Language Development in Individuals With Fragile X Syndrome

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Fragile X syndrome (FXS) is the leading inherited cause of intellectual disability. The syndrome is caused by a single gene mutation on the X chromosome. Although individual differences are large, most individuals with FXS display weaknesses across all language and literacy domains compared with peers of the same chronological age with typical cognitive and language development. Expressive, receptive, and pragmatic language abilities as well as literacy skills are similar to those of younger, typically developing peers at similar cognitive and language developmental levels, although there are areas in which impairments exceed developmental-level expectations. One area of special impairment is the higher occurrence of repetition in the language of individuals with FXS compared with developmentally matched peers. In this article, we review the behavioral, language, and literacy profiles of individuals with FXS and discuss potential clinical implications. **Key words:** *fragile X syndrome*, *intellectual disability*, *language*, *literacy*, *speech*

FRAGILE X SYNDROME (FXS) is the leading inherited cause of intellectual disability, accounting for 40% of all X-linked cases of mental retardation (Crawford, Acuna, & Sherman, 2001). The prevalence of FXS is conservatively estimated at 1 in 4,000 males and 1 in 8,000 females. The syndrome results from a mutation in the fragile X mental retardation 1 (FMR1) gene, which is located on the X chromosome at Xq27.3 (Brown, 2002). In the healthy allele, there are 55 or fewer repetitions of the CGG sequence of nucleotides comprising the *FMR1* gene (Nolin, Glicksman, Houck, Brown, & Dobkin, 1994). In the *full mutation* case, there is an expansion to 200 or more repetitions of this triplet of nucleotides. The full mutation typically leads the gene to be "turned off" so that the associated protein (fragile X mental retardation protein) is not produced (Oostra & Willemsen, 2003). Fragile X mental retardation protein (i.e., FMRP) is involved in critical ways in the development and functioning of synapses (Klintsova & Greenough, 1999). Expansions in the *FMR1* gene that are less than 200 repetitions, but exceed approximately 55 are termed *premutations*, and they too can be associated with reduced fragile X mental retardation protein levels as well as with elevated levels of FMR1 messenger RNA (Allen et al., 2005; Nolin et al., 2003; Tassone et al., 2000).

In this article, we review what is known about the language, literacy, and related problems of individuals with FMR1 expansions. We focus primarily on the full mutation because there have been very few studies that have focused on the language phenotype of FMR1 premutation carriers. However, it is important to note that recent research has demonstrated that individuals with the FMR1 premutation display many of the same behavioral features as individuals with FXS (Bailey, Raspa, Olmsted, & Holiday, 2008),

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as well as some problems not seen in FXS (P. J. Hagerman & Hagerman, 2004), which suggests that premutation carriers may have problems with language as well.

THE BEHAVIORAL PHENOTYPE OF FXS: IMPLICATIONS FOR LANGUAGE DEVELOPMENT

The FXS phenotype is defined by a profile of relative strengths and weaknesses in various neurocognitive domains and a heightened probability of various forms of psychopathology (Cornish, Turk, & Hagerman, 2008; Dykens, Hodapp, & Finucane, 2000; Kau, Meyer, & Kaufmann, 2002; Keysor & Mazzocco, 2002). It is reasonable to suppose that these aspects of the phenotype of FXS will shape language and literacy development in important ways in affected individuals (Abbeduto, McDuffie, Brady, & Kover, in press).

FXS is associated with impairments or delays in numerous cognitive domains relevant for language (Abbeduto et al., in press; Belser & Sudhalter, 1995; Cornish, Sudhalter, & Turk, 2004; Mirrett, Roberts, & Price, 2003; Munir, Cornish, & Wilding, 2000; Murphy & Abbeduto, 2003). Cognitive domains that are characterized by especially serious delays or impairments (e.g., greater than expected for their mental ages) include sequential processing (Burack et al., 1999; Dykens, Hodapp, & Leckman, 1987); working memory, including both its auditory and visual–spatial components (Lanfranchi, Cornoldi, Drigo, & Vianello, 2008; Ornstein et al., 2008); and attention, particularly problems with sustained attention and inhibitory control (Bregman, Leckman, & Ort, 1988; Cornish, Scerif, & Karmiloff-Smith, 2007; Mazzocco, Pennington, & Hagerman, 1993; Ornstein et al., 2008; Scerif, Cornish, Wilding, Driver, & Karmiloff-Smith, 2007; Sullivan et al., 2007). Domains of cognition that are relatively strong in FXS, although still delayed relative to chronological age expectations, include simultaneous processing (Dykens, Hodapp, Ort, & Finucane, 1989) and long-term memory (Freund & Reiss, 1991). These domains of cognition are involved in language learning and thus the profile of cognitive impairments associated with FXS is likely to lead to impairments in language; however, the variable extent of delays across cognitive domains would also be expected to produce variability in impairments across linguistic domains.

