:10	98.13
18:14:40	97.1
18:19:10	95.31

18:20:20	96.45
18:24:20	95.47
18:25:50	98.95
18:26:10	99.72

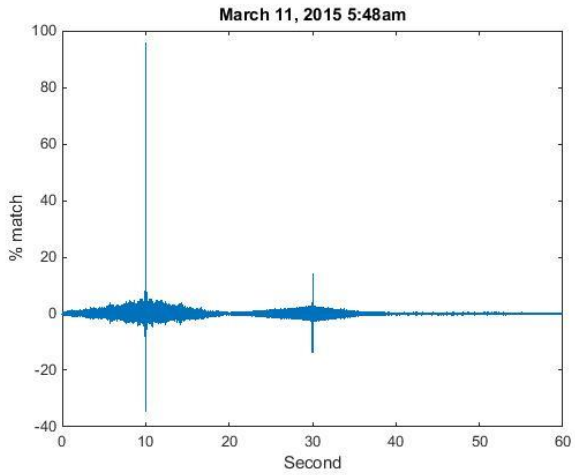

Figure 2. A close up of the audio trigger when identified across one minute (5:10pm to 5:11pm).

Discussion

Current research is limited in the area of Autism and deafness and very little is known about the two together as comorbid diagnoses. Even less is understood about the disruptive behaviours that are commonly experienced by individuals who are deaf and have an ASD and the role that the individual's environment may have in triggering such behaviour. We were interested in testing the efficacy of an improved electronic monitoring system to accurately identify environmental triggers to disruptive behaviours in the home of a deaf child with an ASD. It was hypothesized that the improved system would accurately identify environmental triggers to the child's disruptive behaviour and provide a more complete assessment of potential triggers than earlier models of the system. Support was found for the proposed hypotheses as the electronic monitoring system was capable of accurately identifying an

environmental trigger to the participant's behaviour and was successful in eliminating possible triggers as well. An audio trigger was identified from the environmental information of the participant's home which preceded his disruptive behaviour. The same audio trigger was identified multiple times across the 12 hour observation period. The system did not detect meaningful changes in the temperature or humidity of the participant's home and these stimuli were excluded as possible triggers.

The electronic monitoring system used in the current study is an improvement from the earlier models used in the projects of Gardner (2013) and Cota (2013). The improved model removed the burden placed on the caregiver and child in earlier projects to wear and initiate the device. The system used in the current study was set up around the room and programmed to continuously and autonomously record the participant's environment. A greater amount of video footage and audio data was available to researchers with the improved system due to the fact that quick snapshots were not taken but the recording was continuous. The current model detected a greater amount of environmental stimuli and was not onerous on the caregiver or child allowing for a more accurate assessment of the environmental stimuli that could be triggering the behaviour to be completed.

The automatic processing procedure used in the analysis of the environmental data was effective in reducing the length of time required for a researcher to review the footage for disruptive behaviour and possible triggers. This process provides support for the system being an efficient method of behavioural assessment. Additionally, the system employs many elements of the methods currently used for behaviour assessment with hearing children with ASDs such as FBA, ABA and Behaviour Tracking, However, the electronic monitoring system is unlike the traditional methods of behaviour assessment as it does not require or rely on an individual to personally observe the child and document the behaviour via paper and pencil. The system continuously records the data and provides a playback of the record to

be reviewed at any time. This reduces the human error and biases that are inherent in the traditional methods of behaviour assessment. The system eliminates the need to rely on the memory of an observer and for observer biases to influence what is documented. The Deaf Autism Research Lab has developed an improved method for behaviour assessment that provides a more time efficient, reliable and accurate behaviour assessment that can be reviewed at any time. The analysis procedures effectively and successfully identified environmental triggers and reduced the need for human eyes to detect each occurrence of behaviour and its trigger.

