Contribution of Social and Information-Processing Factors to Eye-Gaze Avoidance in Fragile X Syndrome

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Abstract

The influence of social and information-processing demands on eye-gaze avoidance in individuals with fragile X syndrome, Down syndrome, or typical development were examined by manipulating those demands in a structured-language task. Participants with fragile X syndrome exhibited more gaze avoidance than did those in the comparison groups, but no group differences in avoidance were found between a social and nonsocial condition. Task difficulty affected gaze avoidance in the nonsocial but not in the social condition. In the nonsocial condition, the effect of task difficulty was less pronounced for the fragile X syndrome than comparison groups. Findings suggest that multimodal task demands rather than eye contact per se contribute to gaze avoidance in persons with fragile X syndrome.

Fragile X syndrome is the leading cause of inherited mental retardation (Crawford, Acuna, & Sherman, 2001). It is associated with a variety of behavioral characteristics, including a unique profile of cognitive and language deficits and avoidance of (or withdrawal from) social interaction (for a review see Dykens, Hodapp, & Finucane, 2000, or Hagerman, 2002). The syndrome is also associated with a pronounced difficulty establishing and maintaining eye contact during social interaction, which is manifested as eye-gaze avoidance (Wolff, Gardner, Paccia, & Lappen, 1989). This elevated frequency of gaze avoidance distinguishes males with fragile X syndrome from their unaffected (i.e., typically developing) siblings (Hessl, Glaser, Dyer-Friedman, & Reiss, 2006) and from individuals with other developmental disabilities (Cohen et al., 1988; Cohen, Vietze, Sudhalter, Jenkins, & Brown, 1991; Cohen et al., 1989; Wolff et al., 1989), such as Down syndrome, which tends to be characterized by high levels of sociability and gaze seeking (e.g., Kasari & Freeman, 2001).

In light of the crucial role played by eye contact in everything from the regulation of turn-taking (Clark, 1996, p. 282; Stern, 1973) to signaling understanding of and attention to the speaker's words (Argyle & Cook, 1976; Clark, 1996, p. 276; Clark & Schaefer, 1989; Kendon, 1967), the eye-gaze avoidance characteristic of fragile X syndrome is likely to be highly disruptive of social interactions. Understanding the factors that contribute to gaze avoidance is critical for identifying potential approaches to intervention for facilitating social interaction in this population. The present study was designed to investigate the social and cognitive–linguistic factors that may contribute to the occurrence of eye-gaze avoidance in fragile X syndrome.

In addition to heightened rates of gaze avoidance, many males with fragile X syndrome experience elevated levels of physiological arousal (e.g., Hessl et al., 2002; Wisbeck, Huffman, Gunnar, Davis, & Reiss, 2000) and difficulty modulating arousal (Roberts, Boccia, Bailey, Hatton, & Skinner, 2001). Indeed, associations between arousal and gaze avoidance have been documented (Bel-

ser & Sudhalter, 1995; Cohen, 1995; Hall, De-Bernardis, & Reiss, 2006; Hessl et al., 2006). For example, Hessl and colleagues (2006) reported that levels of the stress hormone, cortisol, are related to the quality of gaze during social tasks, such as conversation and oral reading. Findings such as these have led to the hypothesis that the high levels of avoidance behaviors, including the eye-gaze avoidance of males with fragile X syndrome, arise from the interaction of social demands and heightened levels of physiological arousal (Belser & Sudhalter, 1995; Cohen, 1995). In short, it has been hypothesized that the social demands of eye contact with another person, perhaps together with generalized social anxiety, lead to hyperarousal, which the individual with fragile X syndrome attempts to avoid (Belser & Sudhalter, 1995; Cohen, 1995).

A challenge in interpreting the findings on gaze avoidance in fragile X syndrome, however, is that previous researchers have relied on the measurement of gaze avoidance in naturally occurring social interactions, such as conversation with an adult. In these interactions, social, cognitive, and other demands on the individual are typically confounded. Conversation, for example, requires performing multiple tasks simultaneously, including formulating coherent and purposeful utterances, attending to a speaking partner's utterances, and monitoring the partner's comprehension. Thus, in conversation and other naturally occurring social interactions, the social dimensions are confounded with the nonsocial information-processing dimensions, such as cognitive and linguistic demands (Argyle & Cook, 1976; Clark, 1996; Kendon, 1967).