Individuals with FXS evidence relatively high rates of psychopathology and challenging behaviors, which can function as barriers to language development (Abbeduto & Chapman, 2005). Hyperarousal (Wisbeck et al., 2000); hyperactivity (Baumgardner, Reiss, Freund, & Abrams, 1995; Bregman et al., 1988; Dykens et al., 1989; Freund, Reiss, & Abrams, 1993; Mazzocco et al., 1993); and anxiety, particularly social anxiety (Bregman et al., 1988; Mazzocco, Baumgardner, Freund, & Reiss, 1998), are frequent in individuals with FXS. These forms of psychopathology, which occur at higher rates in FXS than in many other neurodevelopmental disorders (Dykens et al., 2000), are likely to inhibit the types of positive social interactions that foster language growth and development.

A high comorbidity exists between FXS and autism (Lewis et al., 2006). Autistic-like behaviors are common among individuals with FXS (Bailey et al., 1998; Bailey, Hatton, Mesibov, Ament, & Skinner, 2000; Bailey, Hatton, Skinner, & Mesibov, 2001; Feinstein & Reiss, 1998), with more than 90% of this population displaying such behaviors (R. J. Hagerman, 1999). Autistic-like behaviors frequently noted include poor eye contact, language delay, perseveration and echolalia, self-injurious behaviors, motor stereotypes, and poor social relating (see Filipek, 2005). These behaviors are often sufficiently frequent and severe to warrant a comorbid diagnosis of autism (Bailey et al., 2004). The rate of autism in FXS has been suggested to be somewhere between 25% and 50% (Bailey et al., 2004; Brown, 1982; Demark, Feldman, & Holden, 2003; Hatton et al., 2006; Kaufmann et al., 2004; Rogers, Wehner, & Hagerman, 2001; Sabaratnam, Murthy, Wijeratne, Buckingham, & Payne, 2003). It is important to

note, however, that no population-based epidemiological studies of the FXS–autism comorbidity have been conducted. Moreover, the diagnosis of autism is based on behavioral criteria and clinical judgment and thus, the prevalence rate depends on the instrument(s) used to diagnose autism (Harris et al., 2008).

The behavioral phenotype described thus far differs from the phenotypes of several other developmental disorders (McDuffie & Abbeduto, 2009), including those considered in the other articles in this issue of *Topics in Language Disorders*. For example, Down syndrome (DS) is associated with relative strengths in visual–spatial memory compared with poorer auditory skills and equivalent developmental rates for sequential and simultaneous processing skills (Abbeduto & Murphy, 2004; Chapman & Hesketh, 2000); whereas FXS is associated with relative strengths in simultaneous processing and relative weaknesses in both visual–spatial and auditory working memory domains. As another example, although anxiety is a substantial problem in Williams syndrome (WS), anxiety is likely to be manifested as specific phobias rather than as social anxiety in WS (McDuffie & Abbeduto, 2009). Although autism is now recognized to be more frequent in a host of developmental disabilities than previously thought, including DS and WS, the rates appear to be higher in FXS and to possibly reflect a different "weighting" of autism symptoms compared with these other conditions (Kaufmann et al., 2004).

Despite the existence of a phenotype defined by a characteristic profile of problems, it is important to recognize that considerable within-syndrome variability exists. For example, females with FXS generally are less severely impaired than males with FXS (R. J. Hagerman, 1999), and individuals who lack comorbid symptoms of autism tend to have less severe cognitive impairments (Lewis et al., 2006). Phenotypic variation is also related to characteristics of the FMR1 mutation (e.g., fragile X mental retardation protein levels) and many other genes inherited from parents (Belmonte & Bourgeron, 2006). In addition, educational experiences, interactions with parents and other family members, and the broader social context in which the individual with FXS lives can play an important role in shaping his or her developmental course (Murphy & Abbeduto, 2005). Development for all individuals whether they have special needs or not, is the complex result of genes, environments, and their interactions.