Practical Implications

The practical implications of an electronic monitoring system accurately identifying environmental triggers to disruptive behaviour of a deaf child with an ASD is the possibility that exists to reduce or potentially eliminate a child's disruptive behaviour. Caregivers can identify the elements in a child's environment that are triggering their behaviour and can remove the identified triggers to reduce the likelihood of the behaviour occurring again. Modifications can be made to the environment with greater clarity of what specifically is triggering the child's behaviour. Guardino and Antia (2012) conducted a study that examined environmental modification and the effects that physical changes to a classroom can have on the academic engagement and disruptive behaviour of deaf students. The modifications were tailored to the child's needs and consisted of changing seating arrangements, altering acoustic quality in the classroom and changes to classroom organization. It was found that physical changes to the classroom environment influenced the way children behaved and was effective in increasing the child's engagement and decreasing their behaviour.

The same method of altering the environment that an individual is in can be applied for deaf children with an ASD after the electronic monitoring system is used to identify triggers in the environment. This is similar to the practice of Positive Behaviour Support where the ideal environment for learning and engaging is created for a child (Neitzel, 2010). Modifying the child's environment based on the triggers identified from the system would greatly benefit a child and allow them to more actively engage and participate in the world around them and not be distracted by their own behaviour. Caregivers will be better able to understand their child and assist the child in engaging more in their environment. Children can become more attentive and open to learning when their behaviour is reduced or eliminated therefore impacting their overall development (Buschbacher & Fox, 2003). Increased engagement would be expected to have far reaching benefits for a child and could be expected that would be able to learn more effectively and experience impacts in development both cognitively and socially.

Limitations

Limitations of the current study include concerns associated with the generalizability of the results to the larger population of deaf children with an ASD. Due to the fact that this was a case study the results cannot be expected to generalize to all deaf children with an ASD as each individual child experiences an ASD differently (Szymanski & Brice, 2008). Additionally, it is important to note that we may have missed occurrences of disruptive behaviour that occurred outside of the locations and times that the camera was set-up to observe the participant. The participant may have engaged in disruptive behaviour in his bedroom, school or at times which were different from the scheduled recording periods such as in the afternoon or on the weekends. Furthermore, the system is not capable of capturing all possible environmental stimuli that could be a trigger to the participant's behaviour such as their sense of smell and taste.

Lastly, the automatic processing procedure that was used to isolate the hypothesized trigger across the remainder of the data could have resulted in missed or overlooked environmental triggers. In using the automatic processing procedure we were restricted to only viewing the footage where the hypothesized trigger was present. There is an unknown amount of times that the participant's behaviour could have occurred without our hypothesized trigger. While the system assisted in identifying the hypothesized trigger multiple times it omitted the additional occurrences of behaviour with potentially different triggers from our view. It is possible that multiple environmental triggers exist and may even be combined together to trigger disruptive behaviours. More time is required to run multiple variations of the automatic processing in order to obtain a complete picture of the participant's behaviour and potential triggers. Although these limitations exist, this system is a step in the right direction as currently no other research exists that examines the use of a monitoring system to identify environmental triggers to disruptive behaviour in deaf children with an ASD.

Future Research

Future research in this area should consider various changes to the research procedure. It would be beneficial to observe a participant for a longer period of time, across various points in the day as well as in multiple locations to increase the possibility of detecting all possible behaviour. More time would be necessary to complete the full analysis of the environmental information to obtain an accurate understanding of the behaviour and the triggers. The monitoring system and analysis procedures can greatly impact future research within the field of behaviour assessment in providing more accurate assessments of behaviour that are not fraught with human error associated with the reliance of observer memory. Next steps for this research include continuing with the larger study and completing the ongoing clinical trials to yield more information and understanding on this issue.

This research is unique within the field of Autism as it was focused on the external factors within a child's environment that may have a role in triggering disruptive behaviour rather than the internal motivations a child may have. This study was also focused on the population of deaf children with an ASD whereas the majority of research is focused on hearing individuals. The results of this study have the potential to greatly impact the lives of deaf children with an ASD and their families in understanding and reducing their disruptive behaviour. The ability to identify and eventually remove environmental triggers to disruptive behaviour allows a child to engage more adaptively in their world. This system could also be useful with hearing children with an ASD as they too have disruptive behaviours and experience communication difficulties. In conclusion the current study found support for the use of the electronic monitoring system for the purpose of identifying environmental triggers to disruptive behaviour for deaf children with an ASD. The results of the current study are interesting in light of the paucity of research available within the field of Autism and deafness.