A consequence of this social information-processing confound in social interaction is that it is impossible to unambiguously attribute gaze avoidance to social rather than to nonsocial (information-processing) factors in previous studies of fragile X syndrome. It is even impossible to determine whether eye contact with another person per se or the social or information-processing demands normally associated with eye contact lead to hyperarousal and, thereby, gaze avoidance. As such, an experimental approach is needed in which social and nonsocial demands are manipulated independently. In the present study, we took such an approach to examine the relative contributions of social and nonsocial information-processing factors to eye-gaze avoidance in fragile X syndrome.

The need to consider nonsocial information-processing contributions to eye-gaze avoidance in fragile X syndrome is reinforced by findings suggesting that intellectually typical individuals use gaze avoidance as a means by which to minimize distractions and reduce cognitive demands when performing a difficult task, for example, solving a math problem or answering a difficult question (Glenberg, Schroeder, & Robertson, 1998). For example, gaze avoidance in typical individuals occurs at higher rates in cognitively demanding relative to less cognitively demanding tasks. This relationship between gaze aversion and cognitive demands occurs whether those tasks involve another person or nonsocial activities, such as answering questions on a computer (Glenberg et al., 1998). In these nonsocial activities, *gaze avoidance* is defined as averting eye gaze from the task being performed (e.g., the computer screen). Even though the rate of gaze avoidance in individuals with fragile X syndrome is higher than in those with typical development, findings such as these reinforce the need to disentangle social and nonsocial contributions to gaze avoidance in fragile X syndrome.

In further support of considering the nonsocial information-processing contributions to gaze avoidance, fragile X syndrome is associated with especially severe impairments in many of the cognitive and linguistic skills required to participate successfully in social interaction (Abbeduto & Hagerman, 1997; Murphy & Abbeduto, 2003). For example, adolescents with fragile X syndrome are less able than mental age (MA)-matched typically developing children to discern the informational needs of a listener (Abbeduto et al., 2006), and they are not as effective at monitoring their own comprehension of other people's messages (Abbeduto & Murphy, 2004). Thus, if individuals with fragile X syndrome use gaze avoidance as a means of dealing with linguistic and cognitive challenges, they may need to do so more often than their peers simply because they experience the same social interactions as more linguistically and cognitively challenging.

In the present study, we took an experimental approach to disentangling the relative contributions of social and nonsocial information-processing factors to gaze avoidance in fragile X syndrome. In order to do this, we evaluated gaze avoidance in both a social (face-to-face) and nonsocial (computer-based) condition using standardized procedures to systematically manipulate task

difficulty within each condition. We predicted that if social factors contribute to gaze avoidance in fragile X syndrome, more gaze avoidance would occur in the social than in the nonsocial condition regardless of task difficulty. We also examined the possibility of interactive effects of social and nonsocial factors. In addition to fragile X syndrome, we included developmental-level matched comparison groups of typically developing children and individuals with Down syndrome. We expected that the profile of gaze avoidance would distinguish individuals with fragile X syndrome from those with Down syndrome or typical development, especially because these groups are more socially oriented and less subject to hyperarousal than are individuals with fragile X syndrome.

Method

Participants

The participants were 15 male adolescents or young adults with fragile X syndrome, 15 male adolescents or young adults with Down syndrome, and 15 typically developing preschool-age boys. Participants with fragile X or Down syndrome were recruited locally through newspaper advertisements and via mailings to a university-based registry of families that included a child with a developmental disability. Families were also recruited nationally through Internet postings. Families with typically developing children were recruited from community postings and a university-based research registry of local families. These parents confirmed that their child did not have a disability and was not receiving special education services.

The 45 participants for this study were drawn from a larger pool of 66 individuals recruited into a larger project. Participants with Down syndrome and typically developing children were selected from the larger pool so that their nonverbal MAs, as determined by administration of three subtests from the Stanford-Binet, 4th edition (which will be described later), were within the range of MAs found in the fragile X syndrome group (i.e., 3.5 to 6.5 years). The MA range for each of the two comparison groups fell within 6 months of this range. This criterion led to the exclusion of 2 participants with Down syndrome and 4 with typical development from the larger study. An additional 5 participants with Down syndrome and 5 with typical development were excluded because they

refused or were unable to complete the tests on which we report here or because of examiner error. Four participants with fragile X syndrome were excluded because they met criteria for autism (which will be discussed subsequently). One participant with Down syndrome was excluded because he met the screening criteria for autism but was not available to complete the evaluation.

Adolescents and young adults who met *Diagnostic and Statistical Manual of Mental Disorders—DSM-IV* criteria for a diagnosis of autism were excluded, thereby ensuring comparability with the existing literature, in which a distinction is made between males with fragile X syndrome with and without comorbid autism (e.g., Cohen et al., 1988, 1989). All participants in the syndrome groups were screened using the Autism Behavior Checklist (Krug, Arick, & Almond, 1980), which was completed by teachers, mothers, and fathers (in two-parent families). Those who received scores of 44 or above from at least two informants (or one informant in single-parent families) were referred to an experienced clinical psychologist, who made the diagnosis using *DSM-IV* criteria, based on observations and interactions with the participant and a parent interview focused on the participant's developmental history.