LANGUAGE DEVELOPMENT IN FXS

As indicated above, many factors are expected to influence language development in individuals with FXS. As we describe the language development of individuals with FXS in the following sections, we address the influence of gender and comorbid FXS and autism. Relative to other disabilities with associated language learning difficulties, such as DS, little is known about the language development of individuals with FXS. In the following review, we describe the prelinguistic, receptive, expressive, and pragmatic language abilities as well as the repetitive language and speech intelligibility of individuals with FXS. When possible, we also compare the language skills of individuals with FXS to individuals with other intellectual disabilities, such as DS and autism. In addition, we report on factors that have been found to be related to the language development of individuals with FXS. These factors include gender and the presence of characteristics of autism. It is important to note at the outset that the majority of research to date has focused largely on describing rather than explaining the language and literacy behaviors of individuals with FXS. In fact, there have been virtually no studies focused on understanding the language and social environments of individuals with FXS or the ways in which those environments contribute to the phenotype described (Murphy & Abbeduto, 2005).

Prelinguistic communication

Before young children with typical language and cognitive abilities are able to

communicate linguistically using conventional words and signs, they use vocalizations, gestures, and coordinated eye gaze in isolation and combination to express desires and comment on their environment (Bates, O'Connell, & Shore, 1987; Volterra, Caselli, Capirci, & Pizzuto, 2005). At around 12 months of age, children with typical development begin to use words. As such children gain proficiency with words, the use of prelinguistic modes of communication tends to subside. However, for many children with language learning difficulties, such as young children with FXS, first words are acquired much later than 12 months of age and the use of prelinguistic communication persists well into toddlerhood. In a study of 55 children with FXS, 18 months to 3 years of age, over half of the children's biological mothers reported that their children were nonverbal, defined as using no words or producing words only in imitative contexts (Brady, Skinner, Roberts, & Hennon, 2006).

Examination of the specific early communication skills of young children with FXS reveals comparable delays across communicative domains (Roberts, Mirrett, Anderson, Burchinal, & Neebe, 2002). For example, Roberts and her colleagues (2002) found that the mean differences in scores across domains such as communicative function, gestural communicative means, vocal communicative means, and symbolic behavior on the Communication and Symbolic Behavior Scales (Wetherby & Prizant, 1993) were typically within 0.5 *SD* of each other.

Although we know of no studies that have examined the direct impact of gender and autism status on the development of prelinguistic communication, in the study by Brady et al. (2006) described above, a greater proportion of young boys with FXS (25/44; 57%) was reported to be nonverbal communicators than girls with FXS (4/11; 36%). Moreover, the mean age of the boys with FXS, who remained nonverbal communicators, was 26.4 months compared with the mean age of 18.5 months for girls. These results suggest that early in development, the language skills of young boys

with FXS may be more severely affected than those of young girls with FXS.

Receptive language

Individuals with FXS have significant deficits in receptive language when compared with peers who have typical intellectual development. Specifically, individuals with FXS have difficulty in their comprehension of single words, grammatical morphemes, and multiword syntactic forms.

Vocabulary

Individuals with FXS have been shown to have receptive vocabularies that are significantly weaker than those of younger children with typical development, but the picture is mixed. In a study of boys 3 through 15 years of age, Price, Roberts, Vandergrift, and Martin (2007) found that boys with FXS had receptive vocabularies significantly below those of younger children with typical development, even when controlling for nonverbal cognition. In other studies however, the receptive vocabulary skills of individuals with FXS have been found to be no different from those of younger, typically developing peers at similar nonverbal cognitive levels (Abbeduto et al., 2003; Roberts, Price, Barnes, et al., 2007).

Morphology and syntax

A similar pattern has been found in examinations of other receptive language domains, including grammatical morphology and syntax, with some studies reporting the skills of individuals with FXS to be below those of children with typical development matched on nonverbal cognitive level (Price et al., 2007; Roberts, Mirrett, & Burchinal, 2001) and others reporting abilities commensurate with those of younger cognitively matched children with typical development (Abbeduto et al., 2003). Evidence also suggests that receptive language abilities of individuals with FXS improve over time (Roberts et al., 2001). It appears that young children with FXS may be slower to develop their receptive morphology and syntax compared with younger children at similar cognitive

developmental levels, but that, with language growth, the performance gap narrows, allowing the receptive language abilities of individuals with FXS to become on par with cognitive-matched peers.

