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Language and Communication Abilities in Adolescents with Fetal Alcohol Spectrum Disorders

A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy

in

Clinical Psychology

by

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2020

The Dissertation of Lauren D. Poth is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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University of California San Diego

San Diego State University

2020

DEDICATION

Dedicated to my parents, without whom I would not be where I am today, and to my ever-supportive husband.

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Acknowledgments

I would like to gratefully acknowledge Sarah N. Mattson, Ph.D. for her support as the chair of my committee and graduate advisor. Throughout my graduate program and unfailing mentorship on this project, her guidance has been instrumental. Your constant leadership and encouragement have undoubtedly prepared me for my future career endeavors.

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ABSTRACT OF THE DISSERTATION

Language and Communication Abilities in Adolescents with Fetal Alcohol Spectrum Disorders

by

Lauren D. Poth

Doctor of Philosophy in Clinical Psychology

University of California San Diego, 2020
San Diego State University, 2020

Professor Sarah N. Mattson, Chair

Language and communication are two areas of functioning that are largely understudied among youth with fetal alcohol spectrum disorders (FASD). The current study aimed to elucidate the profile of language (i.e., receptive, expressive) and communication (i.e., functional, social) abilities in adolescents with FASD and investigate the relationship of language to communication.

Subjects aged 12-17 years with (alcohol-exposed [AE] = 31) and without (control [CON] = 29) prenatal alcohol exposure were included. Receptive and expressive language were measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition (CELF-5). Parents completed the Children's Communication Checklist – Second Edition (CCC-2) as a subjective measure of general language. Functional communication was measured by the Student Functional Assessment of Verbal Reasoning and Executive Strategies (S-FAVRES) and parents completed the Social Skills Improvement System (SSIS) to measure social communication.

Multivariate analysis of variance determined the overall profile of language and communication and whether it differed between groups. Next, multiple regression analyses examined the relationship of cognitive domains (inhibition, working memory, attention) to receptive and expressive language. Finally, multigroup path analysis determined if the proposed mediated effects of language (receptive, expressive) on communication (functional, social) via cognitive domains (inhibition, working memory, attention) differed between groups.

The AE group performed significantly lower than the CON group on receptive language and parent-report of general language while groups did not significantly differ on expressive language. Groups did not significantly differ in functional communication while social communication was rated as significantly lower in the AE group. All cognitive domains were significantly related to receptive language while attention and inhibition related to expressive language across groups. Expressive language significantly related to both functional and social communication while receptive language significantly related to functional communication only. Overall, no indirect relations via cognitive domains were significant.

The results of this study provide important information regarding the relations between basic language abilities and higher-level communication skills of adolescents with FASD. Interventions targeting working memory, inhibition, and attention may improve language abilities, which in turn may improve communication skills. Ultimately, improving communication skills of youth with FASD may translate to better overall functioning in multiple settings.

Background and Literature Review

During pregnancy, toxic agents can disrupt development of the embryo and fetus leading to altered developmental trajectories. Such agents are referred to as teratogens and include a wide variety of substances (e.g., drugs of abuse, diseases and viruses, environmental toxins, prescription medications). Exposure to teratogens can alter numerous aspects of development, including physical, behavioral, and cognitive development. Such alterations can result in significant consequences later in life. For example, individuals exposed to alcohol in utero may experience cognitive impairments (e.g., impaired cognitive ability, executive function, memory, attention), behavioral impairments (e.g., hyperactivity, impaired social functioning, high rates of co-occurring psychiatric disorders), and physical dysmorphology (e.g., deficient growth, facial dysmorphology) (Mattson, Crocker, & Nguyen, 2011; Mattson & Riley, 1998). Almost five decades of research have investigated the behavioral and cognitive impacts of prenatal alcohol exposure with the goal of identifying the neurobehavioral profile of abilities for individuals affected by alcohol exposure. Ultimately, such knowledge will provide a foundation to develop tools for identification of these individuals and interventions to alleviate functional impacts associated with prenatal alcohol exposure.

Fetal Alcohol Spectrum Disorders

Fetal alcohol spectrum disorders (FASD) encompass the range of neurobehavioral and physical impacts due to prenatal alcohol exposure, with fetal alcohol syndrome (FAS) representing one of the most severe consequences (Bertrand, Floyd, & Weber, 2005; Mattson et al., 2011). FASD represents a serious public health concern with prevalence estimates ranging between 2-5% of the school-age population (May et al., 2014; May et al., 2015; May et al., 2018). Despite the known detrimental effects of prenatal alcohol exposure, alcohol consumption while pregnant continues to represent a serious public health concern. The Centers for Disease Control reports that one in 10 women drinks while pregnant, with one in 33 engaging in binge drinking episodes, and these rates have not decreased with time (Tan, Denny, Cheal, Sniezek, & Kanny, 2015). In light of several decades of preventative measures, women continue to drink heavily while pregnant leading to children who suffer from significantly impairing behavioral and cognitive challenges. Notably, the effects of prenatal alcohol exposure continue to impact the lives of these individuals over the lifetime (Spohr, Willms, & Steinhausen, 1993). As highlighted above, effects include behavioral, cognitive, and physical features (Mattson et al., 2011).

Neurobehavioral Disorder Associated with Prenatal Alcohol Exposure. *Neurobehavioral Disorder Associated with Prenatal Alcohol Exposure* (ND-PAE) is included in the appendix of the *Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition* (DSM-5; American Psychiatric Association, 2013) under "conditions for further study" as one possible FASD. ND-PAE encompasses the range of neurobehavioral effects commonly seen following prenatal alcohol exposure and can occur in children with histories of alcohol exposure independently of any physical effects (i.e., an exposed child with or without FAS can meet diagnostic criteria for ND-PAE). In addition to a history of more than minimal prenatal alcohol exposure, the proposed criteria for ND-PAE require impairment in three functional domains: neurocognitive functioning, self-regulation, and adaptive functioning.

Neurocognitive functioning. Prenatal alcohol exposure can affect cognitive functioning across several domains, including intellectual functioning, executive function, learning and memory, and visual-spatial skills. While Intellectual Disability (ID), defined as the combination of IQ <70 and adaptive function deficits, is not required for an alcohol-related diagnosis, individuals with prenatal alcohol exposure may demonstrate impaired intellectual functioning with average IQ scores falling within the low average to borderline ranges (Coles et al., 1991). As described below, adaptive function deficits can also occur independently of IQ deficits in this population.

Executive functioning deficits have been well documented in FASD research. Numerous studies have evidenced deficits in executive functioning among those exposed to alcohol prenatally (Kodituwakku & Kodituwakku, 2014; Mattson et al., 2011; Ware et al., 2012). Executive function deficits may manifest as impaired cognitive flexibility or set shifting, verbal fluency, abstraction, and spatial working memory (Mattson et al., 2013). Parent reports suggest the most salient deficits are in problem solving and inhibition (Nguyen et al., 2014), deficits that have likewise been supported by neuropsychological testing (McGee, Schonfeld, Roebuck-Spencer, Riley, & Mattson, 2008; Schonfeld, Mattson, Lang, Delis, & Riley, 2001; Vaurio, Riley, & Mattson, 2008).

Learning impairments due to prenatal alcohol exposure can greatly impact these individuals' academic achievement. Children affected by prenatal alcohol exposure demonstrate impaired reading and math abilities (Carmichael Olson, Sampson, Barr, Streissguth, & Bookstein, 1992; Howell, Lynch, Platzman, Smith, & Coles, 2006; Mattson & Riley, 1998). Such deficits can lead to a diagnosis of specific learning disability (Coles et al., 1991). Children with prenatal alcohol exposure also have difficulty recalling complex (Streissguth et al., 1994) and simple non-verbal and verbal information (Mattson, Riley, Delis, Stern, & Jones, 1996; Mattson & Roebuck, 2002). Notably, these difficulties endure after controlling for IQ (Goldschmidt, Richardson, Stoffer, Geva, & Day, 1996). Importantly, learning impairments can have considerable and lasting effects on these individuals' academic functioning (Glass & Mattson, 2016).

Children affected by prenatal alcohol exposure also display extensive deficits in memory. These deficits include spatial memory, auditory memory, and memory for designs and stories (Mattson et al., 2011). Among individuals exposed to alcohol prenatally, memory deficits are widespread and include both verbal and nonverbal material. Further, memory deficits endure even after controlling for mental age or when compared to IQ matched controls (Mattson, Riley, Delis, Stern, & Jones, 1996; Vaurio, Riley, & Mattson, 2011). Some studies suggest these memory deficits stem from trouble encoding new material as retention of material learned is similar to that of controls (Crocker, Vaurio, Riley, & Mattson, 2011; Kaemingk, Mulvaney, & Halverson, 2003; Mattson, Riley, Delis, Stern, & Jones, 1996; Willoughby, Sheard, Nash, & Rovet, 2008), while others suggest retention is equally impacted and deficits may be due to impaired learning strategies (O'Leary et al., 2015).

Limited evidence supports impairments on measures of visual-spatial reasoning and construction tasks in youth with histories of prenatal alcohol exposure (Aronson & Hagberg, 1998; Conry, 1990; Hunt, Streissguth, Kerr, & Olson, 1995; Jirikowic, Carmichael Olson, & Kartin, 2008; Mattson & Riley, 1998; Uecker & Nadel, 1996). Further, studies have shown that children with prenatal alcohol exposure process visual information differently than non-exposed children. Specifically, children with prenatal alcohol exposure have difficulty processing local features (smaller symbols making up a larger symbol) than typically developing controls (Mattson, Gramling, Delis, Jones, & Riley, 1996). Overall, prenatal alcohol exposure is associated with neurocognitive impairment across many domains, and results in significantly impactful consequences in academic, social, and occupational settings. Importantly, neuropsychological impairments appear to persist over time and similar deficits are noted in children and adolescents (Panczakiewicz et al., 2016).

Self-regulation. Children affected by prenatal alcohol exposure experience a wide array of deficits in self-regulation. Mood or behavioral regulation impairments include increased rates of internalizing and externalizing problems (Kodituwakku & Kodituwakku, 2014). Additionally, children with prenatal alcohol exposure display higher rates of negative affect than non-exposed individuals and are at higher risk of developing major depressive disorder (Fryer, McGee, Matt, & Mattson, 2007; O'Connor, 2001; O'Connor & Paley, 2006). Alcohol-exposed children also show increased rates of oppositional defiant disorder and conduct disorder (Burd, Klug, Martsolf, & Kerbeshian, 2003; D'Onofrio et al., 2007; Disney, Iacono, McGue, Tully, & Legrand, 2008; Fryer et al., 2007; Ware et al., 2013). These highly co-occurring conditions suggest impaired mood and behavioral regulation.