In the fragile X syndrome group, DNA test results confirmed a diagnosis of the full mutation ($n = 11$) or mosaicism ($n = 4$) for all participants. Confirming reports from an appropriate health care professional indicated that 14 of the participants with Down syndrome had trisomy 21 and 1 was mosaic.

Language and Cognitive Skills Related to Performance

We used the following measures to assess aspects of language and cognitive skill related to eye-gaze task performance. These measures were part of a more extensive protocol, which took place during two 120- to 160-min long visits to a laboratory testing room. The two visits for any given participant were typically scheduled on different days; however, visits on the same day were occasionally required to accommodate the participant's schedule. Same-day visits were separated by at least an hour break for lunch.

Nonverbal cognition. Participants were individually administered the Bead Memory, Pattern Analysis, and Copying subtests from the Stanford-Binet–IV (Thorndike, Hagen, & Sattler, 1986).

These subtests measure short-term memory for visually presented information, visual perception and analysis, and motor coordination and visual spatial ability, respectively. Each subtest requires nonverbal responses from the participant and minimal verbal instructions from the examiner. A partial composite IQ was obtained according to procedures specified in the manual (see Table 1). Mental age-equivalent scores were obtained by taking the mean of the age-equivalent scores for the three subtests (see Table 1).

Receptive vocabulary. The Test for Auditory Comprehension of Language–III (TACL-III) Vocabulary subtest (Carrow-Woolfolk, 1999) was administered. This subtest required pointing to the one drawing out of three that went with a word said by the examiner. Even though this test was normed for children 3.0 to 9.92 years of age, it has been used frequently with adolescents with mental retardation (Abbeduto et al., 2003; Chapman, Schwartz, & Kay-Raining Bird, 1991; Lewis et al., 2006). Standard and age-equivalent scores were derived (see Table 1).

Experimental Eye-Gaze Task

Task overview. Gaze avoidance was assessed during a computerized "picture-naming" task. During the task, the participant sat in front of a computer screen and was presented with a series of pictures, some with and some without a verbal label. The participant's job was to provide a verbal label for the picture-only items (the easy items) or a synonym for the picture–label combination items (the difficult items). The task was completed twice, but under different conditions. One condition involved face-to-face interaction with a live examiner (the social condition), and the second involved non-face-to-face interaction with a prerecorded voice on a computer (the nonsocial condition). In both conditions, the task was controlled by the examiner via a laptop computer.

During the social condition, an examiner sat facing the participant, but to the side of the computer screen. This way both the computer screen and examiner were directly visible to the participant. In the nonsocial condition, the examiner was "replaced" by a distracter, a large blue ball filled with swirling liquid (subsequently described in detail). This manipulation was done to control for the physical presence of the examiner in the social condition. During the nonsocial condition, pilot testing indicated that to ensure on-task behavior, the physical presence of an examiner was required rather than leaving the participant alone in the testing room. Consequently, the examiner remained in the room but sat out of the participant's direct view in order to avoid eye contact. The design of the task allowed us to examine gaze avoidance based on the type of task (labeling or synonym) and the face-to-face demands of the interaction (present or absent).

The social/nonsocial manipulation and the presentation of labeling and synonym items were counterbalanced across participants. In order to accomplish this, labeling and synonym items were divided into two forms of comparable difficulty. One form was assigned to the social condition, whereas the other was assigned to the nonsocial condition. The items in each form were randomly ordered within each item type (labeling, synonym) and blocked together. Thus, in the social and nonsocial conditions, half of the participants received the labeling and then the synonym items, whereas the other half received the reverse order.

Materials. The stimuli were color graphics of animals and objects that were presented in the center of a 1024 × 768 pixel, white background on a 15-inch LCD flat screen desktop monitor.

Table 1. Mean and *SD*s of Participant Characteristics by Group

Characteristic	Fragile X syndrome		Down syndrome		Typical development	
	Mean	SD	Mean	SD	Mean	SD
Nonverbal IQ[a]	40.27	7.24	39.93	6.12	96.53	11.47
Nonverbal MA[a]	4.73	1.05	4.77	1.04	4.79	1.26
Vocabulary Age[b,c]	5.83	1.34	5.60	1.56	5.98	1.73
CA[b]	16.52	3.29	17.84	2.61	4.92	.88

Note. There were 15 participants in each group.
[a]Derived from performance on three Stanford–Binet–IV subtests: Pattern Analysis, Copying, and Bead Memory. [b]In years. [c]Obtained from the Test for Auditory Comprehension of Language-III Vocabulary subtest.

