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Expecting the Worst: Observations of Reactivity to Sound in Young Children with Williams Syndrome

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Abstract

The study examined behavioral reactions to sound, including startle eye blinks, in young children with Williams syndrome (WS) using video-based observational techniques. Participants were 21 children with WS and 20 children with other developmental disabilities of mixed etiology between the ages of 2½ and 6. Groups were matched for chronological age and developmental level. All children participated in a semi-structured play interaction including exposure to mild intensity sounds as emitted from conventional toys. Overall, 90% of the children in the WS group were observed to exhibit overt behavioral reactivity to mild intensity sounds, compared to only 20% in the mixed etiology group. Examination of the temporal sequence indicated that children with WS generally exhibited these behaviors before exposure to sound stimuli, suggesting a relation to anticipatory anxiety. Children with WS also exhibited significantly greater acoustic startle eye blinks, often viewed as an indication of heightened emotional state. Taken together, the current findings confirm the presence of heightened reactivity to sound in WS, behaviors previously investigated using parent report alone. The observed behaviors and their potential relation to anxiety are also discussed.

In recent years there have been a number of examinations of the behavioral characteristics of people with Williams syndrome, as a thorough and precise understanding is necessary for the study of gene-brain-behavior relationships. Williams syndrome (WS) is caused by a sporadic microdeletion of at least 19 genes on chromosome 7q11.23 (Hillier et al., 2003). In addition to a distinct cognitive profile, individuals with WS exhibit unique behavioral and emotional difficulties (Dilts, Morris, & Leonard, 1990; Dykens, 2003a; Klein-Tasman & Mervis 2003; Levitin, Cole, Lincoln, & Bellugi, 2005; Leyfer, Woodruff-Borden, Klein-Tasman, Fricke, & Mervis, 2006). One recurrent observation in the literature is that people with WS report an intense sensitivity to and/or dislike for noises not generally perceived as loud or aversive by others (Don, Schellenber, & Rourke, 1999; Gosch & Pankau, 1994; Klein, Armstrong, Greer, & Brown, 1990; Levitin et al., 2005; Udwin, 1990). For example, Nigam and Samuel (1994) described a young child with WS who became deeply distressed at the sound of doorbells and telephones. This aversion to commonly encountered sounds is accompanied by marked behavioral responses and is reported to occur in as many as 95% of individuals with WS (Klein et al., 1990; Gothelf, Farber, Raveh, Apter, & Attias, 2006).

To date, the majority of research on behavioral reactivity to commonly encountered sounds in WS has focused on documenting its existence using information gathered almost exclusively from parent-report measures and researchers' informal observations (Gothelf et al., 2006; Klein

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et al., 1990; Levitin et al., 2005; Van Borsel, Curfs, & Fryns, 1997). Reports often highlight the occurrence of complex defensive behaviors such as covering ears with hands, crying, cringing, hiding, and/or making verbalizations to stop the sound in question. Observed less frequently are severe reactions to sound such as violent inconsolable screaming, repetitive rocking, and self-injurious behavior. In addition to overt defensive behaviors, Gothelf and colleagues (2006) also suggested that more basic reflexive reactions to sound such as exaggerated startle eye blinks fall within this constellation. Based on reports of parents with children with WS, Down syndrome, autism spectrum disorders, and typically developing controls, Levitin et al. (2005) found that these reactions are by far most prevalent in individuals with WS, have an early time of onset (approximately 1 year of age), and generally decrease in severity as individuals reach adulthood.

Observation of these behaviors has led to numerous investigations attempting to highlight potential neurological and auditory abnormalities that may contribute to sound reactivity in this population (Gothelf et al., 2006; Hickok et al., 1995; Holinger et al., 2005; Johnson Comeau, & Clarke, 2001; Marler, Elfenbein, Ryals, Urban & Netzloff, 2005). In addition, recent literature has suggested an association to emotional difficulties also commonly reported in WS (Dykens, 2003b; Blomberg, Rosander, & Andersson, 2006). Individuals with WS are repeatedly characterized in the literature as having heightened levels of anxiety, fear, and phobias when compared to others with developmental delay (Davies, Udwin, & Howlin, 1998; Dykens, 2003a; Gosch & Pankau, 1994, 1997; Leyfer et al., 2006; Udwin, 1990). As a heightened reactivity to sound is documented for numerous clinical populations experiencing emotional difficulties (Andersson, Lindwall, Hursti, & Carlbring, 2002; Stanfield, 1992), a similar finding for individuals with WS might be expected. Additionally, Blomberg and colleagues found strong relationships between reports of sound reactivity and scores on the Fear Survey Schedule for Children (FSSC-R; Ollendick, King, Frary, 1989), a commonly-used parent rating scale of childhood fears. Of interest is the finding that sound reactivity correlates robustly with ratings on items on the FSSC-R that have little to do with noise-related fears, for example a fear of animals. This suggests that sound reactivity in WS may indeed be more generally related to a proclivity to act with fear or anxiety in a variety of situations.