Attention is perhaps the most widely reported aspect of functioning affected by prenatal alcohol exposure, and many studies have shown deficits in this domain among alcohol-exposed children (Burden, Jacobson, Sokol, & Jacobson, 2005; Carmichael Olson et al., 1992; Coles et al., 1991; Fryer et al., 2007; Jacobson, Jacobson, & Sokol, 1994; Mattson & Riley, 1998; Nanson & Hiscock, 1990; Streissguth et al., 1986; Streissguth et al., 1994). Specific deficits have been reported on measures of information processing, reaction time, and vigilance (Burden et al., 2005; Jacobson et al., 1993; Jacobson et al., 1994; Streissguth et al., 1986; Streissguth et al., 1984; Streissguth et al., 1994). Particularly salient impacts on attention include inhibitory ability and variable reaction times on computerized attention tasks (Streissguth et al., 1994). However, attention does not appear to be globally affected. Individuals with prenatal alcohol exposure are able to maintain auditory attention at shorter intervals, while visual attention is consistently impaired across time intervals (Mattson, Calarco, & Lang, 2006). These impairments in attention among alcohol-exposed children may manifest as difficulty organizing, maintaining, or investing attention as well as inhibiting impulsive responses (Nanson & Hiscock, 1990). Notably, both parents (Janzen, Nanson, & Block, 1995; Mattson & Riley, 2000; Nash et al., 2006) and teachers (Aragón et al., 2008; Brown et al., 1991; Carmichael Olson et al., 1992; Ware, Crocker, O'Brien, Deweese, Roesch, Coles, Kable, May, Kalberg, Sowell, Jones, Riley, Mattson, et al., 2012) report attention difficulties in alcohol-exposed children relative to their non-exposed peers. In addition, rates of attention-deficit/hyperactivity disorder (ADHD) are elevated among alcohol-exposed individuals, with estimates occurring in greater than 60% of the FASD population (Bhatara, Loudenberg, & Ellis, 2006; Burd et al., 2003; D'Onofrio et al., 2007; Fryer et al., 2007).

The clinical presentations of ADHD and FASD have highly overlapping symptomology. However, while deficits in attention are also seen in youth with ADHD, the pattern of deficits seen in those with prenatal alcohol exposure may be unique (Mattson et al., 2011). Increased impulsive responses and impaired inhibition are notable among children affected by prenatal alcohol exposure (Mattson & Riley, 1998). In addition, children exposed to alcohol prenatally show significantly higher rates of externalizing behaviors than non-exposed children with ADHD (Raldiris, Bowers, & Towsey, 2014), suggesting impaired impulse control. Children with prenatal alcohol exposure are also more likely to be identified as "unable to wait their turn" by teachers (Carmichael Olson et al., 1992). Higher rates of conduct and oppositional defiant disorder among alcohol-exposed youth (Burd et al., 2003; D'Onofrio et al., 2007; Disney et al., 2008; Fryer et al., 2007; Steinhausen & Spohr, 1998) may also suggest trouble controlling impulsive responses or following rules.

Adaptive functioning. Individuals with prenatal alcohol exposure display impairments in adaptive functioning that persist over time and occur independently of IQ. Multiple studies of individuals with prenatal alcohol exposure support deficits in multiple aspects of adaptive functioning, although some studies suggest that socialization is the most severely impacted adaptive functioning domain (Crocker, Vaurio, Riley, & Mattson, 2009; Streissguth et al., 1991; Thomas, Kelly, Mattson, & Riley, 1998; Whaley, O'Connor, & Gunderson, 2001). Children affected by prenatal alcohol exposure also demonstrate difficulty in social interactions (Coggins, Olswang, Carmichael Olson, & Timler, 2003; Coggins, Timler, & Olswang, 2007; Timler, Olswang, & Coggins, 2005) and parents of children with FASD note social problems and poor communication even after controlling for IQ (Mattson & Riley, 2000).

In sum, neurobehavioral impacts of prenatal alcohol exposure are wide-ranging and significantly impactful across the lifespan in multiple domains of functioning. Continued research is necessary to help disentangle the specific neurobehavioral profile of FASD to assist in identification of these individuals, as many are currently misdiagnosed or undiagnosed (Chasnoff, Wells, & King, 2015), and to ascertain targets for development and refinement of interventions with the aim of alleviating functional deficits associated with FASD.

Clinical Interventions. Research and development of evidence-based therapies specific to FASD are limited. Studies have focused on medication or nutritional supplementation, individual therapy with the child, and parent-focused or family intervention. Nutritional supplementation (e.g., choline), both through prenatal care with the mother (Kable et al., 2015) and postnatal care with the child (Wozniak et al., 2015; Wozniak et al., 2013), has shown some promising results in tempering effects of alcohol on cognitive abilities such as working memory and learning. While encouraging, a majority of studies that have been conducted are largely preclinical animal models (Schneider & Thomas, 2016) or clinical studies with small sample sizes, suggesting further investigation is warranted. Pharmaceutical intervention may also be beneficial to reduce problem behaviors or ADHD-like symptoms commonly occurring with FASD; however, such treatment should supplement behavioral therapeutic intervention rather than be stand-alone, necessitating close collaboration and consultation among health care providers (Young et al., 2016).

Behavioral and academic interventions developed for other neurodevelopmental disorders have shown promise in being adapted for treating children with FASD. For example, math skills interventions (Kable, Coles, & Taddeo, 2007; Kable, Taddeo, Strickland, & Coles, 2015) and social skills interventions (O'Connor et al., 2006) have been adapted with encouraging results. Direct intervention with the child includes those focused on reducing behavioral issues and substance use (Coles, Kable, Taddeo, & Strickland, 2015; O'Connor, Quattlebaum, Castañeda, & Dipple, 2016; Petrenko, Tahir, Mahoney, & Chin, 2014) and attenuating cognitive impacts associated with prenatal alcohol exposure (Kerns, Macoun, MacSween, Pei, & Hutchison, 2016; Nash et al., 2015; Zarnegar, Hambrick, Perry, Azen, & Peterson, 2016). Interventions aimed at improving self-regulation and executive functioning through direct child-focused or group therapy have shown promising results in improving parent-report of child disruptive behavior (Nash et al., 2015; Wells, Chasnoff, Schmidt, Telford, & Schwartz, 2012). As academic domains are frequently impacted by FASD symptoms, an individualized education program (IEP) is often necessary to supplement general education (Young et al., 2016).

Parent or caregiver support and family intervention are helpful in addition to direct intervention with the child as parental attribution of their child's behavior shows to impact the child's well-being (Petrenko, Pandolfino, & Roddenbery, 2016). Thus, treatment benefits by providing parent training on positive ways to interact and redirect the child, particularly during high-stress situations (e.g., behavioral outbursts, aggressive behaviors). Behavioral interventions targeted at reducing behavioral disruptions associated with ADHD (e.g., parent management training, behavioral management therapy) also likely provide helpful tools for parents managing these types of behaviors, as ADHD is highly prevalent in the FASD population (Burd et al., 2003; Disney et al., 2008; Fryer et al., 2007). Continued research and development of FASD-specific interventions, including accessible interventions across the lifespan (Petrenko et al., 2014; Reid et al., 2015), is essential to address the significant and currently unmet needs of this population.

Introduction to the Current Study

Extensive research has investigated the impact of prenatal alcohol exposure on several domains of neurobehavioral functioning (Mattson, Bernes, & Doyle, 2019; Mattson et al., 2011; Mattson & Riley, 1998; Riley et al., 2011) as described above. However, there has been minimal study on the effects of prenatal alcohol exposure on language (i.e., receptive and expressive abilities) and communication (i.e., social and functional exchange of information), despite the clear clinical and functional relevance of such abilities for individuals with FASD. Impaired language and communication can translate into increased rates of psychiatric, behavioral, and emotional disorders (Prizant et al., 1990). Prenatal alcohol exposure disrupts development of language, but the exact mechanism has not been determined (Mattson & Riley, 1998). Limited neuroimaging findings (Gautam et al., 2015; Sowell et al., 2008; Sowell et al., 2002; Treit et al., 2013; Treit et al., 2014) suggest that individuals with FASD likely have alterations in brain areas involved with language. Further, alcohol-exposed children have demonstrated impaired abilities in basic neuropsychological processes that contribute to language (Kodituwakku & Kodituwakku, 2014; Kodituwakku, 2007; Mattson et al., 2011; Riley, Infante, & Warren, 2011).

Children with FASD also display impaired functioning in daily living skills, especially in communication and social skills, which does not appear to improve over time (Crocker, Vaurio, Riley, & Mattson, 2009) and is significantly impairing. However, no known studies have examined how language ability in particular impacts social and functional communication of individuals with FASD. Therefore, the current proposal seeks to address this gap in current knowledge by examining the comprehensive profile of language and communication abilities of adolescents with FASD, the cognitive domains responsible for language and communication impairments in these individuals, and the social and functional impacts of these abilities.

Findings will provide clinically valuable information regarding the possible causes of social and functional communication impairment in individuals with FASD and inform future development of interventions to improve communication of adolescents with FASD.

Language and Communication in FASD

While few studies have comprehensively examined language and communication abilities in children with FASD, certain findings have been consistently shown. Children with prenatal alcohol exposure show deficits in receptive and expressive language (Akbarian, 1992; Carney & Chermak, 1991; Church, Eldis, Blakley, & Bawle, 1997; Church & Kaltenbach, 1997; Gentry et al., 1998; McGee, Bjorkquist, Riley, & Mattson, 2009; Wyper & Rasmussen, 2011). One study in particular also found that alcohol-exposed children perform better on tests of receptive than expressive language ability though this difference did not reach statistical significance (McGee et al., 2009). Additionally, prevalence estimates of language related disorders (i.e., expressive language disorder, receptive language disorder, developmental disorder of speech and language) among youth with FAS are significant, ranging from 67.2% to 81.8% (Popova et al., 2016); thus, rates of language-related disorders may also be elevated among youth with FASD.

A majority of studies conducted regarding the effects of prenatal alcohol exposure on language and communication have focused on children with FAS, and show that children with FAS have delays in language acquisition (Church & Kaltenbach, 1997). Furthermore, documented verbal learning and memory deficits in children with FAS (Mattson, Riley, Delis, Stern, & Jones, 1996) can significantly impact language development. One small study of 10 children with FAS found that older children (9-12 years of age) were more impaired than controls on sentence combining, word ordering, and grammatical completion. This study also concluded that younger children with FAS have more global language deficits, while older children are more impaired on syntactic manipulation (Carney & Chermak, 1991). Additionally, children with FAS perform worse than their chronological age on language tests, making fewer grammatically correct and complete sentences (Akbarian, 1992). In another study, 80% of subjects with FAS showed impairment on one or more measures of speech, language, voice, or fluency (Iosub, Fuchs, Bingol, & Gromisch, 1981). These studies, while useful, were limited in sample size and most did not include controls for comparison. Thus, further investigation is needed.