Related factors

Gender and autism status have been found to have significant associations with receptive language development. Although receptive language abilities are negatively affected in both males and females with FXS, the receptive language abilities of females have been found to be less impaired than those of males (Abbeduto et al., 2003). Regarding the comorbidity with autism, it is important to note that methods for identifying autism have varied across studies. Some studies have relied on the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002) and/or Autism Diagnostic Interview (ADI; Lord, Rutter, & Le Couteur, 1994), which constitute the current gold standards for diagnosing autism. Other studies have relied on screening tools such as the Autism Behavior Checklist (ABC; Krug, Arick, & Almond, 1980) or clinician judgment, which rely more heavily on subjective observation. Such variability makes it difficult to integrate findings across studies. Nevertheless, the findings to date suggest that individuals with FXS who meet the criteria for autism have more impaired receptive language abilities than individuals with FXS who do not meet the criteria (Lewis et al., 2006; Philofsky, Hepburn, Hayes, Hagerman, & Rogers, 2004; Roberts et al., 2001).

Receptive language ability in these studies was based on standardized normative measures of general receptive language skills such as the Mullen Scales of Early Learning (Mullen, 1995), the Test for Auditory Comprehension of Language (Carrow-Woolfolk, 1985), and the Reynell Developmental Language Scales (Reynell & Gruber, 1990). It is important to note, however, that not all studies have found strong associations between autism status and receptive language abilities when similar standardized measures were used to assess language development (e.g., Kaufmann et al., 2004; Price et al., 2007).

Expressive language

Similar to their receptive language abilities, the expressive language abilities of individuals with FXS are significantly impaired relative to chronological age expectations. These impairments span all communicative domains, including expressive vocabulary, morphology, and syntax.

Vocabulary

The expressive vocabulary skills of individuals with FXS have generally been found to be significantly reduced compared with developmentally matched peers with typical intellectual development based primarily on the number of different words produced (Roberts et al., 2002; Roberts, Price, Barnes, et al., 2007; Roberts, Price, & Malkin, 2007). For example, in one investigation of young boys with FXS ranging from 21 to 77 months of age, expressive vocabulary skills, based on the total number of different words and different multiword combinations produced in the Communication and Symbolic Behavior Scales (Wetherby & Prizant, 1993), were found to develop at a significantly slower rate than in younger children with typical cognitive development (Roberts et al., 2002).

Morphology and syntax

Expressive morphology and syntax also present particular developmental challenges for individuals with FXS. Similar to vocabulary development, compared with younger, typically developing children at similar cognitive developmental levels, the expressive morphologic and syntactic abilities of individuals with FXS are delayed. Such delays have been identified on general measures of expressive language as well as on measures addressing more specific aspects of expressive language. For example, the mean length of utterance of males with FXS has been found to be significantly shorter than that of younger, typically developing children, controlling for nonverbal mental age and maternal education levels (Roberts, Hennon, et al., 2007;

Sudhalter, Scarborough, & Cohen, 1991). When using the Expressive Language Scale of the Reynell Developmental Scales (Reynell & Gruber, 1990), boys with FXS between the ages of 20 and 86 months have been found to have significantly slower expressive language development than the normative sample (Roberts et al., 2001).

Impairments in expressive language ability are also evident when measures are used that document the presence of specific morphological and syntactic forms, such as the Index of Productive Syntax (IPSyn) scores (Scarborough, 1990). IPSyn scores reveal that individuals with FXS have a tendency to produce fewer complex noun and verb phrases in their conversational language than younger, typically developing individuals, when nonverbal mental age and maternal education levels are controlled (Roberts, Hennon, et al., 2007; Sudhalter et al., 1991). One noteworthy exception to this trend is that on the IPSyn Questions/Negations subscale, no differences have been found between boys with FXS and younger boys with typical development (Roberts, Hennon, et al., 2007; Sudhalter et al., 1991). Thus, some, but not all, aspects of morphology and syntax appear to be particularly challenging for individuals with FXS.

Although delayed, expressive narration may be a relative language strength for adolescents and young adults with FXS. In a study conducted by Keller-Bell and Abbeduto (2007) in which the narrative language skills of adolescents and young adults were examined, no significant language differences were found between the FXS group and the DS and typical development comparison groups matched on nonverbal mental age. Specifically, no differences were identified based on the microstructural measures of mean length of communication units in words, percentage of grammatical communication units, clause density, and mean number of causal and conditional connectors.

Related factors

We know of no studies comparing the expressive language abilities of males and females with FXS. Moreover, the impact of autism status on the expressive language abilities of individuals with FXS is unclear, which may be due, in part, to the use of different measures for diagnosing autism across studies. Studies examining the impact of a comorbid FXS and autism spectrum disorder diagnosis that have controlled for nonverbal mental age and chronological age have yielded inconsistent findings regarding expressive language performance. For example, in one study of children with FXS ranging in age from 22 to 45 months, the expressive language performance of those with FXS with comorbid autism spectrum disorder was found to be significantly lower on measures from the Mullen Scales of Early Learning than for children with the FXS diagnosis only (Mullen, 1995; Philofsky et al., 2004). In contrast, other studies have found no differences between individuals with FXS who also met criteria for autism spectrum disorder and those with FXS only when comparing performance on measures such as mean length of utterance (Price et al., 2008), IPSyn scores (Price et al., 2008) and the Oral Expression Scale of the Oral and Written Language Scales (Carrow-Woolfolk, 1995; Lewis et al., 2006).