As mentioned, observations of exaggerated startle eye blinks have been reported as early as the first year of life in WS, based on maternal interview (Gothelf et al., 2006). The inclusion of exaggerated startle as a behavior characteristic of sound reactivity in this population is potentially of great interest given its demonstrated relation to anxiety in the literature (Grillon & Bass, 2003; Lang, Bradley & Cuthbert, 1990; Vrana, Spence & Lang, 1988). The acoustic startle eye blink reflex has been widely used as an ongoing probe of emotional state, with reliable increases in eye blink magnitude corresponding to heightened levels of anxiety and fear. Findings of exaggerated startle eye blinks are also documented among numerous clinical populations including PTSD (Shalev, Peri, Brandes, Freedman, Orr, & Pitman, 2000), specific phobia, panic disorder (Grillon, Ameli, Goddard, Woods, & Davis, 1994), and OCD (Kumari, Kaviani, Raven, Gray, & Checkley, 2001). Hence, an empirical observation of startle reactivity may potentially contribute to our understanding of behaviors characteristic of sound reactivity; in addition, it shows great promise as a tool to explore potential relations to emotional difficulties in the WS population.

Thus, in the current study we sought to examine reactivity to sound, including exaggerated startle eye blinks, in a semi-naturalistic context using video-based event recording techniques. Data yielded from observational methods can provide a broader understanding of patterns of behavior and their time course in relation to environmental stimuli than information gathered from informant-based reports alone (McConaughy & Ritter, 1995). Additionally, since information gathered across broad age groups may mask possible developmental changes regarding these behaviors, we restricted our sample to children between the ages of 2½ to 6

years of age. We also made comparisons to a contrast group with developmental delays of mixed etiology in an attempt to discern behavioral characteristics that are specific to WS rather than characteristic of individuals with developmental delay more generally.

It is important to note that reactivity to sound in WS has previously been used by researchers to infer auditory abnormality, commonly referred to in the literature as “hyperacusis.” This condition, defined medically as a heightened sensitivity to sound (Dirckx, 2001; Venes, Thomas, & Taber, 2001), is typically assessed by audiologists using threshold audiograms. However, in the developmental literature this term has been routinely assigned without medical confirmation of true auditory pathology, instead relying mainly on parent reports of behavioral reactivity to everyday sounds (Blomberg et al., 2006; Gothelf et al., 2006; Klein et al. 1990; Van Borsel et al., 1997). As Levitin et al. (2005) suggest, the term has been used somewhat indiscriminately by researchers to describe what may be several distinct auditory abnormalities that exist among the WS population. Furthermore, Blomberg and colleagues (2005) found that heightened fear may also mediate these behaviors. Thus, in the current paper we eschew the term “hyperacusis” and instead refer to “sound reactivity” to describe the constellation of behaviors typically associated with exposure to sound. We thereby make no assumptions as to the association between the observed behaviors and underlying audiological pathology.

Method

Participants

The initial sample consisted of 29 children with a genetically-confirmed diagnosis of WS and 23 children with other developmental disabilities of mixed etiology (ME). The ME group included children with autism spectrum disorders (7), Down syndrome (5), Kabuki syndrome (2), IDIC 15 (2), and developmental delay of unknown etiology (7). All children were between the ages of 2½ and 6. Participants were recruited as part of a larger study looking at the communication and social interaction abilities of young children with developmental delays. All participants were seen at either the University of Louisville, the University of Wisconsin-Milwaukee, or at the National/International Williams Syndrome Conventions in 2002 and 2004.