Although the aforementioned differences in language and communication have been found, some findings are inconsistent (Flak, Bertrand, Denny, Kesmodel, & Cogswell, 2014). Some prospective studies have found that children exposed to alcohol prenatally are more likely to be diagnosed with a language delay (Kuehn et al., 2012), while others have found no association between language skills and prenatal alcohol exposure (Davis, Gagnier, Moore, & Todorow, 2013). Further, Greene and colleagues (Greene, Ernhart, Martier, Sokol, & Ager, 1990) found little association between prenatal alcohol exposure and language development in the absence of FAS. Another study found that children with FASD performed significantly lower on the language composite of the NEPSY-II, but did not perform worse on measures of receptive and expressive vocabulary (Nash et al., 2013). In contrast, retrospective studies have rather consistently documented language deficits (i.e., grammatical, semantic, pragmatic). One potential explanation for this discrepancy is differing levels of alcohol exposure in these study designs. Prospective studies typically involve lower levels of alcohol exposure, while retrospective studies focus on heavy prenatal alcohol exposure and tend to rely on the use of clinical samples. As some have previously pointed out, use of clinical samples may result in biased information as those individuals with more extreme behavior may be disproportionately assessed (Davis et al., 2013).

Results from several neuroimaging studies have shown that children with prenatal alcohol exposure have reduced gray matter asymmetry within the posterior inferior temporal lobes. This alteration in gray matter density is more affected in the left hemisphere than the right, an area that is associated with Brodmann's areas 21, 22, and 37 and thought to be highly involved in language (Sowell et al., 2002). These findings suggest that individuals with FASD may display impairments in language and cognitive domains related to communication that may have significant clinical implications.

Another reason to study language in FASD is the overlap with ADHD; FASD and ADHD have similar neurobehavioral features and rates of ADHD in FASD are high (Burd et al., 2003; Fryer et al., 2007; Landgren et al., 2010; Mattson et al., 2011; O'Connor & Paley, 2009; Rasmussen et al., 2010). Children with ADHD have more language problems than typically developing controls (Sciberras et al., 2014) and thus, it is reasonable to expect language and communication difficulties in individuals with FASD. Based on these findings, there is a great need for examination of the comprehensive language and communication skills of individuals with FASD. As previously stated, most studies have either focused on young children with FASD or individuals with FAS alone. Additionally, some studies have been more descriptive in nature, rather than an empirical evaluation of language (Gentry et al., 1998). Therefore, there is a need to examine language and communication abilities to contribute to the comprehensive neurobehavioral profile of strengths and weaknesses in individuals with FASD.

Neuropsychological Bases of Language and Communication

An extensive amount of research has shown that children with FASD have deficits in attention, executive function (i.e., inhibition, working memory), and memory (Mattson et al., 2011; Riley et al., 2011). These abilities, however, have not been examined in relation to language and communication. In children with specific language impairment (SLI), impairments on measures of attention, executive function, and working memory relate to language abilities (Finneran, Francis, & Leonard, 2009; Im-Bolter, Johnson, & Pascual-Leone, 2006; Spaulding, Plante, & Vance, 2008). Regarding attention, preschool children with SLI are impaired compared to typically developing controls, on measures of auditory sustained attention (Spaulding et al., 2008) and have slower attention processing (Finneran et al., 2009). Deficits in processing speed and the resulting change in sustained attention may contribute to language learning difficulties (Finneran et al., 2009; Spaulding et al., 2008).

Others have shown that aspects of executive functioning (i.e., mental attention, inhibition of responses, and updating working memory contents) are impaired in children with SLI (Im-Bolter et al., 2006). On a competing language processing task, children with SLI performed similarly to controls on true/false sentence comprehension, but significantly worse on word recall, suggesting impairments in verbal working memory (Weismer, Evans, & Hesketh, 1999). Evidence for differences in neuropsychological bases of language impairment in SLI suggests this may also be the case in children with FASD, as similar cognitive impairments have been demonstrated. As in SLI, specific aspects of language are more difficult and thus are more vulnerable to impairment in FASD (Akbarian, 1992). Furthermore, attention and executive function are central aspects to cognitive, behavioral, and affective control, which are implicated in social communication (Singer & Bashir, 1999), and as such are important aspects to comprehensively study the clinical impacts of language and communication impairment in individuals with FASD. Examination of differences in neuropsychological bases of language and communication impairment in adolescents with FASD may highlight causes of social and functional communication deficits and suggest targets for clinical interventions.

Clinical Impacts of Language and Communication

To be successful in social communication, one must invoke language skills, social cognition, and executive function skills. As highlighted above, children with FASD show an array of deficits in these areas, but no clear pattern has emerged (Coggins et al., 2007). Young children with prenatal alcohol exposure and children with ADHD score lower on measures of adaptive functioning (i.e., socialization, communication, daily living skills) than typically developing controls. However, adolescents with prenatal alcohol exposure show greater impairment in these abilities than adolescents with ADHD, suggesting an arrest in development of communication and socialization skills in FASD, rather than the delay in development of these abilities seen in ADHD (Crocker et al., 2009). Further, children with FASD have social, but dysfunctional, communicative interactions (Akbarian, 1992).

The behavioral phenotype of FASD is characterized by social, communicative, and behavioral problems that can disrupt interactions with peers and impact school achievement negatively (Carmichael Olson et al., 1992; Crocker et al., 2009; Mattson & Riley, 2000; Riley & McGee, 2005; Thomas, Kelly, Mattson, & Riley, 1998). Additionally, children with FASD are less socially engaged than their typically developing peers (Olswang, Svensson, & Astley, 2010). Functional language and social cognition deficits may contribute to impaired social communication ability in individuals with FASD. Further, children with FASD are more variable in their social performance than typically developing children, which contributes to perceived social difficulties (Kjellmer & Olswang, 2012). Similar to children with autism spectrum disorders (ASD), children with FASD display an array of social inadequacies (Bishop, Gahagan, & Lord, 2007; Stevens, Nash, Koren, & Rovet, 2013). Both groups display socially inappropriate behavior and have difficulty interacting with peers, but unlike children with ASD, children with FASD have a natural tendency to initiate social interaction (Bishop, Gahagan, & Lord, 2007). Children with FASD also appear to have the greatest difficulty in social and communicative functioning, and the least difficulty in repetitive or restrictive behavior (Stevens, Nash, Koren, & Rovet, 2013).

A link between communication disorders, emotional disorders, and behavioral disorders has been shown in children and adolescents. Delays in speech and language put children at risk for psychiatric and learning disorders. For example, in one study, of 40 children admitted to a psychiatric facility, 20 had severe language disorders (Prizant et al., 1990). This risk is evident among individuals with prenatal alcohol exposure, as psychiatric disorders are highly comorbid with FASD (Fryer et al., 2007). Importantly, those with a pure language disorder (i.e., language expression, comprehension, or processing) but normal speech were at greatest risk for psychiatric illness (Prizant et al., 1990). As such, children with FASD may be at increased risk for impaired social communication and interaction as well as psychiatric illnesses due to impairments in language and communication. Further, language problems in children with ADHD contribute to poorer academic functioning (Sciberras et al., 2014), highlighting the array of impacts impaired language can produce. Notably, individuals with FASD are overly represented in the criminal justice system (Boland, Burrill, Duwyn, & Karp, 1998; Fast & Conry, 2004; Fast & Conry, 2009) and studies show that language differences and disorders among this population can impact how these individuals understand and navigate justice systems (Kippin et al., 2018). Therefore, determining the impact of language impairment on functional and social communication abilities of individuals with FASD is of great clinical significance. During adolescence, academic and social demands are increased and difficulties emerge due to the requirement of independent functioning, decreased adult supervision, and increased peer pressure (Streissguth, 1986). Furthermore, social deficits have been shown to persist across the lifespan of individuals with FASD, and may even worsen with age (Kully-Martens, Denys, Treit, Tamana, & Rasmussen, 2012). Thus, the adolescent age range is of critical importance for studying language and communication abilities in this population.

Summary

While a handful of studies have shown differences in language and communication due to prenatal alcohol exposure, no known studies have comprehensively examined the profile of language and communication in individuals with FASD. Further, language and communication abilities in adolescents with FASD are largely unexplored. It is reasonable to expect that differences in language observed in young children with FASD may become more pronounced with age due to increased demands in language and communication tasks. Language and communication are highly correlated with adaptive functioning and behavior in other neurodevelopmental disorders; as such, adolescents with FASD may have impaired social and functional communication due to impairments in language acquisition. Furthermore, costs associated with language related disorders within the FASD population are substantial; as such, adequate identification and intervention are of paramount importance to reduce this economic burden and decrease secondary disabilities associated with language related impairments (Popova, Lange, Burd, Shield, & Rehm, 2014). Therefore, there is a great need to determine the strengths and weaknesses in language and communication of adolescents with FASD. Findings may help identify potential causes of social and functional communication impairment to aid in understanding the clinical presentation of adolescents with FASD and identify targets for future studies to develop interventions to improve communication of adolescents with FASD.

Purpose and Specific Aims

The current study aimed to comprehensively examine language and communication abilities in adolescents with FASD, and the clinical implications of these abilities. Examination of differences in the underlying neuropsychological bases of language and communication deficits will help identify potential causes of social and functional communication impairment in individuals with FASD and inform targets for future development of interventions to improve communication of adolescents with FASD. To this end, two main aims were outlined to achieve study goals.

Aim 1: Establish a comprehensive profile of strengths and weaknesses in language, communication, and cognition of adolescents with FASD and compare this profile to that of typically developing controls.

Language and communication ability in adolescents aged 12:0-17:11 was evaluated using the Clinical Evaluation of Language Fundamentals – Fifth Edition (CELF-5; Wiig, Semel, & Secord, 2013) and the Goldman-Fristoe Test of Articulation – 3 (GFTA-3; Goldman & Fristoe, 2015) was administered to rule out speech-level deficits. Parents or caregivers completed the Children's Communication Checklist – 2 (CCC-2; Bishop, 2006) to obtain caregiver report of language abilities. As part of additional, ongoing studies at the Center for Behavioral Teratology, a neuropsychological battery comprising measures of general cognitive functioning and executive function (inhibition, working memory, attention) was available.

Hypothesis 1a. Adolescents with FASD will display impaired language and communication ability as well as overall impaired performance on selected measures as compared to controls. Further, adolescents with FASD will display poorer expressive than receptive language ability. Controls will show intact performance across all domains.

Hypothesis 1b. Inhibition will most strongly positively correlate with language ability within both groups followed by working memory, while attention will more strongly positively correlate with language ability of adolescents with FASD than controls.

<u>Aim 2</u>: Evaluate the performance of adolescents with FASD on measures of functional and social communication to elucidate the clinical implications of the comprehensive language profile of these individuals.

Subjects were administered the Student Functional Assessment of Verbal Reasoning and Executive Strategies (S-FAVRES; MacDonald, 2013) to determine how language ability impacts functional communication and interaction. Parents or caregivers completed the Social Skills Improvement System Rating Scales (SSIS; Gresham & Elliott, 2008) to obtain a subjective report of social communication and interaction abilities of these individuals.

Hypothesis 2a. Adolescents with FASD will display impaired performance on measures of functional and social communication as compared to controls. Parents of adolescents with FASD will report greater communication difficulties than parents of typically developing controls.