Pragmatics

Pragmatic competencies are needed to support social language use, such as using language for different purposes (e.g., greeting, informing, requesting, commenting), changing language based on the needs of the listener (e.g., speaking differently to a baby than to an adult), and following conversational and storytelling rules (e.g., rephrasing when misunderstood, introducing characters in a story) (American Speech-Language-Hearing Association, 2008). Several studies have showed the pragmatic language skills of individuals with FXS to present particular challenges (Ferrier, Bashir, Meryash, & Johnston, 1991; Roberts, Martin, et al., 2007). In this section, we describe the pragmatic skills of individuals with FXS within conversational, narrative, and informative contexts and the ability to repair communication breakdowns.

Conversational language

Examinations of social use of language within conversational contexts reveal that both males and females with FXS have difficulty relative to developmental-level expectations maintaining coherent, semantically rich conversational discourse (Mazzocco et al., 2006; Roberts, Martin, et al., 2007; Sudhalter & Belser, 2001; Sudhalter, Cohen, Silverman, & Wolf-Schein, 1990). For example, in studies designed to compare the discourse abilities of individuals with FXS to individuals with typical development while controlling for the impact of developmental level, it has been found that boys with FXS produce fewer conversational turns in which they add or request new information (Roberts, Martin, et al., 2007). Research has also found that females with FXS produce fewer questions that facilitate the continuation of the conversational topic (Mazzocco et al., 2006). We found no studies that have compared directly the conversational language skills of males with FXS with those of females with FXS.

Despite the tendency for individuals with FXS to have weaker conversational pragmatic abilities than developmentally similar children, the conversational pragmatic skills of individuals with FXS have been shown to be both weaker and, in some circumstances, better than those with intellectual disability due to other causes. For example, it has been noted that males with FXS are more likely to produce tangential, or unrelated, utterances in their conversational language (Sudhalter & Belser, 2001) than developmentally matched males with autism and individuals with intellectual disabilities due to unknown etiologies. However, males with FXS are better able to engage in conversational turn taking (Sudhalter et al., 1990) than males with autism with similar chronological and mental ages.

The conversations of boys with FXS and comorbid autism include significantly more utterances that fail to continue the conversation because the utterances have not fulfilled semantic or informational expectations than those of boys with FXS who do not meet criteria for autism, as well as to boys with DS and younger boys with typical development, controlling for nonverbal mental age (Roberts, Martin, et al., 2007). Group comparisons have also shown that children with FXS and autism are more likely to produce utterances that abruptly change the conversational topic following a direct question or directive (Roberts, Martin, et al., 2007). Although such differences in language profiles are to be expected given that the diagnosis of autism implies serious challenges in the social and communicative domains, such findings provide a more detailed picture of the intervention needs of individuals with FXS with a comorbid autism diagnosis.

Narrative language

Narrative language abilities of individuals with FXS at the macrostructural level present a mixed picture. Some evidence shows them to be below younger individuals with similar mental ages; other evidence shows them to be no different from mental age-matched peers. Narrative macrostructure refers to connected text at a global level, reflecting the text as a whole, and includes measures of content, organization, and overall quality (Kintsch & van Dijk, 1978). In a study evaluating narrative pragmatic skills of women with FXS (Simon, Keenan, Pennington, Taylor, & Hagerman, 2001), researchers found that females with the full mutation FXS had more difficulty than females with the premutation and females with typical development (controlling for chronological age and intelligence level) to select coherent endings to jokes and stories. Contrasting evidence was found in a study in which a high-point analysis was used to document the occurrence of evaluation devices such as mental state verbs, character name, character dialogue, and fantasy or exaggeration. In that study, adolescents with FXS were found to use a similar number and types of evaluation devices as younger typically developing children at a similar level of cognitive development (Keller-Bell & Abbeduto, 2007).

In the study by Keller-Bell and Abbeduto (2007), the performance of the adolescents with FXS was also compared with that of adolescents with DS with similar intellectual abilities. Despite the tendency for individuals with DS to have weaker language skills than individuals with FXS in general, comparisons revealed that the adolescents with FXS produced significantly fewer different types of narrative evaluation devices than those with DS.