Given the semi-structured play environment, 7 children with WS and 3 ME controls were excluded from our analyses due to a large proportion of off-camera behavior. Groups were then stringently matched for developmental level and chronological age. Age equivalent (AE) scores were used to match the participant groups for developmental level, as many children (9 WS; 9 ME) fell below the basal cut-off on their overall developmental composites. To adequately match each group, one child with WS with average intellectual abilities was excluded resulting in a final sample of 21 participants with WS and 20 ME controls. Group means were compared using independent samples *t*-tests with the criterion that all *p*-values exceed 0.5 (see Table 1), indicating a well-matched sample (Mervis & Klein-Tasman, 2004).

Materials

The Mullen Scales of Early Learning (Mullen, 1995) were administered to each child. This is an individually administered measure of developmental functioning for infants and preschool children. The measure yields an Early Learning Composite (ELC) standard score, providing a general estimate of a child’s developmental level, as well as estimates of nonverbal reasoning, fine motor abilities, expressive language, and receptive language abilities. Raw scores, *T*-scores, and age equivalents are available for each subtest.

Children were also administered the Autism Diagnostic Observation Schedule-Module 1 (ADOS; Lord, Rutter, DiLavore, & Risi, 2002), a semi-structured, standardized assessment of

social interaction, communication, and play behavior for children with limited language skills. The ADOS is commonly used in diagnostic assessments for autism spectrum disorders. In this study, it was used to provide a standardized context in which to observe heightened reactivity to sound and exaggerated startle. The ADOS-Module 1 consists of 10 activities, many of which involve toys that emit sounds to be presented over the course of approximately 30 to 45 minutes. To obtain optimal cooperation from the child, the order of presentation for these activities is flexible. However, an administrative sequence based on convenience and effectiveness is offered and most commonly used. This sequence is as follows: free play, response to name, response to joint attention, bubble play, anticipation of routine with objects, responsive social smile, anticipation of social routine, functional and symbolic imitation, birthday party, and snack. See Table 2 for a detailed procedural description of activities included in the current study. The ADOS session was conducted in the presence of one parent, an administrator (second author), and in some cases a camera technician.

Coding Procedures

Toys emitting various sounds during the ADOS were chosen as target stimuli as they appeared to elicit heightened reactivity to sound in many of the participants with WS. These included a pop-up toy, motorized bunny, battery-operated bubble gun, and a deflating balloon. A digital sound level meter was used to determine the peak amplitude of each toy at the approximate distance that they were presented to the children. The mechanized bunny, bubble gun, and balloon releasing ranged in their peak volumes from 70 to 75 dB[A] SPL. In addition to coding for heightened reactivity to sound, exposure to the pop-up toy was also observed to code startle as it remains stationary on a table allowing for a more detailed observation of eye blink magnitude. The pop-up toy elicits an abrupt burst of noise with a rapid rise-time. The pop-up toy was significantly higher in peak volume, recorded at 85 dB[A] SPL.

Coding for heightened reactivity to sound—The coding scheme included overt behaviors commonly reported to be characteristic of sound reactivity in the WS literature (Gothelf et al., 2006; Klein et al., 1990; Levitin et al., 2005). During exposure to each target stimulus, the occurrence of any of the following behaviors was recorded: covers ears with hands/arms, cries, verbalizes to stop the sound, walks or backs away from the sound (not to a caregiver), goes to caregiver for protection/comfort, cringes in a defensive manner, or “other” indication of aversion to sound (i.e. tantrums, rocking back and forth, etc.).

Each behavior was further categorized in terms of its temporal relation to the sound stimulus in question, classified as either a direct reaction to or an anticipation of the target sound. A “direct reaction” was defined as any target behavior occurring during the presence of, or immediately following the sound stimulus (e.g., as the balloon was releasing air). An “anticipation” was defined as any target behavior that occurred when there was a likelihood that the sound stimulus would occur (e.g., examiner bringing the balloon to her mouth or holding up the bubble gun). Any behavior that was elicited more than five seconds after the offset of the sound stimulus with no indication of additional exposure from the ADOS administrator was excluded from the analyses.

For analytic purposes, children were classified as exhibiting heightened reactivity to sound during an activity if one or more target behaviors (mentioned above) was observed. Classification was based on the child’s response to only the first or second exposure to a sound stimulus during a particular activity in order to limit the possible effects of unequal numbers of exposures across the sample. Undergraduate research assistants who were blind to the diagnoses of the participants were trained to code for behavior according to detailed operational definitions. Once both observers met the criterion of 85% agreement using practice tapes, they viewed the videotaped ADOS-Module 1 administrations at normal speed. Observers were able

to stop the tape and review the behaviors again if necessary. Each observer coded approximately 50% of the participant tapes. In order to determine inter-rater reliability, the first author coded 25% of the participant tapes which were chosen at random. Inter-rater reliability (Cohen's κ) for the author and two observers based on a total of 138 classifications was .86.