Hypothesis 2b. Expressive language abilities of adolescents with FASD will impact social and functional communication more so than receptive language abilities; more severe language difficulties will result in greater social and functional communication deficits. Controls will show equal impact of expressive and receptive abilities. Relationships between language ability and social communication will be mediated by potential neuropsychological differences found from the cognitive component of Aim 1.

Research Design and Methods

Preliminary Studies

Previous studies through the Center for Behavioral Teratology where the study was completed have gathered data on various aspects of language-related abilities in individuals with FASD. One such study found that children prenatally exposed to alcohol have impaired receptive and expressive language ability as compared to typically developing children (McGee et al., 2009). Further, another study showed that children and adolescents with prenatal alcohol exposure are significantly impaired on language-related neuropsychological measures (e.g., phonological processing, speeded naming) as compared to typically developing controls (Glass, Graham, Akshoomoff, & Mattson, 2015). Verbal fluency (an aspect of executive functioning) shows a stronger relationship with communication ability among adolescents with prenatal alcohol exposure than controls, suggesting differences in the bases of communication between these two groups (Doyle et al., 2018). Therefore, the current study aimed to build upon these findings by comprehensively examining language and communication ability in adolescents with FASD to supplement means of identifying these individuals and determine the clinical impacts of these abilities.

General Methods for the Current Study

The current study had three main components: (1) determine the comprehensive profile of language and communication abilities in adolescents with FASD; (2) examine performance on various cognitive measures to determine which areas contribute to group differences in language and communication abilities; and (3) investigate clinical implications of language impairment on social and functional communication. Subjects (N = 60) were tested within one, 2-hour testing session. All subjects completed a brief hearing screening with an audiometer for pure tone thresholds (20-30 dB, 1000-4000 Hz) at the start of testing to ensure intact hearing at the level of conversational speech. No subjects were excluded due to hearing loss. Parents or caregivers completed questionnaires while the subject underwent testing. Informed consent was obtained from parents or caregivers, and informed assent was obtained from subjects.

Subjects. All subjects were primary English speakers between the ages of 12:0-17:11. Full scale IQ (FSIQ) was obtained through the Wechsler Intelligence Scale for Children – Fifth Edition (WISC-V; ages 12:0-16:11) or the Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; ages 17:0+). Adolescents from all ethnicities, races, and sexes were included in the study based on exclusion and inclusion criteria outlined below. Groups were matched on demographic data (i.e., socioeconomic status, race, ethnicity, sex, and age). Research criteria for ADHD was determined using the ADHD Rating Scale – 5 for Children and Adolescents (DuPaul, Power, Anastopoulos, & Reid, 2016). The sponsor of the current study, Dr. Mattson, is the PI of the Collaborative Initiative on Fetal Alcohol Spectrum Disorders (CIFASD) Neurobehavioral Project, which includes subjects in the proposed age range. In addition to neurobehavioral testing, all CIFASD subjects received a dysmorphological evaluation conducted by Dr. Kenneth Lyons Jones, PI of the CIFASD Dysmorphology Core, to determine alcohol-related diagnoses (Jones et al., 2006). The CIFASD criteria for FAS require two of three facial dysmorphology markers as well as growth deficiency (weight and/or height $\leq 10^{th}$ percentile) and/or microcephaly (head circumference $\leq 10^{th}$ percentile; Mattson et al., 2010). Subjects for the current study were recruited from the CIFASD sample and met the following criteria to be enrolled in the alcohol-exposed (AE) or control (CON) group.

Inclusion criteria. *AE group.* Individuals in the AE group ($N = 31$) had heavy prenatal alcohol exposure, defined as maternal intake of >4 drinks per occasion at least once per week, or

>13 drinks per week. Information on maternal alcohol use and other prenatal exposure was obtained through caregiver questionnaires and interview, if available. In cases where direct maternal report was not available, a review of medical, social services, or court records was completed. In these cases, subjects were included in the AE group if there was documentation of alcohol abuse or dependence in the biological mother or if exposure was suspected and the child met criteria for FAS.

CON group. Subjects in the CON group ($N = 29$) were non-exposed controls with minimal or no prenatal alcohol exposure and with or without other clinical or behavioral concerns. Minimal exposure is defined as <1 drink per week and never more than 2 drinks per occasion during pregnancy.

Exclusion criteria. Subjects were excluded from the study if they had a medical (e.g., uncorrected hearing or vision loss) or psychiatric illness (e.g., active psychotic episode) that precluded inclusion in the study, or serious head injury with loss of consciousness >30 min. Individuals with another known cause of mental deficiency (e.g., chromosomal abnormality, neurofibromatosis) were excluded from participation. Further, subjects were excluded from the CON group if alcohol exposure information was unavailable or greater than minimal exposure was suspected or known. Information for subjects with delayed language was obtained and sub-analyses on those who fall into this subgroup were performed.

Recruitment. The Center for Behavioral Teratology has a pre-existing system for recruitment of subjects. Alcohol-exposed subjects are referred through self-referrals and professional referrals including from Dr. Kenneth Lyons Jones. Additional recruitment took place through local schools, clinics, and community groups. Recruitment for control subjects included typically developing children, children with ADHD or other learning, behavioral, or developmental disabilities.

General statistical analyses. SPSS statistical software v.26 was used for the majority of analyses. Demographic data were analyzed with analysis of variance (ANOVA; for continuous variables) or chi-square (for categorical variables) statistical procedures. Multivariate analysis of variance (MANOVA) was used to address the majority of the primary hypotheses, as correlations among target dependent variables was expected. Assumptions of homogeneity of variance and covariance were examined with Box's M and Levene's test statistics for these analyses. An alpha level of .05 was used to determine statistical significance and effect sizes were consulted to determine practical significance. Multiple regression techniques were used for analyses that involved continuous predictor variables.

Potential confounding factors. Information regarding opportunities for language and communication development in the home was collected along with demographic data to determine whether such differences account for group differences in language and communication. In addition, information regarding parental socioeconomic status, including highest level of education and income, was collected.

Sample size. G*Power statistical software (Faul, Erdfelder, Lang, & Buchner, 2007) was used to conduct power analyses to estimate the required sample size for a given analysis. Presented here is a power analysis for a target MANOVA, as the majority of the proposed analyses used this specific statistical procedure. Previous studies on language-related ability in individuals with FASD have found medium to large effect sizes for related outcome variables (Glass et al., 2015; McGee et al., 2009). Using a medium effect size ($partial\ \eta^2 = .148$), an alpha level of .05, and 80% power to detect a significant omnibus effect, targeted recruitment is

78 subjects. Using a large effect size ($partial\ \eta^2 = .245$), an alpha level of .05, and 80% power to detect a significant omnibus effect, targeted recruitment is 50 subjects. Based on these analyses and conservative estimates, the proposed sample size was 80 subjects. Given our sample size of 60 subjects, post hoc power analyses revealed that large effect sizes ($partial\ \eta^2 > .200$) would be required to detect a significant omnibus effect. See discussion of sample size attainment in "Limitations and Future Directions" section.

<u>Aim 1</u>: Establish a comprehensive profile of strengths and weaknesses in language, communication, and cognition of adolescents with FASD and compare this profile to that of typically developing controls.

Subjects were administered the Clinical Evaluation of Language Fundamentals – Fifth Edition (CELF-5; Wiig, Semel, & Secord, 2013) and the Goldman-Fristoe Test of Articulation-Third Edition (GFTA-3; Goldman & Fristoe, 2015) to obtain a comprehensive profile of language and communication abilities. The GFTA-3 was used to obtain information regarding subjects' speech abilities to rule out speech-level deficits. Caregivers completed the Children's Communication Checklist-Second Edition (CCC-2; Bishop, 2006).

CELF-5. The CELF-5 is a comprehensive measure to assess language and communication disorders in children and adolescents ages 5:0-21:11. The CELF-5 is widely used within school systems and is recognized as a valid measure of language and communication abilities. The CELF-5 was standardized and normed on a sample of more than 4,500 individuals and demonstrates sound psychometric properties. The Receptive and Expressive Language Index standard scores were used in analyses.

GFTA-3. The GFTA-3 measures speech and articulation abilities for individuals aged 2:0-21:11. The child engages in both spontaneous and imitative sound production to obtain a comprehensive measure of the child's speech abilities. The Sounds-in-Words standard score was used in analyses.

CCC-2. The CCC-2 is a parent- or caregiver-report questionnaire that addresses the child's language (i.e., speech, syntax, semantics, and coherence) and communication abilities (i.e., initiation, scripted language, context, nonverbal communication, social relations, and interests). It is sensitive to deficits in language and pragmatic communication in children aged 4:0-16:11. The General Communication Composite standard score was used in analyses as it is sensitive to general language deficits. Parents of subjects over the age of 16:11 ($n = 3$) did not complete this measure due to being out of the normative age range.

Cognitive component. Data were collected from other ongoing studies conducted at the Center for Behavioral Teratology and were available to determine potential cognitive differences (i.e., inhibition, working memory, attention) in bases of language and communication impairment. The Inhibition Total Errors scaled score (Delis-Kaplan Executive Function System Color-Word Inhibition Test; Delis et al., 2001) was used to measure inhibition. Attention and working memory were measured by variables from the National Institutes of Health (NIH) Toolbox Cognition Battery. Standard scores from the Flanker Inhibitory Control and Attention Test were used to measure attention and standard scores from the List Sorting Working Memory test were used to measure working memory.

Hypothesis 1a. Adolescents with FASD will display impaired language and communication ability as well as overall impaired performance on selected measures as compared to controls. Further, adolescents with FASD will display poorer expressive than receptive language ability. Controls will show intact performance across all domains.

Data analysis. A MANOVA with group (AE, CON) as the between-subjects variable and domain (Receptive, Expressive, Speech, Parent-Report) as the within-subject variable was conducted to determine the overall profile of language and communication ability of adolescents with FASD and how this profile differs from typically developing controls. Paired samples t-tests investigated the relationship between receptive and expressive language abilities within each group.

Hypothesis 1b. Inhibition will most strongly positively correlate with language ability within both groups followed by working memory, while attention will more strongly positively correlate with language ability of adolescents with FASD than controls.

Data analysis. Two stepwise multiple regression analyses were conducted to examine the contribution of inhibition, working memory, and attention to receptive and expressive language ability. Predictors included group (AE and CON), each neuropsychological domain (inhibition, working memory, attention), and interactions between group and each neuropsychological variable to formally test for differences between groups. Significant effects were followed up with univariate ANOVAs on each dependent variable. Effect size estimates were consulted to determine the practical significance of any statistically significant findings. Non-significant variables were removed to identify the most parsimonious models.

<u>Aim 2</u>: Evaluate the performance of adolescents with FASD on measures of functional and social communication to elucidate the clinical implications of the comprehensive language profile of these individuals.

Subjects were administered the Student Functional Assessment of Verbal Reasoning and Executive Strategies (S-FAVRES; MacDonald, 2013) to objectively determine the functional communication and interaction abilities of these individuals. Parents or caregivers completed the

Social Skills Improvement System Rating Scales (SSIS; Gresham & Elliott, 2008) to obtain a subjective report of social communication and interaction abilities of these individuals.