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Appendix A

Environmental Trigger Analyses Output

Frequency of the Identified Audio Trigger for the Entire Data Set

Date	Recording Start Time	Segment	Second	Time Trigger Identified	Raw	Similarity to Hypothesized Trigger (%)
2015-03-09	16:30	22	3	16:33:30	2707.82	93.8602823
2015-03-09	16:30	49	8	16:38:00	2768.65	95.96882105
2015-03-09	16:30	162	26	16:56:50	2865.09	99.31163499
2015-03-09	16:30	213	35	17:05:20	2786.76	96.59671817
2015-03-09	16:30	263	43	17:13:40	2742.32	95.05604387
2015-03-09	16:30	284	47	17:17:10	2829.39	98.07441509
2015-03-09	16:30	292	48	17:18:30	2804.81	97.22227002
2015-03-09	16:30	358	59	17:29:30	2752.51	95.40925236
2015-03-09	16:30	376	62	17:32:30	2647.49	91.76919848
2015-03-09	16:30	388	64	17:34:30	2805.83	97.25761532
2015-03-09	16:30	408	67	17:37:50	2882.32	99.90893866
2015-03-09	16:30	423	70	17:40:20	2826.08	97.95947053
2015-03-09	16:30	427	71	17:41:00	2812.51	97.48926953
2015-03-09	16:30	429	71	17:41:20	2811.19	97.44355843
2015-03-09	16:30	459	76	17:46:20	2602.22	90.20009543
2015-03-09	16:30	465	77	17:47:20	2695.1	93.41927135

2015-03-09	16:30	478	79	17:49:30	2745.79	95.1763035
2015-03-09	16:30	478	79	17:49:30	2745.79	95.1763035
2015-03-09	16:30	562	93	18:03:30	2799.99	97.05511118
2015-03-09	16:30	633	105	18:15:20	2768.27	95.95563234
2015-03-09	16:30	739	123	18:33:00	2823.85	97.88206653
2015-03-09	16:30	743	123	18:33:40	2823.85	97.88206653
2015-03-09	16:30	761	126	18:36:40	2277.03	78.92812012
2015-03-09	16:30	796	132	18:42:30	2475.64	85.81248595
2015-03-09	16:30	816	135	18:45:50	2737.96	94.90499545
2015-03-09	16:30	816	135	18:45:50	2737.96	94.90499545
2015-03-09	16:30	831	138	18:48:20	2828.72	98.05090772
2015-03-09	16:30	874	145	18:55:30	2683.8	93.02757223
2015-03-09	16:30	888	147	18:57:50	2828.74	98.05168385
2015-03-09	16:30	959	159	19:09:40	2568.24	89.02201063
2015-03-10	05:30	1	0	5:30:00	2879.89	99.82478143
2015-03-10	05:30	30	4	5:34:50	2752.6	95.41253752
2015-03-10	05:30	45	7	5:37:20	2814.48	97.55731482
2015-03-10	05:30	122	20	5:50:10	2851.5	98.84078983
2015-03-10	05:30	132	21	5:51:50	2815.08	97.5781768
2015-03-10	05:30	257	42	6:12:40	225.467	7.815293118
2015-03-10	05:30	266	44	6:14:10	2499.47	86.63818508
2015-03-10	05:30	282	46	6:16:50	2805.62	97.25036482