Coding for startle responses—As observation of startle eye blinks require the participant to remain stationary, a separate coding scheme during exposure to the pop-up-toy was utilized. The coding scheme was adapted from a rating system specifically designed and validated for the purposes of recording startle eye blinks via videotape observation (Essex, Goldsmith, Smider, Dolski, Sutton & Davidson, 2003). Eye blink magnitude was scored according to a five-point scale ranging from low to high and based on the following criteria: A score of 1 was given when participants exhibited no sign of muscle movement around the eye in response to the startle stimulus. A score of 2 was given when the rater observed a small flutter of the eyelids in response to the startle stimulus but did not fully close them. This was detected by slowing the tape down frame by frame and ruling out any signs of a fully closed eyelid. A score of 3 was given when participants were observed to fully close their eyelids in response to the startle stimulus; however, no noticeable additional muscle tightening around the eye or face could be observed. A score of 4 was given when participants were observed to fully close their eyelids, as well as exhibit additional facial muscle movement or “scrunching” around the eye. Finally, a score of 5 was given when participants in addition to the preceding criteria also exhibited a full body startle, as defined by any bodily muscle movement that accompanies a startle eye blink response with facial tightening. Eye blinks that occurred directly at or before the onset of an auditory stimulus were not included in the analysis. See Figure 1 for exemplars of each score.

Due to the semi-naturalistic nature of the ADOS-Module 1, there were times when the camera did not capture the participant's frontal view and it was not possible to code for eye blink magnitude. Therefore, only the first four ‘codable’ responses during exposure to the pop-up toy were examined. Two research assistants, blind to the diagnosis of each participant, were trained using practice videotapes. After code correspondence between them rose above 85%, each rater proceeded to code approximately 50% of the participant tapes. ProCoder DV (Tapp & Walden, 1993) was used to view the video-taped administrations and code the magnitude of a participant's eye blink response to each sound stimulus. All tapes were viewed first at normal speed and then reviewed at slower speeds until the raters felt confident in their assessment. In order to determine inter-rater reliability, the first author coded 25% of the participant tapes which were chosen at random. Inter-rater reliability (Cohen's κ) for the author and two observers based on a total of 44 startle eye blink magnitude ratings was .80. At no time did ratings differ by more than one scale point.

Results

Reactivity to Sound

To examine differences in reactivity to sound, percentages of the participant groups exhibiting one or more target behaviors during each activity were compared using z-tests for proportions. The pop-up toy task did not result in any target behavioral reactions in either group, therefore, was not included in further analysis of overt sound reactivity. Exposure to the mechanized bunny resulted in no significant group differences, $z = .27, p = .783$; 28.6% of children in the WS group exhibited reactivity to sound, compared to 20% in the ME group. In contrast, there was a significant group difference during exposure to the bubble gun, $z = 2.54, p = .01$; 52.4% of children in the WS group exhibited sound reactivity compared to only 10% in the ME group. Finally, group differences were most striking during exposure to the balloon release, $z = 3.32$,

$p < .001$; 81% of children in the WS group exhibited sound reactivity compared to only 20% in the ME group (See Figure 2). Interestingly, the mechanized bunny, bubble gun, and balloon releasing possess lower decibel levels than the pop-up toy, yet elicited significantly more behavioral reactivity.

In order to provide a sense of the extent to which sound reactivity was observed throughout the play interaction, children were further recorded as exhibiting target behaviors during either 0, 1, 2, or 3 events. Only 2 children with WS in our sample exhibited no target behaviors during the observed play interaction, whereas 19 out of 21 children (90.4%) exhibited target behaviors during at least one activity. This finding is similar to prior prevalence estimates using similar classification criteria (Gothelf et al., 2006; Klein et al., 1990). Ten children (47.6%) showed target behaviors during at least two activities during the play interaction, while 5 children (23.8%) exhibited target behaviors during all three activities observed. This is in contrast to 15 children in the ME group (75%), who did not exhibit any target behaviors during the observed play interaction. A total of 5 children (25%) exhibited target behaviors during at least one activity, while 3 children (15%) showed target behaviors during at least two activities. Finally, only 2 children in the ME group (10%) exhibited target behaviors during all three activities observed.