S-FAVRES. The S-FAVRES is a measure of higher order cognitive and communication skills for individuals aged 12:0-19:11. Beneficially, this measure is sensitive to higher-order language and communication deficits that may emerge during adolescence and has been standardized on language unimpaired and impaired populations. Constructs tapped by the S-FAVRES include verbal reasoning, social communication, planning, problem solving, and meta-cognition. The Total Reasoning Subskills standard score was included in analyses as a measure of verbal reasoning and functional communication. This subtest requires subjects to answer a series of questions regarding their process in solving four different real-world problems.

SSIS. The SSIS is a parent- or caregiver-report questionnaire that assesses problem behaviors and social skills in children ages 3:0-18:0. Further, the SSIS provides a measure of ASD behaviors that may help differentiate social problem behaviors between adolescents with FASD and ASD. The Social Skills subscale integrates information important for social functioning and interactions including communication, cooperation, assertion, responsibility, empathy, engagement, and self-control. The Social Skills standard score was included in analyses as a measure of social communication.

Hypothesis 2a. Adolescents with FASD will display impaired performance on measures of functional and social communication as compared to typically developing controls. Parents of adolescents with FASD will report greater social communication difficulties than parents of typically developing controls.

Data analysis. A MANOVA with group (AE, CON) as the between-subjects factor and communication (SSIS, S-FAVRES) as the correlated outcome was conducted to examine differences in communication between AE and CON.

Hypothesis 2b. Expressive language abilities of adolescents with FASD will impact social and functional communication more so than receptive language abilities; more severe language difficulties will result in greater social and functional communication deficits. Controls will show equal impact of expressive and receptive abilities. Relationships between language ability and social communication will be mediated by potential neuropsychological differences found from the cognitive component of Aim 1.

Data analysis. To determine if the proposed mediated effects differ between alcohol-exposed and control subjects, multigroup path analysis was used. Baseline models in each group were first tested to determine the viability of each mediated effect within each group. For example, the relationship between receptive language and functional communication was expected to be mediated by attentional ability. Subsequent to this, the path coefficients that comprised the target mediated effects were constrained to equivalence between groups. This formally tested whether or not there were significant differences for the mediated effect between the alcohol-exposed and control group. Overall model fit, mediation tests, and modification indices provided by the MPlus software (Muthén & Muthén, 1998-2015) were used. As Duffy et al. (Duffy, Watt, & Duffy, 1981) have highlighted, path analysis is an excellent method for investigating relationships among variables within retrospective data. While the goal of Aim 2 is not to define the causal relationship among variables within this project, path analysis is useful in determining which models are more probable than others based on observed data (Duffy et al., 1981). As such, Aim 2 of this project is largely exploratory due to the fact that no known studies have investigated the relationship between language and communication in adolescents with FASD.

Results

Demographic Data

Groups did not significantly differ on handedness (p = .139), sex (p = .796), ethnicity (p = .135), race (p = .152), or age (p =.814). As expected, groups significantly differed on FSIQ (p = .049) and rate of ADHD diagnosis ($p < .001$). Specifically, the AE group (M = 89.5; SD = 15.02) had significantly lower FSIQ scores than the CON group (M = 98.4; SD = 18.97). In addition, the AE group had a significantly higher proportion of subjects that met research criteria for ADHD (n = 24; 77%) than the CON group (n = 9; 32%). Demographic data are presented in Table 1. Due to statistical and methodological limitations, FSIQ was not considered as a covariate in subsequent analyses (Dennis et al., 2009). However, correlation analyses conducted within each group revealed that FSIQ significantly correlated with expressive and receptive language (ps $\leq$ .001) in both groups. Group differences on all neuropsychological variables were tested using independent samples t-tests. Group performance on all variables is presented in Table 2. Correlations for measures used in MANOVA analyses are presented in Table 3.

Potential confounding factors. Groups did not significantly differ on number of subjects with delayed speech and language acquisition (p = .245). Of those subjects with delayed speech and language acquisition, groups did not significantly differ on subjects that received early intervention services (p = .665). In addition, groups did not significantly differ on number of subjects with existing expressive language disorder (p = .185) or auditory processing disorder (p = .156) diagnoses. Groups also did not significantly differ on parental education (p = .738) or family income (p = .066). As such, these variables were not considered in the following analyses.

Table 1. Demographic information by group. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, ADHD = attention-deficit/hyperactivity disorder, FAS = fetal alcohol syndrome. Full Scale IQ (FSIQ), an estimate of general intellectual ability, was measured using the Wechsler Intelligence Scale for Children – Fifth Edition (WISC-V) for subjects ages 12:0-16:11 and the Wechsler Abbreviated Scale of Intelligence– Second Edition (WASI-II) for subjects ages 17:0+.

Demographic Variable	**AE (*n* = 31)**	**CON (*n* = 29)**
Sex [*n* (% Female)]	16 (51.6)	14 (48.3)
Age [*Mean* (SD)]	14.5 (1.71)	14.6 (1.36)
Race [*n* (% White)]	22 (71.0)	25 (86.2)
Ethnicity [*n* (% Hispanic)]	11 (35.5)	12 (41.4)
Handedness [*n* (% Right)]	30 (96.8)	25 (86.2)
FSIQ [*Mean* (SD)]*	89.6 (15.02)	98.4 (18.97)
Research Diagnosis	--	--
ADHD [*n* (%)]*	24 (77.4)	9 (32.1)
FAS [*n* (%)]*	5 (16.1)	0 (0.0)
Parental Education [*n* (%)]	--	--
Partial High School	0 (0.0)	1 (3.5)
High School Graduate	3 (9.6)	1 (3.5)
Partial College	7 (22.6)	7 (24.1)
Standard College/University	11 (35.5)	11 (37.9)
Graduate/Professional Training	10 (32.3)	9 (31.0)
Family Income [*n* (%)]	--	--
$10,001-20,000	3 (9.7)	2 (6.9)
$20,001-30,000	0 (0.0)	3 (10.3)
$30,001-50,000	2 (6.5)	0 (0.0)
$50,001-75,000	9 (29.0)	2 (6.9)
$75,001-100,000	6 (19.3)	9 (31.0)
$100,000+	11 (35.5)	13 (44.8)
Delayed Speech/Language [*n* (%)]	8 (25.8)	4 (13.8)
Early Intervention [*n* (%)]	5 (62.5)	3 (75.0)
Expressive Language Disorder [*n* (%)]	4 (12.9)	1 (3.4)
Auditory Processing Disorder [*n* (%)]	6 (19.4)	2 (6.9)

Table 2. Group performance on neuropsychological variables. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, CELF-5 = Clinical Evaluation of Language Fundamentals – Fifth Edition; GFTA-3 = Goldman-Fristoe Test of Articulation – Third Edition Sounds-In-Speech; S-FAVRES = Student Functional Assessment of Verbal Reasoning and Executive Strategies Total Reasoning Subskills; CCC-2 = Children's Communication Checklist – Second Edition General Communication Scale; SIDI = Social Interaction Difference Index (SIDI) from the CCC-2; SSIS = Social Skills Improvement System Rating Scales Social Skills Scale; D-KEFS CWIT = Delis-Kaplan Executive Function System Color-Word Interference Test Inhibition Total Errors; NIH LSWM = National Institute of Health (NIH) Toolbox List Sorting Working Memory; NIH FICA = NIH Toolbox Flanker Inhibitory Control and Attention. All variables were measured using standard (CELF-5, GFTA-3, S-FAVRES, CCC-2, SSIS, NIH) or scaled scores (D-KEFS). The SIDI is calculated from scaled scores on the CCC-2 with positive scores indicating greater non-pragmatic language impairment and negative scores indicating greater pragmatic and social impairments. Number of subjects with language impairment was determined by CELF-5 Core Language Index ≤ 1 SD below the mean or 2 or more core subtests ≤ 1 SD below the mean.

Neuropsychological Variable [*Mean* (SD)]	**AE (*n* = 31)**	**CON (*n* = 29)**
LANGUAGE	--	--
Receptive Language (CELF-5)*	87.8 (12.68)	96.5 (17.41)
Expressive Language (CELF-5)	90.3 (13.99)	96.2 (16.47)
Language Impairment (*n* [%])	11 (38%)	10 (35%)
Speech (GFTA-3)	102.0 (3.97)	103.0 (0.78)
Communication (S-FAVRES)	79.0 (14.58)	85.8 (21.15)
PARENT-REPORT	--	--
General Language (CCC-2)*	79.0 (22.62)	98.7 (19.67)
SIDI (CCC-2)	-6.5 (8.32)	-1.6 (7.43)
Social Communication (SSIS)*	77.1 (18.68)	92.4 (19.95)
COGNITIVE	--	--
Inhibition (D-KEFS CWIT)	10.1 (3.33)	8.3 (3.95)
Working Memory (NIH LSWM)	94.0 (10.61)	97.8 (15.49)
Attention (NIH FICA)	78.3 (6.95)	80.3 (15.24)

Table 3. Correlations among MANOVA dependent variables for language and communication analyses, respectively. *Note:* * $p < .001$ level. Receptive and Expressive Language were measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition. Speech was measured by the Goldman-Fristoe Test of Articulation – Third Edition Sounds-In-Speech subtest. Parent-Report of general language was measure by the Children's Communication Checklist – Second Edition General Communication Scale. Social Communication was measured by the Social Skills Improvement System Rating Scales Social Skills Scale. Functional Communication was measured by the Student Functional Assessment of Verbal Reasoning and Executive Strategies Total Reasoning Subskills.

Measure	*1*	*2*	*3*	*4*
1. Receptive Language	--			
2. Expressive Language	.737*	--		
3. Speech	.123	.212	--	
4. Parent-Report	.576*	.635*	.199	--
1. Social Communication	--			
2. Functional Communication	.530*	--		

<u>Aim 1</u>: Establish a comprehensive profile of strengths and weaknesses in language, communication, and cognition of adolescents with FASD and compare this profile to that of typically developing controls.

Hypothesis 1a. A MANOVA with group (AE, CON) as the between-subjects variable and domain (Receptive, Expressive, Speech, Parent-Report) as the within-subject variable was conducted to determine the overall profile of language and communication ability of adolescents with FASD and how this profile differs from typically developing controls. Results are presented in Table 4. Using an alpha level of .001 to evaluate homogeneity assumptions, Box's M test of homogeneity of covariance ($p < .001$) was statistically significant and Levene's homogeneity test (all *p*s > .026) was not statistically significant. Using Wilk's criterion (Λ) as the omnibus test statistic, the combined dependent variables resulted in a significant main effect for group [$F(4, 48) = 3.135$, $p = .023$, partial $\eta^2 = .207$].