For labeling items, a single picture was presented to be labeled (e.g., a spoon); whereas for synonym items, a picture and a verbal label were presented (e.g., an angry-looking man and the word *angry*). The participant was asked to provide a synonym (e.g., *mad* or *furious*). Labeling items were designed to be conceptually less difficult than synonym items, making it possible to assess performance as a function of processing demands (Williams, 1997).

The items used in the picture-naming task were designed to be similar to those in the Expressive Vocabulary Test (Williams, 1997), a standardized measure of expressive vocabulary. Chronological age (CA) norms from this test were used to select target words that were well within (labeling items) or just beyond (synonym items) the approximate MA range of the study participants. Target words were matched with computer graphics in Corel Office Suite 2000, with conceptually similar words added to accommodate graphic availability. As described subsequently in the *Results*, the performance of our participants suggested that, on average, the two sets of items differed in difficulty as intended.

The distracter was a blue "Mystic Light" (Rabbit Tanaka, Fluid in motion, 2001). The Mystic Light was a blue-tinted glass ball approximately 15.24 cm in diameter attached to a black pedestal approximately 8.89 cm high, and 16.51 cm wide and long. An electric powered fan in the pedestal circulated a light blue liquid within the ball continuously.

Procedure. The social and nonsocial conditions were administered in separate sessions by a female examiner. The same examiner administered both conditions to a given participant, except in a very few cases when scheduling constraints made this impossible.

In the social condition, the examiner sat next to the computer screen facing the participant. She read the instructions and presented each item aloud. Her behavior was highly scripted to ensure that there was standardization of the task instructions and materials as well as the direction and orientation of her eye gaze. Specifically, the examiner directed her eye gaze toward the participant's face when presenting each item and maintained this direction of gaze until the participant produced an answer.

In the nonsocial condition, the examiner gave a brief introduction saying, "You are going to play a game on the computer. I have some work to do,

so I am going to sit over there while you do this activity." She then moved to a position out of direct view and did not interact further with the participant during the task, although she surreptitiously controlled the execution of the prerecorded messages and stimuli via a remote laptop computer. All of the verbal directions, stimuli, prompts, and feedback used in the nonsocial condition were prerecorded by a female voice using Cool Edit Pro 2.0, and played over computer speakers. The position of the distracter and examiner next to the computer screen were the same for any given participant and were counterbalanced across participants.

To begin the task, the examiner or computer said: "We are going to play a game on the computer." In the social condition, the examiner added, "I am going to sit over here so that we can see each other." The labeling items were introduced by saying, "I am going to show you some pictures of animals and other objects. When I show you a picture, I want you to tell me what the picture is called." To make sure the participant's attention was directed at the task, each picture was preceded by the verbal instruction, "Tell me what this picture is called." The synonym items were introduced by saying,

> I am going to show you some pictures and say a word that describes the picture. When I have finished, I want you to tell me another word that means the same thing as the word I said. For example, if I show you this picture and say "Mother," [picture of woman feeding infant] you would say "mom, mommy, or mama" because those words mean the same thing as mother.

Each picture for the synonym items was presented with the verbal instruction, "Tell me another word for ___." Practice items immediately followed the instructions for both item types to ensure the task was understood.

In both conditions, the examiner recorded the participant's answer. Each condition was videotaped for later coding of gaze avoidance. The video captured a frontal and a profile view of the participant in order to ensure an adequate view of the participant's face and upper body.

Coding eye-gaze avoidance. Gaze behavior was coded for the interval between stimulus onset and proffered answer. Prior to coding gaze, uncodable items were excluded (i.e., those items in which the participant moved outside the view of the camera or failed to respond to an item because of a distraction in the testing room). The remaining items comprised the total number of engaged items,

which were coded for avoidance. Across the three groups, 99% of the items were codable. The total number of engaged items was calculated, and gaze avoidance for those items was analyzed as a function of context (i.e., social, nonsocial) and difficulty (i.e., labeling, synonym).

Gaze avoidance was coded in reference to the *task space*, which consisted of the space directly occupied by the computer screen and examiner (social condition) or computer screen and distracter (nonsocial condition). *Gaze avoidance* was defined as a marked turning of the eyes, head, or trunk of the body away from the task space; for example, turning the head away from the computer screen and examiner in the direction opposite to where the examiner/distracter was situated or tilting head upward to look at the ceiling. Covering the eyes or face and putting the head down so as to avoid gazing at the task space were also coded as gaze avoidance. The occurrence of any of these behaviors led to coding the interval as avoidance, regardless of the duration or number of repetitions of a single behavior or behaviors.