As mentioned, we also sought to record the temporal sequence of each individual behavior in relation to the sound stimuli. A total of 159 overt target behaviors for the WS group and 44 total target behaviors for ME controls across all activities were analyzed. Overall, children with WS tended to exhibit target behaviors *in anticipation of* exposure to sound stimuli, with 65.4% of behaviors occurring before the onset of a sound stimulus compared to only 34.6% of behaviors occurring during or immediately following a sound stimulus. This is a significant contrast to distributions from the ME controls for whom only 34.1% of behaviors occurred before stimulus onset, and 65.9% were elicited as immediate responses, $\chi^2(1, n = 203) = 13.94$, $p \leq .001$.

In terms of the types of behaviors documented, going to caregiver for protection or comfort was observed most commonly among children in the WS group, with 13 of 21 children engaging in this behavior at least once during the play interaction. Approximately half of the group (10 children) were observed to cover their ears, followed by cringing (7 children), verbalizing to stop the sound (4 children), backing away from the sound (3 children), and crying (2 children). Refer to Table 3 and Table 4 for group comparisons.

Startle Responses

To examine startle reactivity, the first four responses to sound stimuli emitted by the pop-up toy (labeled Startle Trials 1 through 4) were examined. Startle magnitude ratings for the same 21 children with WS and 20 ME controls, matched for CA and AE were compared using a 2×4 repeated measures ANOVA for Group and Startle Trial. A main effect for Group was found, $F(1, 39) = 21.62$, $p \leq .001$ (see Figure 3), with participants with WS showing more exaggerated startle responses than participants in the ME group. No within-subjects effects of Startle Trial ($F(3, 117) = .51$, $p = .674$) or interaction between Group and Startle Trial ($F(3, 117) = .39$, $p = .760$) were found. Means and standard deviations for both groups across all four startle trials are presented in Table 5.

Finally, we examined the relationship between startle and sound reactivity for both groups combined. A significant relation between mean startle magnitude and observations of sound reactivity across all activities was found, $r = .451$, $p = .003$. However, this relationship did not reach levels of significance once groups were separated, with a trend found in the WS group (WS, $r = .372$, $p = .097$; ME, $r = -.112$, $p = .637$). The restricted range of scores and limited variability of sound reactivity observed within each group may contribute to this finding. In

other words, the majority of children with WS exhibited high startle magnitudes and sound reactivity during at least one activity, whereas the majority of ME controls exhibited low startle magnitudes and did not exhibit sound reactivity in general.

Discussion

The purpose of the current study was to broaden our understanding of atypical behavioral reactivity to everyday sounds in the WS population using observational methods. We sought to examine both overt behaviors and more subtle acoustic startle responses. Almost all of the children with WS reacted adversely to at least one sound introduced within the context of the observed play session. Observations also revealed that a large proportion of the behaviors may be interpreted as “anticipations,” rather than “direct responses” to aversive sound stimuli, highlighting the undercurrent of anxiety that is pervasive among children with WS. Using fine-tuned analyses, exaggerated startle among children with WS was also observed. Overall, startle reactivity was significantly related to observations of sound reactivity. Interestingly, differences in startle were observed in the complete absence of overt behavioral reactivity to sound. The implications of these findings as well as the limitations of the current study are discussed below.

Heightened Reactivity to Sound in Young Children with Williams Syndrome

While sound reactivity in WS has been commonly investigated using questionnaire methods, the present study is the first to use empirical observational techniques to document these behaviors. As expected, approximately 90% of the young children in the WS group behaved in a manner indicating discomfort, fear, and/or anxiety in response to (or in anticipation of) everyday sounds, compared to only 20% of mixed etiology controls. Over half the children with WS exhibited two or more different behaviors reflective of sound reactivity during the brief play interaction, compared to only 15% in the ME group. The most common behaviors observed for the children with WS was seeking proximity to the parent and placing hands over ears, whereas no one behavior in particular appeared to stand out in the ME group.