Findings from the aforementioned investigations provide evidence that both males and females have significant deficits in narrative pragmatic skills. However, there are no known studies that have specifically examined the impact of gender or the impact of a comorbid FXS and autism diagnoses on narrative abilities.

Informative language

In addition to evaluating the pragmatic language skills of individuals with FXS in conversation and narrative contexts, the pragmatic skills of adolescents and young adults with FXS have been examined in contexts in which individuals with FXS are instructed to describe unique shapes to a listener through an opaque barrier with the goal to have the listener successfully select the described item (Abbeduto et al., 2006). Results of such evaluations indicate that individuals with FXS are less likely to use consistent, unique descriptors that reliably distinguish shapes being described to a listener than younger children at similar developmental levels. This finding suggests that individuals with FXS do not adequately consider the informational needs of the listener. This lack of consideration is likely to negatively impact both the conversation and narrative discourse of individuals with FXS. Differences in informative language skills between males and females with FXS as well as between those who do and do not meet criteria for autism have not yet been documented.

Communication breakdowns

During communicative exchange, it is not only important for the speaker to use clear, consistent, and coherent conversational and narrative language, it is also important for the listener to continually process linguistic information in an attempt to comprehend and understand the speaker's message. If at any point during the linguistic exchange the listener becomes confused and fails to understand the speaker's message, this may result in a communication breakdown. It is important for listeners to be aware of and able to indicate this lack of understanding. The ability of individuals with FXS to signal noncomprehension in such circumstances appears to be limited. For example, one study (Abbeduto et al., 2008) specifically designed to evaluate the signaling of noncomprehension by adolescents and young adults with FXS in a task in which some of the instructions were deliberately inadequate found that individuals with FXS signaled their lack of understanding significantly less frequently than younger, typically developing children at similar developmental levels. In this study, signaling of noncomprehension of language was significantly related to receptive language ability, with stronger receptive language abilities more likely to be associated with greater use of noncomprehension signals. In addition, this study included an analysis of the impact of gender on task performance. Results of this analysis revealed that males with FXS tend to signal noncomprehension significantly less often than females with FXS. The impact of comorbid autism has yet to be investigated in this area.

Repetitive language

Repetitive language, or perseveration, refers to repetition of oneself and includes many types, such as phoneme, word, phrase, utterance-level, topic, or conversational device repetitions (Belser & Sudhalter, 2001; Murphy & Abbeduto, 2007). In general, it appears that individuals with FXS produce a greater proportion of repetitive language than expected on the basis of developmental level (Levy, Gottesman, Borochowitz, Frydman, & Sagi, 2006; Mazzocco et al., 2006). For example, in a study including Hebrew-speaking boys between 9 and 13 years of age, significantly more repetitive language within

utterances was found in the context-bound language samples of participants with FXS than typical children with similar language abilities (Levy et al., 2006). Individuals with FXS tend to include more repetitions at all language levels (Belser & Sudhalter, 2001; Sudhalter et al., 1990) than individuals with similar language abilities and chronological ages but different developmental disabilities (e.g., autism spectrum disorder, intellectual disability of unknown origin). Moreover, the repetitive language of individuals with FXS appears to be distinct from delays in syntactic language development (Sudhalter et al., 1991). It has been claimed that this feature of language is unique to individuals with FXS and is a core feature of the FXS phenotype (Sudhalter et al., 1990).

In terms of gender, it has been found that both males and females with FXS include a large proportion of utterances with repetitions (e.g., 26% of utterances; Murphy & Abbeduto, 2007). However, the only noted difference between the repetitions of males and females is that males with FXS tend to use more conversational device repetitions such as "that's a wrap" or "right on" than females with FXS, suggesting that males may rely more on rote expressions in their expressive language. No gender differences were found on the basis of utterance-level or topic repetitions (Murphy & Abbeduto, 2007). We know of no studies that have specifically examined repetitive language use of individuals with comorbid FXS and autism.