Reliability. Interrater reliability was computed for eight randomly selected videotapes coded by two independent raters. Kappa reliability (Cohen, 1960) for coding gaze avoidance across diagnostic group and condition had a mean of .68 and a range of .61 to .76, which is considered to be substantial (Landis & Koch, 1977). The mean percentage agreement across all coding categories was .88 (range =.86 to .91).

Dependent variables. The primary dependent variable, proportion of avoidance, was calculated separately for each of the four conditions (i.e., the social/labeling, social/synonym, nonsocial/labeling, nonsocial/synonym) by dividing the total number of engaged items during which at least one instance of avoidance occurred by the total number of engaged items for that condition. Based on these proportions, four summary variables were calculated for use in the planned analyses: (a) the mean proportion of avoidance across all conditions, (b) the difference in avoidance between the social and nonsocial conditions regardless of difficulty, (c) the difference in avoidance on synonym versus labeling items in the social condition, and (d) the difference in avoidance on synonym versus labeling items in the nonsocial condition.

For each of the four conditions, the proportion of correct responses was also calculated. This variable was the total number of correct answers to the engaged items divided by the total number of engaged items.

Results

A series of planned analyses were used to evaluate the hypotheses about gaze avoidance. Planned analyses enabled us to test our hypotheses while controlling for Type I error rate and maximizing the power to detect significant differences. All analyses were conducted using arcsine transformed proportions (Anscombe, 1948; Laubscher, 1961). This transformation is necessary because the mean and variance of proportions are correlated, which violates the homogeneity of variance assumption required for analysis of variance. Inferential statistics are reported for the transformed proportions; however, for ease of interpretation, descriptive statistics are reported for the untransformed proportions.
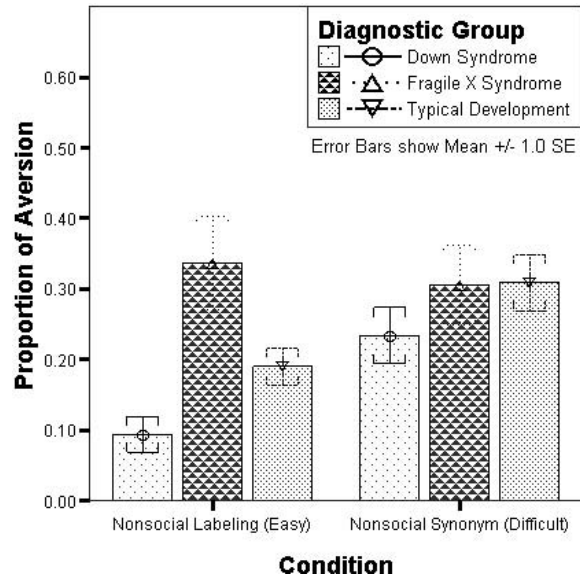
Gaze Avoidance

A 3 diagnostic group (fragile X syndrome, Down syndrome, typical development) MANOVA was conducted with four dependent variables: the mean proportion of gaze avoidance (i.e., the average across conditions), the difference in the proportion of gaze avoidance in the social versus nonsocial condition, the difference in gaze avoidance between the synonym and the labeling items in the social condition, and the difference in gaze avoidance between the synonym and the labeling items in the nonsocial condition. The multivariate effect of diagnostic group was found to be significant, Wilks Lambda $F(8, 78) = 3.79$, $p = .001$, partial $\eta^2 = .28$.

The mean proportion of gaze avoidance differed across the three diagnostic groups, $F(2, 42) = 11.91$, $p < .001$, partial $\eta^2 = .36$. Follow-up comparisons using Fisher's least significant difference (LSD) indicated that participants with fragile X syndrome averted gaze proportionally more than did those with Down syndrome, $p < .001$, or typical development, $p = .006$. The mean proportion of avoidance was .33 for fragile X syndrome, .12 for Down syndrome, and .19 for typical development. The difference between the group with Down syndrome and the group with typical development in gaze avoidance just failed to reach significance, $p = .054$.