To probe the statistically significant multivariate effects, univariate ANOVAs were conducted on each individual dependent variable (Receptive, Expressive, Speech, Parent-Report). Overall, the AE group performed below the CON group on all measures and significantly differed from the CON group on receptive language and parent-reported abilities (see Figure 1). Expressive and receptive language scores did not significantly differ within the AE group ($t(29) = -1.469$, $p = .153$) or the CON group ($t(28) = .146$, $p = .885$). For receptive language, there was a significant main effect for group [$F(1, 51) = 6.117$, $p = .017$, partial $\eta^2 = .107$]. Receptive language scores were significantly higher for the CON group ($M = 96.5$) relative to the AE group ($M = 87.8$). For parent-report, there was a significant main effect for group [$F(1, 51) = 10.365$, $p = .002$, partial $\eta^2 = .169$]. Parents rated the general language skills of the CON group ($M = 98.7$) higher relative to the AE group ($M = 79.0$). The main effect for group was not statistically significant for expressive language [$F(1, 51) = 2.831$, $p = .099$, partial $\eta^2 = .053$] or speech [$F(1, 51) = 1.386$, $p = .245$, partial $\eta^2 = .026$].

Table 4. MANOVA results for language profile by group. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom. Standard scores from each measure were included in analyses. Receptive Language and Expressive Language were measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition. Speech was measured by the Sounds-In-Words subtest from Goldman-Fristoe Test of Articulation – Third Edition. Parent-Report was measured by the General Communication Scale from the Children's Communication Checklist – Second Edition.

Language Variable	**Group [F (df)]**	***p***	**Partial η^2**
Omnibus*	3.135 (4, 48)	.023	.207
Receptive Language*	6.117 (1, 51)	.017	.107
Expressive Language	2.831 (1, 51)	.099	.053
Speech	1.386 (1, 51)	.245	.026
Parent-Report*	10.365 (1, 51)	.002	.169

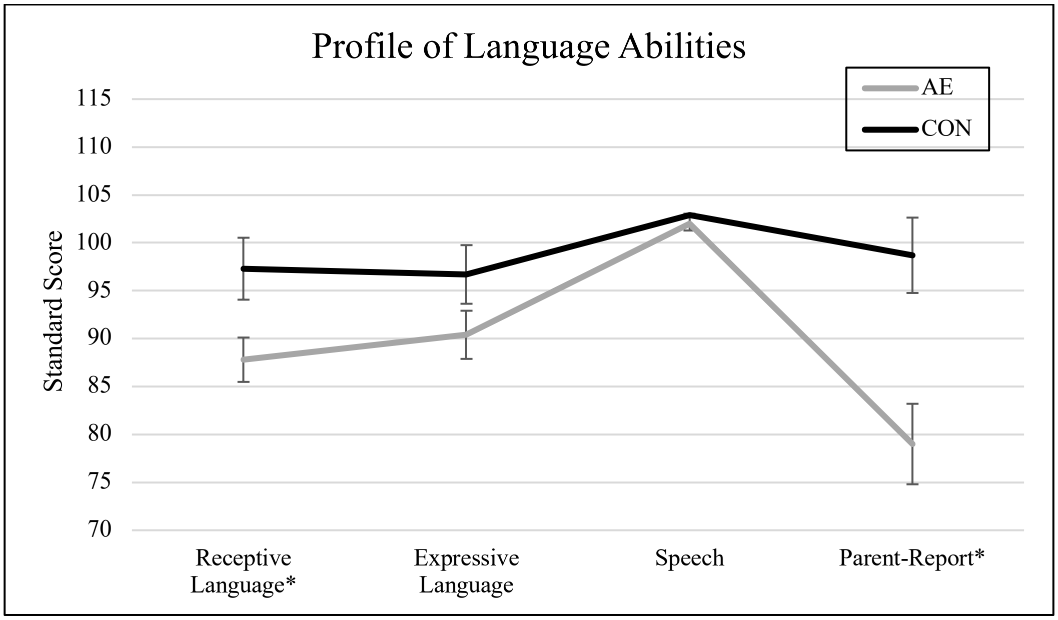

Figure 1. Profile of language abilities by group. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). Groups significantly differed on receptive language and parent-report of general language. *Note:* * $p < .05$ level. Receptive Language and Expressive Language were measured the Clinical Evaluation of Language Fundamentals – Fifth Edition. Speech was measured by the Sounds-In-Words subtest from Goldman-Fristoe Test of Articulation – Third Edition. Parent-report was measured by the General Communication Scale from the Children's Communication Checklist – Second Edition.

Hypothesis 1b. Two multiple regression analyses were conducted to examine the relative contribution of inhibition, working memory, and attention to receptive and expressive language ability. Predictors included group (AE and CON), each neuropsychological domain (inhibition, working memory, attention), and interactions between group and each neuropsychological domain to formally test for differences between groups. Significant effects were followed up with univariate ANOVAs on each dependent variable.

Receptive language. Results from the receptive language regressions are presented in Table 5. No significant interaction effects were noted for group and attention ($p = .104$), working memory ($p = .653$), or inhibition ($p = .386$). Upon removing the non-significant interaction effects, the overall model was significant [$F(4, 57) = 11.152$; $p < .001$] with significant main effects for group (p = .003), attention (p = .038), working memory (p = .018), and inhibition (p = .030). Significant cognitive variables (i.e., attention, working memory, inhibition) were used in subsequent receptive language analyses for Aim 2b.

Table 5. Stepwise multiple regression results for receptive language model. Results presented are from stepwise multiple regression analyses investigating the relation between neuropsychological variables and receptive language ability. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). The final model consisted of main effects for group, working memory, inhibition, and attention. *Note:* * $p < .05$ level. Inhibition was measured by the Inhibition Total Errors scaled score from the Delis-Kaplan Executive Function System Color-Word Interference Test; Working Memory was measured by the List Sorting Working Memory standard score from the National Institutes of Health (NIH) Toolbox Cognition Battery; Attention was measured by the Flanker Inhibitory Control and Attention standard score from the NIH Toolbox. The dependent variable, Receptive Language, was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Receptive Language Index standard score. β = standardized coefficients, B = unstandardized coefficients.

INTERACTION MODEL	**B**	**Standard Error**	**β**	***p***
Group	35.290	40.843	1.212	.392
Attention	.379	.145	.293	.012
Inhibition	1.596	.638	.392	.016
Working Memory	.291	.185	.237	.122
Group x Attention	-.641	.388	-1.750	.104
Group x Inhibition	-.907	1.038	-.348	.386
Group x Working Memory	.145	.320	.476	.653
Constant	25.107	18.049	--	.170
R^2	.500	--	--	--
FINAL MODEL	**B**	**Standard Error**	**β**	***p***
Group*	-9.890	3.212	-.340	.003
Attention*	.285	.134	.220	.038
Inhibition*	1.111	.498	.273	.030
Working Memory*	.367	.151	.299	.018
Constant	29.255	15.884	--	.071
R^2	.457	--	--	--

Expressive language. Results from the expressive language regressions are presented in Table 6. No interaction effects were noted for group and attention (p = .845), working memory

(p = .331), or inhibition (p = .739). Upon removing the non-significant interaction effects, the overall model was significant [$F(4, 58) = 6.457$; $p < .001$] with a significant main effect for attention (p = .008). The main effects for group (p = .066) and inhibition (p = .055) were trending towards significance and the main effect for working memory (p = .265) was not significant. Upon removing working memory as a non-significant effect, the overall model was significant [$F(3, 58) = 8.147$; $p < .001$] with significant main effects for group (p = .019), inhibition (p = .006), and attention (p = .004). Significant cognitive variables (i.e., attention, inhibition) were used in subsequent expressive language analyses for Aim 2b.

Table 6. Stepwise multiple regression results for expressive language model. Results presented are from stepwise multiple regression analyses investigating the relation between neuropsychological variables and expressive language ability. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). The final model consisted of the main effects for group, attention, and inhibition. *Note:* * $p < .05$ level. Inhibition was measured by the Inhibition Total Errors scaled score from the Delis-Kaplan Executive Function System Color-Word Interference Test; Working Memory was measured by the List Sorting Working Memory standard score from the National Institutes of Health (NIH) Toolbox Cognition Battery; Attention was measured by the Flanker Inhibitory Control and Attention standard score from the NIH Toolbox. The dependent variable, Expressive Language, was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Expressive Language Index standard score. β = standardized coefficients, B = unstandardized coefficients.

INTERACTION MODEL	**B**	**Standard Error**	**β**	***p***
Group	23.540	38.647	.786	.545
Attention	.378	.170	.290	.030
Inhibition	1.335	.748	.318	.080
Working Memory	.329	.216	.264	.135
Group x Attention	.076	.385	.200	.845
Group x Inhibition	-.383	1.146	-.144	.739
Group x Working Memory	-.342	.349	-1.089	.331
Constant	22.804	21.160	--	.286
R^2	.348	--	--	--
FINAL MODEL	**B**	**Standard Error**	**β**	***p***
Group*	-8.342	3.465	-.279	.019
Attention*	.442	.148	.340	.004
Inhibition*	1.404	.488	.334	.006
Constant*	49.694	12.279	--	<.001
R^2	.308	--	--	--

Post hoc analyses. Follow-up analyses examined whether inclusion of a heterogeneous CON group influenced results, specifically the contribution of ADHD to results. Subjects within the CON group that met research criteria for ADHD ($n = 9$) were excluded and Aim 1 analyses were re-examined. Results for Aim 1a remained except the group difference in expressive language was significant [$F(1, 44) = 5.140$, $p = .028$, partial $\eta^2 = .105$]. Expressive language scores were significantly higher for the CON group ($M = 100.2$) relative to the AE group ($M =$

90.3). Results for Aim 1b revealed that only the main effects of group ($p = .004$) and working memory ($p < .001$) related to receptive language and only the main effects of attention ($p = .005$) and working memory ($p = .015$) related to expressive language.

<u>Aim 2</u>: Evaluate the performance of adolescents with FASD on measures of functional and social communication to elucidate the clinical implications of the comprehensive language profile of these individuals.

Hypothesis 2a. A MANOVA with group (AE, CON) as the between-subjects factor and communication (SSIS, S-FAVRES) as the correlated outcome was conducted to examine differences in communication between AE and CON. Results are presented in Table 7. Using an alpha level of .001 to evaluate homogeneity assumptions, Box's M test of homogeneity of covariance ($p = .213$) and Levene's homogeneity test (all ps > .025) were not statistically significant. Using Wilk's criterion (Λ) as the omnibus test statistic, the combined dependent variables resulted in a significant main effect for group [$F(2, 54) = 4.5000$, $p = .016$, partial $\eta^2 = .143$]. To probe the statistically significant multivariate effects, univariate ANOVAs were conducted on each individual dependent variable (SSIS, S-FAVRES).

Overall, groups did not differ on functional communication performance, but parents rated the social communication abilities of the AE group as significantly worse than the CON group (see Figure 2). For functional language (S-FAVRES), the main effect for group was not statistically significant [$F(1, 55) = 2.374$, $p = .129$, partial $\eta^2 = .041$]. For parent-report on social communication (SSIS), there was a significant main effect for group [$F(1, 55) = 9.167$, $p = .004$, partial $\eta^2 = .143$]. Parents rated the CON group ($M = 92.4$) as having significantly higher (i.e., stronger) social communication abilities relative to the AE group ($M = 77.1$).