2015-03-10	05:30	300	49	6:19:50	2830.09	98.09857016
2015-03-10	05:30	307	51	6:21:00	2807.96	97.33140404
2015-03-10	05:30	312	51	6:21:50	2703.77	93.71976316
2015-03-10	05:30	313	52	6:22:00	2822.52	97.83611403
2015-03-10	05:30	328	54	6:24:30	2780.8	96.38997541
2015-03-10	05:30	335	55	6:25:40	633.459	21.95740051
2015-03-10	05:30	353	58	6:28:40	2793.75	96.83895851
2015-03-10	05:30	356	59	6:29:10	2799.77	97.04756827
2015-03-10	05:30	373	62	6:32:00	1461.06	50.64420459
2015-03-10	05:30	390	64	6:34:50	2829.43	98.07559029
2015-03-10	05:30	395	65	6:35:40	2686.73	93.12911778
2015-03-10	05:30	428	71	6:41:10	2502.84	86.75529335
2015-03-10	05:30	436	72	6:42:30	2700.74	93.61480451
2015-03-10	05:30	452	75	6:45:10	2562.55	88.82469834
2015-03-10	05:30	455	75	6:45:40	2683.15	93.00513996
2015-03-10	05:30	463	77	6:47:00	1161.62	40.26500712
2015-03-10	05:30	470	78	6:48:10	2776.03	96.22472784
2015-03-10	05:30	476	79	6:49:10	2753.19	95.43288764
2015-03-10	05:30	482	80	6:50:10	2823.61	97.87384894
2015-03-10	05:30	497	82	6:52:40	2732.57	94.71839091
2015-03-10	05:30	529	88	6:58:00	2823.75	97.87861925
2015-03-10	05:30	529	88	6:58:00	2823.75	97.87861925

2015-03-10	16:30	129	21	16:51:20	2823.28	97.86232599
2015-03-10	16:30	129	21	16:51:20	2823.28	97.86232599
2015-03-10	16:30	226	37	17:07:30	2764.82	95.83622857
2015-03-10	16:30	256	42	17:12:30	2823.33	97.86423472
2015-03-10	16:30	277	46	17:16:00	2738.05	94.90806795
2015-03-10	16:30	286	47	17:17:30	2825	97.9222445
2015-03-10	16:30	344	57	17:27:10	2883.43	99.94729025
2015-03-10	16:30	379	63	17:33:00	2709.11	93.90517974
2015-03-10	16:30	450	74	17:44:50	2440.05	84.5786798
2015-03-10	16:30	487	81	17:51:00	2465.9	85.47463587
2015-03-10	16:30	496	82	17:52:30	1738.81	60.27191331
2015-03-10	16:30	518	86	17:56:10	2819.65	97.73673035
2015-03-10	16:30	584	97	18:07:10	2830.87	98.12567503
2015-03-10	16:30	629	104	18:14:40	2801.33	97.10160595
2015-03-10	16:30	656	109	18:19:10	2749.73	95.31316753
2015-03-10	16:30	663	110	18:20:20	2782.56	96.45111672
2015-03-10	16:30	687	114	18:24:20	2754.34	95.47267187
2015-03-10	16:30	696	115	18:25:50	2854.75	98.95318089
2015-03-10	16:30	698	116	18:26:10	2876.34	99.70163363
2015-03-10	16:30	700	116	18:26:30	2686.22	93.11171029
2015-03-10	16:30	715	119	18:29:00	2732.28	94.70828258
2015-03-10	16:30	715	119	18:29:00	2732.28	94.70828258

2015-03-10	16:30	734	122	18:32:10	2312.22	80.14773644
2015-03-10	16:30	767	127	18:37:40	2824.64	97.90959712
2015-03-10	16:30	832	138	18:48:30	2824.12	97.89164365
2015-03-10	16:30	900	149	18:59:50	2806.07	97.26591672
2015-03-10	16:30	910	151	19:01:30	2830.02	98.09611629
2015-03-10	16:30	940	156	19:06:30	2814.27	97.55019
2015-03-10	16:30	1016	169	19:19:10	2742.2	95.05185377
2015-03-10	16:30	1021	170	19:20:00	2744.55	95.13365376
2015-03-11	05:30	28	4	5:34:30	2816.8	97.63771887
2015-03-11	05:30	34	5	5:35:30	2522.75	87.44545181
2015-03-11	05:30	44	7	5:37:10	606.945	21.03832858
2015-03-11	05:30	57	9	5:39:20	2858.95	99.09903826
2015-03-11	05:30	67	11	5:41:00	2771.57	96.06996594
2015-03-11	05:30	76	12	5:42:30	2767.28	95.92125146
2015-03-11	05:30	89	14	5:44:40	2789.09	96.67733204
2015-03-11	05:30	95	15	5:45:40	2831.92	98.16206933
2015-03-11	05:30	110	18	5:48:10	2763.97	95.80653138
2015-03-11	05:30	112	18	5:48:30	408.647	14.16478621
2015-03-11	05:30	145	24	5:54:00	2807.62	97.31965928
2015-03-11	05:30	223	37	6:07:00	2821.42	97.79802604
2015-03-11	05:30	238	39	6:09:30	2807.59	97.31844408
2015-03-11	05:30	262	43	6:13:30	2794.4	96.86125757