The mean difference in gaze avoidance between the social and nonsocial conditions did not vary across diagnostic groups. Thus, there was no
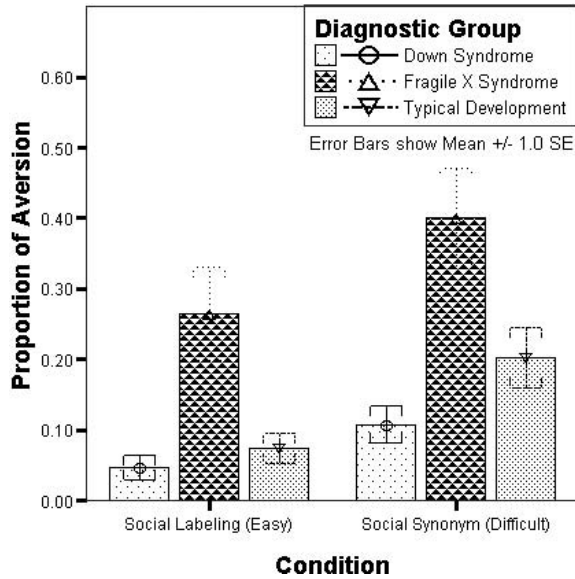
Figure 1. Proportion of gaze avoidance based on task difficulty in the social condition.

Figure 2. Proportion of gaze avoidance based on task difficulty in the nonsocial condition.

difference between the participants with fragile X syndrome and those with Down syndrome or typical development in the effect of the social/nonsocial task manipulation on the proportional occurrence of gaze avoidance. The mean difference between the social and nonsocial condition was .01 for fragile X syndrome, −.09 for Down syndrome, and −.11 for typical development.

The main effect of diagnostic group for the difference in the proportion of gaze avoidance between synonym (difficult) and labeling (easy) items in the social condition also failed to reach significance, suggesting that differences in gaze avoidance as a function of task difficulty were similar across groups in the social condition (see Figure 1). The mean difference in avoidance between the synonym and the labeling items was .14 for fragile X syndrome, .06 for Down syndrome, and .13 for typical development. In contrast, the difference in the proportion of gaze avoidance between synonym and labeling items in the nonsocial condition varied significantly across groups, $F(2, 42) = 3.98$, $p = .026$, partial $\eta^2 = .16$ (see Figure 2). Pairwise comparisons using Fisher's LSD method indicated that the difference in the proportion of gaze avoidance on the nonsocial labeling versus the synonym items was smaller for the fragile X syndrome than for the Down syndrome group, $p = .009$. The difference in gaze avoidance for the nonsocial labeling and synonym items between the fragile X syndrome and the

typically developing groups just failed to reach significance, $p = .051$. No difference was found between the Down syndrome and typically developing groups. The mean difference in avoidance between the nonsocial synonym and labeling items was −.03 for fragile X syndrome, .14 for Down syndrome, and .12 for typical development.

Supplemental Analyses

Correlation between gaze avoidance and CA. We assessed the relationship between proportion of gaze avoidance and CA. Such analyses are important given the wide age range of participants in the syndrome groups (13 to 22 years), and the finding that IQ declines with age in fragile X syndrome, whereas other aspects of the phenotype increase with age (Hagerman, 2002). No significant correlations were observed in the whole sample or in the fragile X syndrome or typically developing groups. In the Down syndrome group, however, the proportion of gaze avoidance was negatively related to CA, $r = −.53$, $p = .04$, indicating that the proportion of gaze avoidance decreases during the adolescent period for those with Down syndrome.

Performance accuracy. We conducted a 3 (diagnostic group) × 2 (difficulty: labeling, synonym) ANOVA, with repeated measures on the last factor on the proportion of correct responses. A main effect of difficulty emerged, $F(1, 42) =$

690.68, $p < .001$, partial $\eta^2 = .94$. The mean percentage of correct responses across groups was 92% on the labeling and 32% on the synonym items. Thus, our task difficulty manipulation functioned as intended.

There also was no main effect of diagnostic group for the proportion of correct responses. The mean percentage correct across the labeling and synonym items were 66% for fragile X syndrome, 59% for Down syndrome, and 60% for typical development. Thus, there was no evidence that the participants with fragile X syndrome were less attentive to the task than were the other groups. Moreover, no Diagnostic Group × Difficulty interaction was found, suggesting that the difficulty manipulation was comparable across the groups.

The proportion correct was not significantly correlated with the proportion of gaze avoidance in the whole sample or within any of the three groups. Although none of the correlations was significant, the direction of the correlation in all three groups was negative, such that greater response accuracy tended to be associated with less gaze avoidance.

Discussion

Excessive eye-gaze avoidance can negatively impact an individual's ability to fully participate in a range of everyday social situations. It is important, therefore, to know the factors that elicit gaze avoidance so appropriate interventions can be designed. However, the contextual factors that elicit gaze avoidance have not yet been fully identified. Here, we examined the extent to which gaze avoidance among adolescent males with fragile X syndrome varies as a function of the social and information-processing demands of a task. Gaze avoidance in fragile X syndrome was assessed relative to adolescents with Down syndrome or typically developing children. The social context (social vs. nonsocial) and task difficulty (labeling vs. synonym) of a picture-naming task were experimentally manipulated with four main findings.