Table 7. MANOVA results for communication profile by group. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom. Social Communication was measured by the Social Skills standard score from the Social Skills Improvement System Rating Scales completed by parents. Functional Communication was measured by the Total Reasoning Subskills standard score from the Student Functional Assessment of Verbal Reasoning and Executive Strategies test.

Communication Variable	Group [F (df)]	*p*	Partial η^2
Omnibus*	4.500 (2, 54)	.016	.143
Social Communication*	9.167 (1, 55)	.004	.143
Functional Communication	2.374 (1, 55)	.129	.041

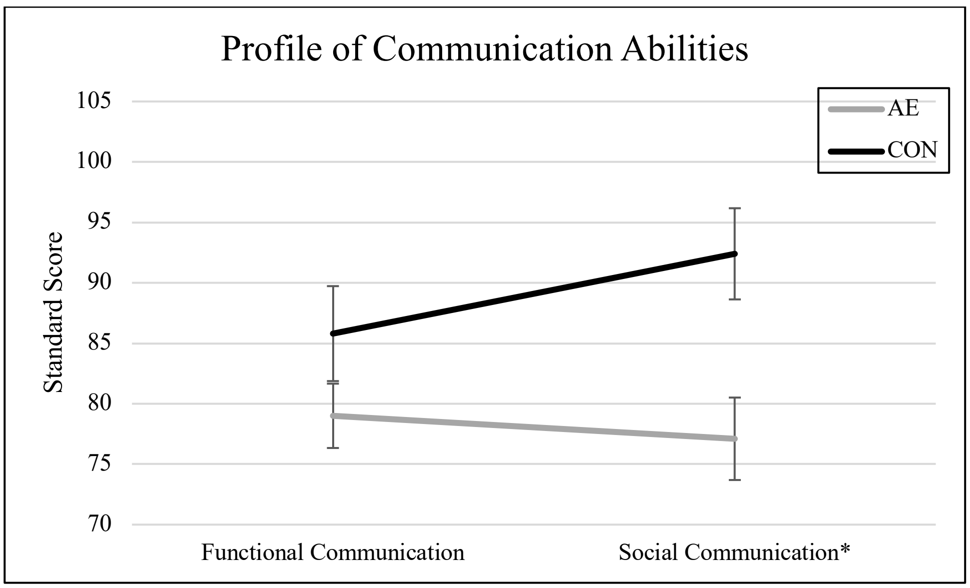

Figure 2. Profile of communication abilities by group. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). Groups significantly differed in social communication. *Note:* * $p < .05$ level. Groups significantly differed on social communication. Functional Communication was measured by the Total Reasoning Subskills standard score from the Student Functional Assessment of Verbal Reasoning and Executive Strategies test. Social Communication was measured by the Social Skills standard score from the Social Skills Improvement System Rating Scales completed by parents.

Post hoc analyses. Follow-up analyses examined whether inclusion of a heterogeneous CON group influenced results. Subjects within the CON group that met research criteria for ADHD ($n = 9$) were excluded and Aim 2a analyses were re-examined. Results for Aim 2a remained except the group difference in functional communication was significant [$F(1, 47)$ =

4.864, $p = .032$, partial $\eta^2 = .094$]. Functional communication scores were significantly higher for the CON group ($M = 89.9$) relative to the AE group ($M = 79.0$).

Hypothesis 2b. To determine if the proposed mediated effects differ between alcohol-exposed and control subjects, multigroup path analysis was used. Baseline models in each group were first tested to determine the viability of each mediated effect within each group. Subsequent to this, the path coefficients that comprise the target mediated effects were constrained to equivalence between groups. Due to sample size restrictions, separate models were analyzed testing the relation between language (Receptive, Expressive) and communication (Functional, Social) with significant cognitive variables (Aim 1b) included as mediators.

Receptive language on social communication. Three path-analytic models were tested to explore the relations between receptive language and attention, working memory, and inhibition, on social communication. The target models specified indirect relations from receptive language to social communication via attention, working memory, and inhibition mediating variables, respectively. Moreover, a direct path from receptive language to social communication was specified within each model. Results are presented in Tables 8-10. Overall, subjects who scored higher on receptive language performed better on measures of inhibition and working memory. Higher receptive language scores related to higher attention scores in the control group only. However, inhibition, working memory, and attention did not, in turn, predict social communication (see Figure 3).

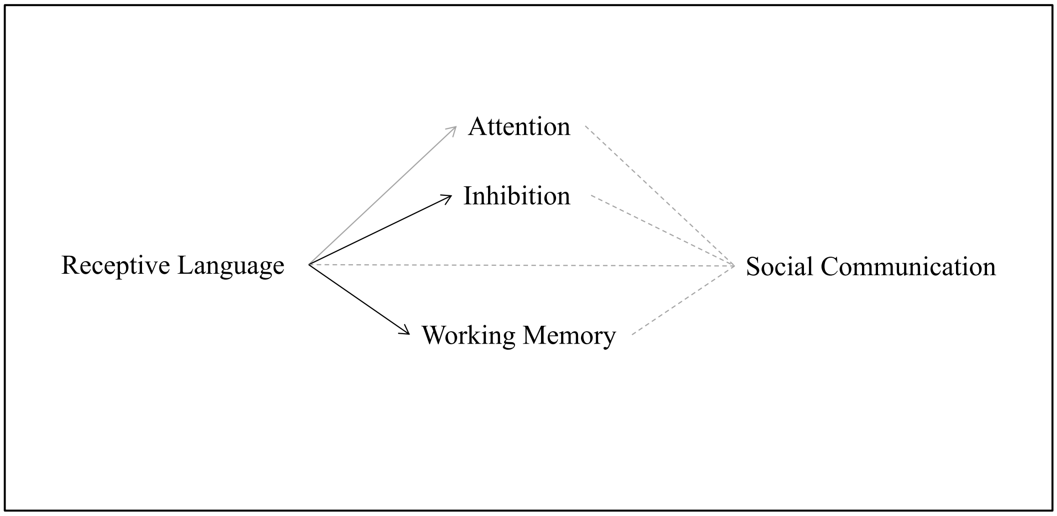

Figure 3. Relations between receptive language and social communication via attention, inhibition, and working memory. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). Non-significant pathways are indicated by dashed grey lines. Significant pathways across groups are indicated by solid black lines. The relation between receptive language and attention was significant only in the CON group as indicated by a solid grey line.

With respect to the relations specified within each model, the direct effect from receptive language to social communication was not significant in either group (*p*s $\geq$ .123). Furthermore, the compound paths composing each indirect effect were not statistically significant. In both groups, there was a statistically significant relation between receptive language and inhibition (*p*s $<$ .001) as well as working memory (*p*s $<$ .001). Attention was significantly related to receptive language in the CON group ($p < .001$) but not the AE group ($p = .648$). However, inhibition, working memory, and attention were not significantly associated with social communication (*p*s $\geq$ .423).

Table 8. Final multigroup path analysis results for receptive language on social communication via attention. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Social Communication was measured by the Social Skills standard score from the Social Skills Improvement System Rating Scales completed by parents. Receptive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Receptive Language Index standard score. Attention was measured by the Flanker Inhibitory Control and Attention standard score from the National Institutes of Health Toolbox.

ATTENTION	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	1.329 (2, 59)	.515	1.000	.000	.056
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Receptive Language on Attention	--	--	--	--	--
AE	-.039	.085	-.083	.181	.648
CON*	.536	.165	.582	.138	< .001
Attention on Social Communication	--	--	--	--	--
AE	.167	.242	.053	.079	.500
CON	.167	.242	.135	.193	.484
Receptive Language on Social Communication	--	--	--	--	--
AE	.257	.183	.174	.123	.155
CON	.257	.183	.225	.164	.169

Table 9. Final multigroup path analysis results for receptive language on social communication via working memory. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Social Communication was measured by the Social Skills standard score from the Social Skills Improvement System Rating Scales completed by parents. Receptive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Receptive Language Index standard score. Working Memory was measured by the List Sorting Working Memory standard score from the National Institutes of Health Toolbox.

WORKING MEMORY	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	2.742 (3, 59)	.433	1.000	.000	.242
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Receptive Language on Working Memory	--	--	--	--	--
AE*	.496	.093	.564	.095	< .001
CON*	.496	.093	.596	.107	< .001
Working Memory on Social Communication	--	--	--	--	--
AE	.009	.246	.005	.144	.972
CON	.009	.246	.007	.183	.972
Receptive Language on Social Communication	--	--	--	--	--
AE	.312	.206	.208	.135	.123
CON	.312	.206	.279	.187	.136

Table 10. Final multigroup path analysis results for receptive language on social communication via inhibition. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Social Communication was measured by the Social Skills standard score from the Social Skills Improvement System Rating Scales completed by parents. Receptive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Receptive Language Index standard score. Inhibition was measured by the Inhibition Total Errors scaled score from the Delis-Kaplan Executive Function System Color-Word Interference Test.

INHIBITION	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	1.493 (3, 59)	.684	1.000	.000	.106
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Receptive Language on Inhibition	--	--	--	--	--
AE*	.132	.026	.470	.096	< .001
CON*	.132	.026	.605	.109	< .001
Inhibition on Social Communication	--	--	--	--	--
AE	.641	.807	.119	.148	.423
CON	.641	.807	.125	.159	.429
Receptive Language on Social Communication	--	--	--	--	--
AE	.237	.189	.157	.126	.213
CON	.237	.189	.213	.169	.208

Receptive language on functional communication. Three path-analytic models were tested to explore the relations between receptive language and attention, working memory, and inhibition, on functional communication. The target models specified indirect relations from receptive language to functional communication via attention, working memory, and inhibition mediating variables, respectively. Moreover, a direct path from receptive language to functional communication was specified within each model. Results are presented in Tables 11-13. Overall, subjects who scored higher on receptive language performed better on functional communication. In addition, subjects who scored higher on receptive language performed better on measures of inhibition and working memory while higher receptive language scores related to higher attention scores in the control group only. However, inhibition, working memory, and attention did not, in turn, predict functional communication (see Figure 4).