Speech intelligibility

Although few studies have examined the speech intelligibility of individuals with FXS, it appears that the speech skills of children with FXS are not dramatically different from the skills of younger, mental age-matched children with typical language and cognitive development. In one thorough study of the phonological accuracy and error patterns of boys with FXS, Roberts et al. (2005) found that boys with FXS were not significantly different from younger, typically developing children matched on mental age in terms of their production of early-, middle-, and late-developing consonants. There were also no differences between the boys with FXS and the typical comparison group based on the use of phonological processes including substitution and syllable structure processes. Similarly, in this study, significant differences were not found between the boys with FXS and the younger mental age-matched children with typical development in their phonological approximations of whole words. The study by Roberts et al. also included a mental age-matched comparison group of individuals with DS. Comparisons based on accuracy of phoneme production, use of phonological processes, and whole-word approximations indicated that the individuals with DS performed significantly below both the mental age-matched FXS and typically developing groups across all measures. We know of no published studies that have examined the impact of gender and autism status on the speech intelligibility of individuals with FXS.

LITERACY DEVELOPMENT IN FXS

The following sections review current evidence concerning the literacy development of children and adolescents with FXS. To date, only a few studies have examined literacy skills and the subprocesses that support reading in this population. Higher-level literacy skills such as reading comprehension and listening comprehension of written text have not yet been examined. Moreover, we know of no studies investigating the impact of related factors, such as gender and comorbid autism, and FXS. In general, individuals with FXS appear to read better than expected when their cognitive abilities are taken into account. In addition, these individuals may use a different pattern of strategies when compared with typically developing children who have been matched for reading abilities.

Phonological processing

A considerable amount of evidence links reading development to the awareness of the sound structure of spoken language for children with developmental disabilities as

well as for those with typical development (Cupples & Iacono, 2000). Numerous studies have demonstrated that phonological awareness is a reliable predictor of individual differences in reading ability (Hulme & Snowling, 1992; Rack, Hulme, Snowling, & Reese, 1993; Siegel, 1993; Wagner & Torgesen, 1987) and that children who are more proficient on phonological processing tasks usually learn to decode words more easily than children with phonological processing difficulties (Menghini, Verucci, & Vicari, 2004). Although these findings are based on research primarily with children who are developing typically, recent work with children with atypical development reveals a similar pattern (e.g., Cardoso-Martins & Frith, 2001; Gombert, 2002; Laws & Gunn, 2002; Snowling, Hulme, & Mercer, 2002).

Johnson-Glenberg (Buckley & Johnson-Glenberg, 2008; Johnson-Glenberg, 2003) assessed the strength of phonemic representations in her research with young men with FXS using four measures from the Phonological Awareness Test (Robertson & Salter, 1997): rhyming, phonemic segmentation, deletion, and isolation. Results showed that the FXS group performed at the seventh percentile for the normative group on rhyme, the eighth percentile on segmentation, the eighth percentile on phoneme deletion, and the second percentile on isolation. These findings suggest that the individuals with FXS in this study had relatively compromised or underdeveloped phonological awareness skills.

Whole-word decoding

There is evidence to suggest that individuals with FXS perform relatively well on whole-word decoding tasks involving real words, but have difficulty with nonword decoding tasks, which require a higher level of phonological processing ability. On the Word Identification subtest of the Woodcock Reading Mastery Tests–Revised (Woodcock, 1998), a measure of whole-word decoding of real words, Johnson-Glenberg (Buckley & Johnson-Glenberg, 2008; Johnson-Glenberg, 2003) found that the FXS group performed almost as well as the typically developing comparison group that was matched on mental age. However, the scores of the participants with FXS on the Word Attack subtest, a nonword-reading task, were significantly lower. Results from an earlier administration of the Word Identification subtest with a younger, typically developing cohort matched for nonverbal mental age were significantly different, with the FXS group outperforming the younger children with typical development. The superior performance of the participants with FXS likely reflects the significant age difference between the two cohorts—the average age of the FXS group was approximately 20 years whereas the typically developing children were, on average, 5 years 6 months old—and thus, the participants with FXS had greater experience with print and vocabulary.

SUMMARY

FXS, the leading inherited cause of intellectual disability, is associated with a variety of challenges to language and literacy development and weaknesses in a number of related neurocognitive domains. Individuals with FXS have particularly weak sequential processing, working memory, and attention skills, skills that are critical for language and reading learning. From an early age, children with FXS demonstrate difficulties acquiring language such that there are significant delays in the acquisition of first words. Across the receptive and expressive language domains, individuals with FXS exhibit delays relative to chronological age expectations in their vocabulary development as well as their understanding and use of morphology and syntax. This is evident by the similar performance of individuals with FXS and typically developing children at similar levels of cognitive development on receptive and expressive language tasks. Individuals with FXS also have significant weaknesses in pragmatics and their ability to identify and provide necessary informative details in language discourse is impaired more than expected on the basis of their levels of cognitive development. The occurrence of repetitive language in the language of individuals with FXS is also significantly greater

than is expected on the basis of their mental age and has been suggested to be a characteristic unique to FXS. Individuals with FXS also exhibit significantly impaired reading skills including their phonological awareness, balanced with slightly better ability to decode whole words. The decoding of nonwords is especially difficult for individuals with FXS, indicating weak phonological processing use in new words.