In addition to empirically confirming the presence of heightened sound reactivity in WS, these results provide support for the notion that behavioral reactivity and anxiety are intertwined for people with WS. Of particular interest is that these behavioral reactions were very frequently observed *before* exposure to sound stimuli. In addition, three children with WS exhibited such behaviors as soon as they saw the examiner first reveal the target object, before ever being exposed to the sound stimulus. It is possible that this behavior was based upon prior experience with these objects, reflecting a fearful response in direct relation to the properties of the sound stimulus. Alternatively, it is also possible that these children were appraising novel stimuli as *potentially* harmful and taking precautionary measures; this would constitute a general appraisal of environmental threat, more akin to generalized anxiety and not necessarily related to sound exposure (Barlow, 2002). Such a distinction mirrors the difference between “fear” and “anxiety” constructs. According to Barlow (2000), fear can be understood as a phasic, state-related response to an object in the environment, whereas anxiety reflects a persistent and generalized feeling of worry and apprehension not clearly linked to a specific stimulus. The distinction between fear and anxiety is an important one, as these phenomena likely stem from dissociable neurobiological mechanisms (Davis, 1998; Dien, 1999; Kalin, Shelton, Davidson, & Kelley (2001).

Another way to highlight the possible role of anxiety in mediating behaviors characteristic of sound reactivity may be to highlight their presence in the absence of any exposure to sound. In the current study, we observed several children with WS who held hands to ears during activities which had nothing to do with noise. For example, one child was observed to engage in this behavior when the examiner approached him to play a game of “I’m gonna get you.”

Another put his hands to his ears when introduced to any novel stimulus during the play interaction, even when asked to imitate sipping from a cup. Hence, parental reports of behavioral reactivity (i.e., hand to ears) may indeed represent fearful reactions directly associated with sound sensitivity, but may also reflect conditioned responses during anxiety-provoking events not necessarily involving sound exposure.

Etiology of Heightened Sound Reactivity

As mentioned, heightened anxiety appears to be particularly characteristic of individuals with Dykens and Rosner (1999) found that WS individuals have more fears and anxiety when compared to children of mixed etiology. Similarly, Klein-Tasman and Mervis (2003) compared parent ratings of personality and temperament for 8 to 10-year-old children with Williams syndrome and mixed etiology controls, finding significantly higher scores on a scale assessing stress reactivity in addition to higher ratings on various items assessing anxiety and worry. Using the Anxiety Disorders Interview Schedule for DSM-IV Parent Version (Silverman & Albano, 1996), Leyfer and colleagues (2006) recently documented elevated rates of Generalized Anxiety Disorder (approximately 12%) among a sample of 119 individuals with Williams syndrome between the ages of 4 to 16 years. More detailed analysis support evidence for age-related trends, with prevalence rates being significantly higher in the older age groups (11–16 year olds). Interestingly, the authors describe frequent reports of continuous question asking behavior and avoidance of upcoming events, highlighting the anxious apprehension that appears to typify these young individuals.

The atypical reactions to everyday sounds observed in the current study may indeed reflect the heightened levels of anxiety and/or fear reported in WS. However, abnormality in auditory functioning associated with the WS deletion may also play a part in setting the stage for these reactive behaviors. Recent studies have revealed high rates of impaired cochlear function and complete absence of ipsilateral acoustic reflexes among young children and adults, both of which are suggestive of sensorineural hearing loss (Gothelf et al., 2006; Marler et al., 2005). At first glance, hearing loss may seem counter-intuitive to understand hypersensitivity to sound in WS. However, a rapid increase in loudness perception, termed recruitment, is a common symptom associated with cochlear hearing loss (Marler et al., 2005; Johnson et al., 2001). It is important to note that this interpretation does not explain why children with WS exhibited more overt behavioral reactions to sounds that were lower in volume (e.g. balloon releasing vs. pop-up toy). Thus, further research is needed to determine the exact roles sound intensity, rise-time, duration, and band-width may have in eliciting behavioral reactivity in this population. Taken together, the current findings suggest that interpretation of these behaviors is not straightforward and likely involves both auditory abnormality and temperamental or behavioral vulnerabilities.

Exaggerated Startle and Heightened Sound Reactivity in WS

Using fine-tuned video-observation techniques, startle eye blinks were also recorded. In the current study, children with WS showed greater startle magnitudes across all four startle trials when compared to ME controls. In addition, startle reactivity was found to be significantly related to heightened sound reactivity in our overall sample. Taken together, these findings suggest exaggerated startle may be an important behavior that characterizes sound reactivity among young individuals with developmental disabilities. Furthermore, including exaggerated startle responses in investigations of sound reactivity may prove particularly useful when examining infants and toddlers whose development does not support more complex responses such as holding hands to ears or verbalizing to stop the sound. Further research is needed to explore the relation between subtle startle responding and more overt behavioral responses to sound in the WS population.