First, regardless of the social or information-processing demands of the task, the participants with fragile X syndrome had a higher proportion of gaze avoidance than did those with Down syndrome or typical development. This finding is consistent with other studies in suggesting that gaze avoidance is especially problematic for individuals with fragile X syndrome and not simply a consequence of mental retardation (e.g., Cohen et al., 1988). In addition, the elevated rate of gaze avoidance in individuals with fragile X syndrome was not accounted for by differences in cognitive or language ability across the groups because the groups were matched on these variables.

Second, the observed results suggest that gaze avoidance in fragile X syndrome is not elicited by the social demands of the task per se. Specifically, if social factors were a primary contributor to gaze avoidance in fragile X syndrome, then relative to peers, we would expect the mean difference in such avoidance between the social and nonsocial conditions to be greater for the group with fragile X syndrome. Further, we expected the difference to favor a higher proportion of avoidance in the social rather than the nonsocial condition for those with fragile X syndrome. In fact, despite an overall higher proportion of gaze avoidance among males with fragile X syndrome, no significant difference in gaze avoidance was observed across groups as a function of social versus nonsocial demands. Indeed, the mean difference in avoidance between the social and nonsocial conditions was almost zero (i.e., .01) for the group with fragile X syndrome. Thus, these findings provide the first demonstration that gaze avoidance in fragile X syndrome is not necessarily induced by social demands. Note that these findings are particularly interesting given the extreme nature of our manipulation of social demands (i.e., face-to-face interaction vs. interaction with a computer). If a difference of this magnitude has no effect on gaze aversion, it is even less likely that the more subtle variations of every day social interaction would have an effect.

More importantly, however, these results suggest that we may need to reconceptualize gaze avoidance. In particular, the avoidant behavior we studied occurred at the same frequency whether the task space included a person who looked at the individual with fragile X syndrome or an inanimate object. Thus, the *task space*, defined by a set of multimodal sensory input creating demands on the individual rather than the possibility of eye contact with another person, led to the behavior we have called *gaze avoidance*. There may be nothing about eye contact per se that is arousing; rather, it may be the sensory stimulation and/or higher order demands associated with eye contact that is problematic for individuals with fragile X syndrome.

Third, variations in nonsocial information-

processing demands did not influence gaze avoidance in fragile X syndrome. That is, if information-processing factors were a primary contributor to gaze avoidance in fragile X syndrome, the difference in avoidance between the synonym (difficult) and labeling (easy) items should be evident regardless of social context. An examination of the difference in gaze avoidance as a function of task difficulty in the social condition revealed no differences between males with fragile X syndrome and the comparison groups. In addition, the group with fragile X syndrome was less sensitive to variations in task difficulty than were the other two groups in the nonsocial condition. The mean difference in gaze avoidance between the synonym and labeling items in the nonsocial condition was essentially zero (i.e., −.03) for the group with fragile X syndrome. In contrast, the proportion of gaze avoidance was higher on the synonym than the labeling items in the nonsocial condition for the other two groups (M synonym-labeling difference = .14 and .12 for Down syndrome and typical development, respectively). Thus, the findings in the fragile X syndrome group are in contrast to those in the Down syndrome and cognitively matched typically developing groups, who were influenced by both the social nature and difficulty of the task at hand. Together with the findings for the social and nonsocial contrast, the findings suggest that gaze avoidance in fragile X syndrome is relatively impervious to environmental variations.

Fourth, one might argue that gaze avoidance in fragile X syndrome is prompted only when both the social and information demands of the task at hand are high. One manifestation of such interactive effects of social and information processing would be a greater effect of our task difficulty manipulation in the social condition than in the nonsocial condition for fragile X syndrome relative to the other groups. As already stated, however, the participants with fragile X syndrome showed no difference in gaze avoidance between labeling and synonym items in the social condition in contrast to the other groups. Thus, the findings of the present study are also inconsistent with the notion of an interactive effect of social and information-processing factors.

Taken together, our findings suggest that neither the social nor information-processing demands of the task alone, or in combination, are sufficient to fully account for gaze avoidance behavior in fragile X syndrome. This prompts the

consideration of two methodological and two theoretical explanations. First, the task might have been too difficult or overwhelming for the participants with fragile X syndrome, with gaze avoidance behavior reflecting a lack of attention to the task. However, this is an unlikely explanation given that each group performed similarly on both the labeling and synonym tasks. Thus, it is not the case that this pattern is simply a reflection of an inability of the participants with fragile X syndrome to perform the task or to distractibility.