Despite weaknesses in cognitive, language, and literacy development, there are areas in which individuals with FXS display relative strengths, although their performances remain below chronological age expectations. Some of these relative strengths include simultaneous processing and long-term memory abilities. Although language development is delayed in individuals with FXS, the majority of individuals with FXS become oral communicators with relatively stronger comprehension than expressive language abilities. Relative to individuals with autism, individuals with FXS demonstrate strengths in conversational turn taking. Moreover, the speech intelligibility of individuals with FXS is good and decoding of whole real words of individuals with FXS is better than expected on the basis of the nonverbal cognitive abilities.

It is important to note that great within-syndrome variability exists in the language and literacy development of individuals with FXS. Two factors that have been identified as contributing to performance variability are gender and comorbid FXS and autism diagnoses. Specifically, females with FXS tend to have stronger language skills than males with FXS and individuals with FXS who also do not meet diagnostic criteria for autism exhibit stronger language skills than individuals with FXS who also meet criteria for a diagnosis of autism.

CLINICAL IMPLICATIONS

The negative impact of FXS across language and literacy domains is associated with widespread developmental delays, but little is known about possibilities for influencing the developmental trajectory through high-quality education and language intervention. When assessing individuals with FXS, it is important to implement comprehensive evaluations of their individual profiles of language and literacy abilities to identify areas of strength as well as impairment so that individualized services may be provided.

Most children with FXS begin speech-language intervention when they are very young (Brady et al., 2006). At an early age, intervention should focus on establishing prelinguistic communication skills such as the use of gestures, vocalization, and coordinated eye gaze alone and in combination to express needs and wants. Depending on their levels of development, as children grow older, delays in speech production may indicate a need for alternative and augmentative supports (Brady et al., 2006). However, as the spoken communication skills of children with FXS develop, the intervention foci can shift accordingly. Over the course of intervention, language goals for children with FXS will most likely include improving the expression and comprehension of vocabulary, morphology, and syntax. For older children and adolescents with FXS, treatment goals are likely to incorporate focus on pragmatic skills, narrative language, and literacy development in meaningful contexts. Strengths in language comprehension, conversational skills, and whole-word recognition should be taken into consideration when selecting intervention goals, contexts, and programs.

Although this review supports a clear need for speech-language and literacy intervention services, there are no known studies that have specifically evaluated language interventions for individuals with FXS. However, intervention programs that have been designed broadly for individuals with language learning difficulties including individuals with intellectual and developmental disabilities may be appropriate for individuals with FXS. For example, programs such as Responsivity Education/Prelinguistic Milieu Teaching (Warren et al., 2006), The Hanen Centre's More Than Words program (Sussman, 1999), and the Picture Exchange Communication System (Charlop-Christy & Jones, 2006) may

be adapted for younger children with FXS. Older children and adolescents with FXS may benefit from adapted phonological awareness programs (Gillon, 2006), interventions incorporating visual strategies (Hoffman & Norris, 2006), and treatments focused on morphological and syntactic skills as well as story-telling abilities such as narrative-based language interventions (Finestack, Fey, Sokol, Ambrose, & Swanson, 2006). Nonetheless, until clinical studies examine the use of these programs with individuals with FXS, the efficacy and language and treatment programs for individuals with FXS remain unknown.

Regardless of the intervention program selected, interventionists should take into account behavioral strengths and weaknesses associated with FXS. For example, an early interventionist may need to design sessions that include behavior management plans that provide a consistent routine and structured environment (Hatton et al., 2000). For some individuals, interventionists may need take special care to design programs that include frequent breaks to maximize attention and/or alleviate anxiety levels.

CONCLUSIONS

Although it is clear from existing examinations of FXS that the language and literacy development of individuals with FXS is severely compromised, relatively little is known about the specific nature of these language and literacy weaknesses. Furthermore, there are no known studies that have examined the efficacy of interventions addressing these weaknesses in this particular population. Thus, it is critical for future studies to investigate more fully the language and literacy profiles of individuals with FXS and to evaluate intervention approaches for this population. It is also important to recognize that little attention has been paid by researchers to the ways in which the language and literacy outcomes of individuals with FXS are shaped by their environments. This latter omission must be corrected if we are to be in a position of improving outcomes for affected individuals.

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