As there is a linear relation between startle and negative emotional state (Grillon & Bass, 2003; Lang, Bradley & Cuthbert, 1990; Vrana, Spence & Lang, 1988), it is possible that the observed exaggerated startle eye blinks, in the absence of overt aversive reactions, reflect a baseline state of anxious arousal. According to the literature, elevations in emotional arousal may result from increased or abnormal amygdala functioning. The amygdala has been repeatedly associated as the key structure for mediating both fear and anxiety responses in animals (LeDoux, Iwata, Cicchetti & Reis, 1988; Hitchcock & Davis, 1986), as well and in humans using neurological patients with specific brain lesions (Funayama, Grillon, Davis & Phelps, 2001). In addition, projections from the central nucleus of the amygdala have been reliably shown to directly modulate the startle circuit (Davis, 1998). Interestingly, Meyer-Lindenberg and colleagues (2005) suggest abnormal regulation of the amygdala may be related to elevated levels of anxiety among individuals with WS. The findings from the current study suggest that further investigation of the relation between anxiety and startle in WS is warranted.

Limitations

This study provides the first empirical examination of sound reactivity and startle using video-observation methods. One significant limitation is the lack of audiological examinations of the participants. Access to such information might enable researchers the opportunity to better differentiate between the effects of anxiety opposed to those in result of auditory abnormality associated with the WS deletion. Unfortunately, these examinations are often difficult to conduct with very young children with developmental disabilities. As mentioned, it is likely that sound reactivity and exaggerated startle in this population may be the additive result of several determinants including elevated anxiety and cochlear damage.

The current study was conducted by observing behavioral reactions to various sounds emitted by developmentally appropriate toys. Coding for sound reactivity during exposure to the balloon and bubble appeared to provide us with a clear indication of differences across groups. It is possible however, that the participants may have responded to different aspects of this compound stimulus, as each stimulus has auditory and visual components. Sounds encountered in everyday situations can also stimulate multiple sensory modalities simultaneously. Certainly, target sounds typically documented in the sound reactivity literature do as well, for example fireworks or mechanical devices (Gothelf et al., 2006; Klein et al., 1990). The high frequency of hand to ears observed during these activities suggests the auditory properties of the stimuli in question are indeed aversive to many. However, as mentioned these behaviors are highly stereotyped among individuals with WS and may for some, merely represent a means of coping in anxiety-provoking situations more generally. Relatedly, using startle stimuli as emitted by children's toys proved useful with this young developmentally delayed population, creating less anxiety than the intense bursts of white noise that are more commonly administered through headphones. Nevertheless, future research examining startle reactivity using a more systematic and standardized set of auditory stimuli in a more controlled environment is needed.

Finally, in contrast to the current literature examining both anxiety and sound reactivity among individuals with WS, this study included a very limited age range (2½ to 6½ years of age) in hopes of exploring the early indications of behavioral difficulties common to this population. Further research is warranted in order to better understand the developmental course of sound reactivity and its relation to anxiety problems in this population. Future studies should make use of longitudinal methods to better understand the extent of these difficulties among the WS population across the age-span.

Conclusion and Future Directions

Findings from recent studies have provided support for a distinctive personality profile in the WS population that is in part characterized by sound sensitivity and heightened anxiety (Blomberg et al., 2006; Dykens, 2003a; Gosch & Pankau, 1997; Klein-Tasman & Mervis, 2003; Gothelf et al., 2006; Levitin et al., 2005; Leyfer et al., 2006). These studies have mainly been limited to parental report measures, which may provide an incomplete representation of the quality and extent of difficulties common to this population. In the current study, we attempted to expand upon information previously gathered from parent report and informal observations through the use of event recording techniques. Future use of observational methods in concert with collateral sources of information may broaden our understanding of sound sensitivity and startle among these populations. Although preliminary, our findings suggest that effects of anxious anticipation on eliciting behaviors commonly characterized as sound sensitivity be explored. Furthermore, the confirmation of exaggerated startle lends support to the future use of startle paradigms in this population. Further investigations may also attempt to discern if these behaviors are good early indicators of vulnerability to future anxiety difficulties.