The other method-related consideration is that the experimental manipulation of the contextual demands did not provide a sufficiently nonsocial task. For example, the nonsocial task retained several social elements, including the use of a human voice to present the instructions and the presence of the examiner in the room during testing, which may have lead to the recognition of being observed. However, this possibility is unlikely because of the different pattern of results observed as a function of social demands. Also, it was rare that the participant acknowledged the examiner during the task.

The theoretical alternative explanations that remain address the possible contribution of physiological factors and learning to gaze avoidance behavior. First, these findings are consistent with the notion that an internal, physiological factor, such as arousal, may contribute to gaze avoidance above and beyond variations in external, contextual factors (Belser & Sudhalter, 1995; Cohen, 1995; Hessl et al., 2006). Indeed, patterns of eye-gaze avoidance and arousal are correlated (e.g., Hall et al., 2006; Hessl et al., 2006). For example, high mean levels of cortisol (a stress hormone) are associated with less eye contact and increased fidgeting behavior during social challenges (Hall et al., 2006). Measuring arousal was beyond our scope in the present study, but should be considered in future studies.

A final alternative explanation is that gaze avoidance may be a learned behavior that provides functional feedback early in development, but not later in life. Early in development, the child with fragile X syndrome may use gaze avoidance to help regulate his or her arousal level. Indeed, even typically developing infants use behaviors such as self-comforting (i.e., rocking, clasping self), self-stimulation, and attempts at escape, such as turning or looking away (Trevarthen, 1977; Tronick, 1989), to regulate emotional state and receptiveness to interaction (as reviewed by

Adamson & Russell, 1999). Over time, however, what originates as a functional behavior for a child with fragile X syndrome may be reinforced and continue as a habitual, over-learned behavior or routine that interferes with development (Murphy & Abbeduto, 2003), including the neuronal development of the brain regions underlying gaze perception (Garrett, Menon, MacKenzie, & Reiss, 2004). Such a hypothesis does not eliminate the contribution of arousal to gaze avoidance but does suggest the importance of considering how arousal and environmental feedback may interact over time to produce or maintain gaze avoidance and the influence on neuronal development.

The results of the present study should be viewed in light of following limitations. First, although the vocabulary task allowed us to control the structure of the task across conditions, results from Hall et al. (2006) suggest that less structured tasks, such as being interviewed or singing, produce more gaze avoidance than structured tasks, such as silent and oral reading, for individuals with fragile X syndrome. However, Hall and colleagues did not control for possible differences in task difficulty between structured and unstructured tasks. As such, it is difficult to determine the extent to which the task demands were consistent between the structured and unstructured tasks. Further investigation is needed to determine the specific contribution of task structure on gaze avoidance in individuals with fragile X syndrome.

In addition, our results suggest that gaze avoidance does not limit the ability of individuals with fragile X syndrome to perform or attend to a task, even a difficult one. However, gaze avoidance is still likely to affect social interaction even if it does not overtly hinder performance on a task like the one used in this study. Many subtle social cues are conveyed via eye-gaze (e.g., turn-taking in conversation). Lack of appropriate gaze behavior may still have an impact on the interpretation and use of these social cues. As a result, intervention targeted at recognizing social cues and appropriate responses to those cues may be of benefit for those with fragile X syndrome. Moreover, skillfulness in recognizing social cues can be addressed in conjunction with or separate from intervention for gaze avoidance and may ultimately help reduce its occurrence. For example, the findings of the present study suggest that minimizing multimodal task demands during social interaction rather than eye contact per se may help to reduce gaze avoidance behavior. As such, intervention fo-

cused on identifying and practicing aspects of social interaction that involve eye gaze, such as turn-taking and monitoring the listener's understanding, may help to improve responsiveness during social interaction.

In summary, elevated rates of gaze avoidance among males with fragile X syndrome do not appear to be the direct result of eye contact with another person because gaze avoidance occurred regardless of whether a person or inanimate object was present. Instead, the findings suggest the need to reconceptualize gaze avoidance not as avoidance of eye contact with another person but as avoidance of a "task space." Such a change reflects the contribution of multimodal task demands, including the sensory and/or higher order demands, to avoidance behavior in fragile X syndrome. Future investigators may examine the role of physiological arousal in nonsocial situations and the possible contribution of learning to such avoidance behaviors. Also, investigating the implications of avoidance behavior for interpreting subtle social cues may contribute to targeted intervention for improving communication skills.

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