2015-03-11	05:30	275	45	6:15:40	2830.54	98.11398192
2015-03-11	05:30	302	50	6:20:10	1561.92	54.14020509
2015-03-11	05:30	307	51	6:21:00	2668.65	92.50251735
2015-03-11	05:30	332	55	6:25:10	2749.51	95.3054878
2015-03-11	05:30	342	56	6:26:50	2788.22	96.64713068
2015-03-11	05:30	390	64	6:34:50	2826.29	97.9668098
2015-03-11	05:30	395	65	6:35:40	2494.83	86.47741724
2015-03-11	05:30	420	69	6:39:50	2881.88	99.89364794
2015-03-11	05:30	456	75	6:45:50	2823.54	97.87158103
2015-03-11	05:30	459	76	6:46:20	2732.25	94.70712984
2015-03-11	05:30	460	76	6:46:30	2884.95	100
2015-03-11	05:30	467	77	6:47:40	2760.01	95.6695182
2015-03-11	05:30	498	82	6:52:50	2823.66	97.87568332
2015-03-11	05:30	499	83	6:53:00	2832	98.16488571
2015-03-11	05:30	507	84	6:54:20	2749.96	95.3209414
2015-03-11	05:30	526	87	6:57:30	2793.78	96.84000404
2015-03-11	16:30	36	5	16:35:50	2454.47	85.07855434
2015-03-11	16:30	131	21	16:51:40	2833.44	98.21457273
2015-03-11	16:30	169	28	16:58:00	2807.76	97.32465989
2015-03-11	16:30	185	30	17:00:40	2793.37	96.8255863
2015-03-11	16:30	206	34	17:04:10	2723.66	94.40920403
2015-03-11	16:30	207	34	17:04:20	2807.61	97.31925799

2015-03-11	16:30	245	40	17:10:40	320.013	11.09251535
2015-03-11	16:30	272	45	17:15:10	2826.82	97.98508993
2015-03-11	16:30	287	47	17:17:40	2778.59	96.31343305
2015-03-11	16:30	314	52	17:22:10	2629.26	91.137089
2015-03-11	16:30	372	61	17:31:50	2671.2	92.5908609
2015-03-11	16:30	399	66	17:36:20	2826.21	97.96405508
2015-03-11	16:30	407	67	17:37:40	2318.49	80.36517001
2015-03-11	16:30	416	69	17:39:10	2805.1	97.23230865
2015-03-11	16:30	463	77	17:47:00	2831.66	98.15290829
2015-03-11	16:30	498	82	17:52:50	2732.36	94.71108592
2015-03-11	16:30	521	86	17:56:40	2731.61	94.68480256
2015-03-11	16:30	607	101	18:11:00	2773.01	96.12003716
2015-03-11	16:30	630	104	18:14:50	674.163	23.36830471
2015-03-11	16:30	631	105	18:15:00	1827.73	63.35401653
2015-03-11	16:30	637	106	18:16:00	2782.64	96.45366581
2015-03-11	16:30	667	111	18:21:00	2824.08	97.89009749
2015-03-11	16:30	697	116	18:26:00	2757.78	95.59209166
2015-03-11	16:30	723	120	18:30:20	2820.99	97.78325967
2015-03-11	16:30	789	131	18:41:20	2795.4	96.89595201
2015-03-11	16:30	891	148	18:58:20	2736.96	94.87026014
2015-03-11	16:30	924	153	19:03:50	2874.64	99.64289317
2015-03-11	16:30	953	158	19:08:40	2824.04	97.88876138

2015-03-11	16:30	1061	176	19:26:40	2785.6	96.55626376
2015-03-11	16:30	1062	176	19:26:50	2438.67	84.53097049