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Code 1 No response to stimulus	Code 2 Flutter (no lid closure)	Code 3 Soft Blink (no additional facial movement)	Code 4 Hard Blink (w/ facial movement)	Code 5 Hard Blink with Body Movement

Figure 1.
Exemplars of startle codes used during exposure to pop-up toy (free-play task).

Figure 2.
Percentages of each group showing overt behavioral reactivity to sound during each play activity.

Figure 3. Mean startle ratings for WS and ME groups during the exposure to the pop-up toy (free-play task).

Table 1

Matched sample comparisons for developmental quotient (DQ), age equivalent (AE), and chronological age (CA).

	WS N=21 (14 male)	ME N=20 (12 male)	$t_{(1,39)}$ value	p value
DQ	55.43 (8.85) 49–76	54.9 (8.42) 49–75	0.196	0.846
AE	23.18 (5.22) 13–33	21.96 (7.67) 9.25–39.25	0.596	0.55
CA	44.48 (10.84) 30–65	44.8 (12.55) 30–78	0.089	0.93

Note. Data are given as mean (SD) and range. One ME participant was 78 months of age and therefore, above the available normative values for this developmental measure. To obtain the developmental quotient the highest normative values available (67–68 months) were used; because this participant performed at floor even when compared to norms for younger children. . However, since age equivalents were used to match participant groups, we choose to retain data from this participant. Scores obtained from the Mullen Scales of Early Learning (Mullen, 1990).

Table 2

Procedure descriptions of selected Autism Diagnostic Observation Schedule activities.

Free Play	Children were typically seated at a table. A pop-up toy was placed in front of them with the examiner initiating the first four or five responses. Children either continued to play with the toy or moved to another toy as they saw fit.
Response to Joint Attention	The examiner made an attempt to draw the child's attention to a mechanized bunny, previously hidden from the child's view. The examiner activated the toy using a battery operated controller, then paused for approximately 5 seconds to observe the child's response. The examiner repeated this process several times, then allowed the child to operate the bunny if he or she desired.
Bubble Play	The bubble gun was typically introduced in the later half of the play interaction, with the examiner operating the toy for a five second duration, approximately three to four times each session. Children were then offered the toy and assisted with operation if they wished to continue playing with this item.
Anticipation of Routine with Objects	The balloon was introduced to each child, typically occurring in the second half of the play interaction. The examiner showed the balloon to the child, blew it up slowly, pinched the neck of the balloon and verbalized "ready, set, go!" The examiner then released the balloon, retrieved it, and repeated the process four to five times. The child was not allowed to attempt blowing up the balloon on his/her own.

Table 3

Matched sample comparisons for type of behavior observed (percentages in parentheses).

	WS N=21	ME N=20
Goes to caregiver	13 (61.9)	2 (10)
Covers ears	10 (47.6)	1 (5)
Cringes	7 (33.3)	2 (10)
Verbalizes to stop	4 (19.0)	2 (10)
Backs away	3 (14.3)	2 (10)
Cries	2 (9.5)	2 (10)

Note. WS = Williams syndrome; ME = Mixed Etiology.

Table 4

Matched sample comparisons showing total number of different behaviors exhibited by each participant (percentages in parentheses).

	WS N=21	ME N=20
6 Behaviors	0	0
5 Behaviors	1 (4.8)	0
4 Behaviors	2 (9.5)	1 (5)
3 Behaviors	4 (19.0)	1 (5)
2 Behaviors	4 (19.0)	1 (5)
1 Behavior	8 (38.0)	2 (10)
0 Behaviors	2 (9.5)	15 (75)

Note. WS = Williams syndrome; ME = Mixed Etiology.

Table 5
Matched sample comparisons for startle mean magnitudes (SD in parentheses).

Trial	ME N=20	WS N=21	t _(1,39) value	p value	Hedge's g ^a
1	1.55(1.10)	3.05(1.53)	3.58	0.001	1.1
2	1.70(1.03)	2.86(1.31)	3.125	0.003	0.96
3	1.55(0.89)	2.71(1.15)	3.624	0.001	1.11
4	1.50(0.90)	2.76(0.94)	4.544	<.001	1.34

Note: WS = Williams syndrome; ME = Mixed Etiology

^aEffect Size