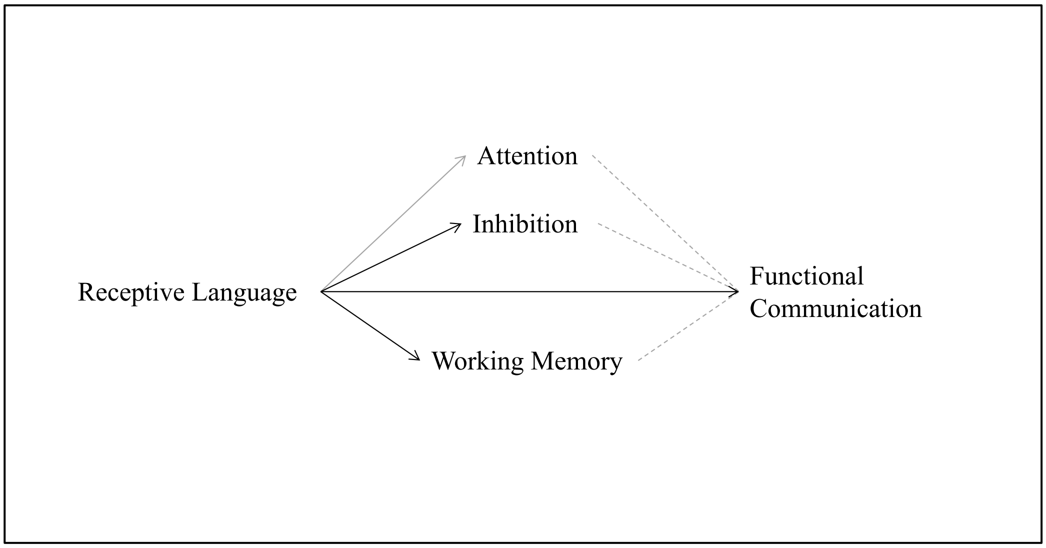

Figure 4. Relations between receptive language and functional communication via attention, inhibition, and working memory. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). Non-significant pathways are indicated by dashed grey lines. Significant pathways across groups are indicated by solid black lines. The relation between receptive language and attention was significant only in the CON group as indicated by a solid grey line.

With respect to the relations specified within each model, the direct effect from receptive language to functional communication was statistically significant in both groups (*p*s < .001). However, the compound paths composing each indirect effect were not statistically significant. In both groups, there was again a statistically significant relation between receptive language and inhibition (*p*s < .001) as well as working memory (*p*s < .001). Attention was significantly related to receptive language in the CON group ($p < .001$) but not the AE group ($p = .648$). However, inhibition, working memory, and attention were not significantly associated with functional communication (*p*s ≥ .491).

Table 11. Final multigroup path analysis results for receptive language on functional communication via attention. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Functional Communication was measured by the Total Reasoning Subskills standard score from the Student Functional Assessment of Verbal Reasoning and Executive Strategies test. Receptive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Receptive Language Index standard score. Attention was measured by the Flanker Inhibitory Control and Attention standard score from the National Institutes of Health Toolbox.

ATTENTION	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	1.311 (2, 59)	.519	1.000	.000	.060
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Receptive Language on Attention	--	--	--	--	--
AE	-.039	.085	-.083	.181	.648
CON*	.527	.165	.575	.140	< .001
Attention on Functional Communication	--	--	--	--	--
AE	.136	.203	.056	.086	.513
CON	.136	.203	.101	.147	.491
Receptive Language on Functional Communication	--	--	--	--	--
AE*	.539	.141	.478	.118	< .001
CON*	.539	.141	.436	.118	< .001

Table 12. Final multigroup path analysis results for receptive language on functional communication via working memory. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Functional Communication was measured by the Total Reasoning Subskills standard score from the Student Functional Assessment of Verbal Reasoning and Executive Strategies test. Receptive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Receptive Language Index standard score. Working Memory was measured by the List Sorting Working Memory standard score from the National Institutes of Health Toolbox.

WORKING MEMORY	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	1.870 (2, 59)	.600	1.000	.000	.236
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Receptive Language on Working Memory	--	--	--	--	--
AE*	.496	.093	.564	.095	< .001
CON*	.496	.093	.596	.107	< .001
Working Memory on Functional Communication	--	--	--	--	--
AE	-.011	.197	-.008	.150	.956
CON	-.011	.197	-.007	.136	.956
Receptive Language on Functional Communication	--	--	--	--	--
AE*	.575	.165	.497	.136	< .001
CON*	.575	.165	.476	.139	.001

Table 13. Final multigroup path analysis results for receptive language on functional communication via inhibition. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Functional Communication was measured by the Total Reasoning Subskills standard score from the Student Functional Assessment of Verbal Reasoning and Executive Strategies test. Receptive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Receptive Language Index standard score. Inhibition was measured by the Inhibition Total Errors scaled score from the Delis-Kaplan Executive Function System Color-Word Interference Test.

INHIBITION	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	1.516 (3, 59)	.679	1.000	.000	.070
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Receptive Language on Inhibition	--	--	--	--	--
AE*	.132	.026	.470	.096	< .001
CON*	.132	.026	.605	.109	< .001
Inhibition on Functional Communication	--	--	--	--	--
AE	.288	.627	.070	.153	.647
CON	.288	.627	.052	.112	.644
Receptive Language on Functional Communication	--	--	--	--	--
AE*	.534	.155	.464	.129	< .001
CON*	.534	.155	.440	.130	.001

Expressive language on social communication. Two path-analytic models were tested to explore the relation between expressive language and attention and inhibition on social communication. The target models specified indirect relations from expressive language to social communication via attention and inhibition mediating variables, respectively. Moreover, a direct path from expressive language to social communication was specified. Results are presented in Tables 14-15. Overall, subjects who scored higher on expressive language also scored higher on social communication. In addition, subjects who scored higher on expressive language performed better on attention and inhibition. However, attention and inhibition did not, in turn, predict social communication (see Figure 5).

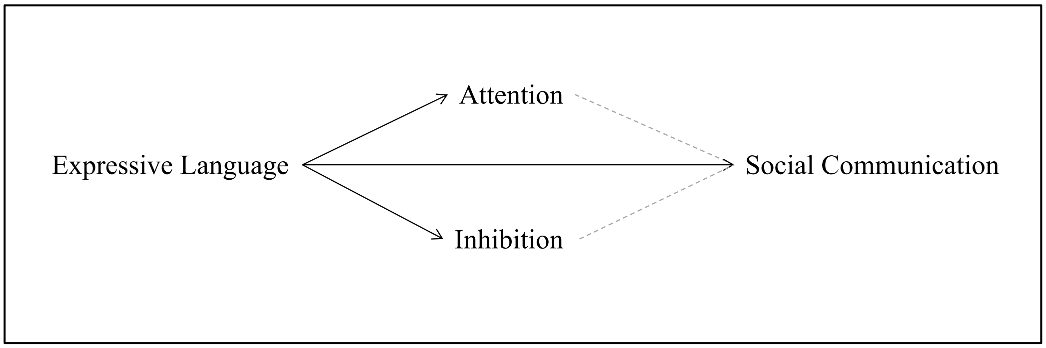

Figure 5. Relations between expressive language and social communication via attention and inhibition. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). Non-significant pathways are indicated by dashed grey lines. Significant pathways across groups are indicated by solid black lines.

With respect to the relations specified within each model, the direct effect from expressive language to social communication was statistically significant in both groups (ps $\leq .009$). However, the compound paths composing each indirect effect were not statistically significant. In both groups, there was a statistically significant relation between expressive language and attention (ps $\leq .025$) as well as inhibition (ps $< .001$). However, attention and inhibition were not significantly associated with social communication (ps $\geq .882$).

Table 14. Final multigroup path analysis results for expressive language on social communication via attention. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Social Communication was measured by the Social Skills standard score from the Social Skills Improvement System Rating Scales completed by parents. Expressive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Expressive Language Index standard score. Attention was measured by the Flanker Inhibitory Control and Attention standard score from the National Institutes of Health Toolbox.

ATTENTION	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	7.257 (3, 60)	.064	.745	.217	.282
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Expressive Language on Attention	--	--	--	--	--
AE*	.200	.081	.380	.136	.005
CON*	.200	.081	.229	.103	.025
Attention on Social Communication	--	--	--	--	--
AE	.072	.239	.303	.101	.764
CON	.072	.239	.048	.158	.762
Expressive Language on Social Communication	--	--	--	--	--
AE*	.487	.171	.391	.139	.005
CON*	.487	.171	.370	.123	.003

Table 15. Final multigroup path analysis results for expressive language on social communication via inhibition. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Social Communication was measured by the Social Skills standard score from the Social Skills Improvement System Rating Scales completed by parents. Expressive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Expressive Language Index standard score. Inhibition was measured by the Inhibition Total Errors scaled score from the Delis-Kaplan Executive Function System Color-Word Interference Test.

INHIBITION	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	7.160 (3, 60)	.067	.810	.215	.180
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Expressive Language on Inhibition	--	--	--	--	--
AE*	.103	.029	.402	.106	<.001
CON*	.103	.029	.458	.129	<.001
Inhibition on Social Communication	--	--	--	--	--
AE	.109	.737	.022	.150	.882
CON	.109	.737	.019	.127	.883
Expressive Language on Social Communication	--	--	--	--	--
AE*	.492	.181	.393	.151	.009
CON*	.492	.181	.377	.125	.003

Expressive language on functional communication. Two path-analytic models were tested to explore the relation between expressive language and attention and inhibition on functional communication. The target models specified indirect relations from expressive language to functional communication via attention and inhibition mediating variables, respectively. Moreover, a direct path from expressive language to functional communication was specified. Results are presented in Tables 16-17. Overall, subjects who scored higher on expressive language also scored higher on functional communication. In addition, subjects who scored higher on expressive language performed better on attention and inhibition. However, attention and inhibition did not, in turn, predict functional communication (see Figure 6).

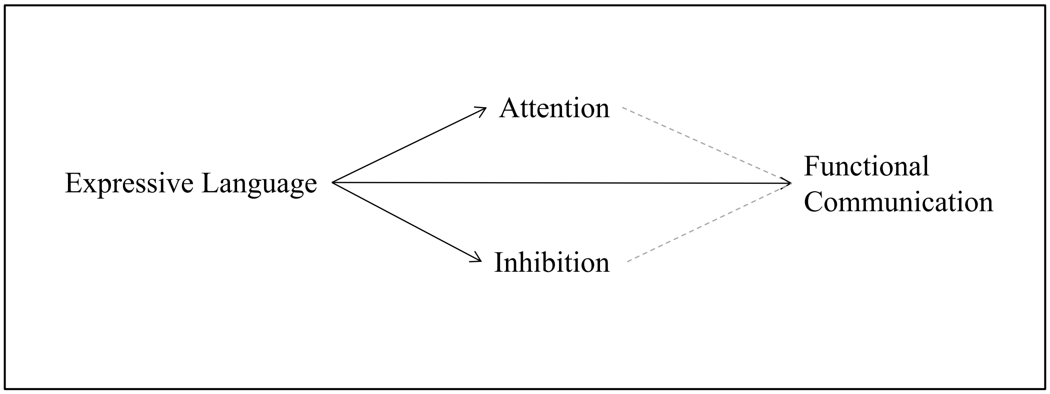

Figure 6. Relations between expressive language and functional communication via attention and inhibition. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). Non-significant pathways are indicated by dashed grey lines. Significant pathways across groups are indicated by solid black lines.

With respect to the relations specified within each model, the direct effect from expressive language to functional communication was statistically significant in both groups (ps $< .001$). However, the compound paths composing the indirect effects were not statistically significant. In both groups, there was a statistically significant relation between expressive language and attention (ps $\leq .025$) as well as inhibition (ps $< .001$). However, attention and inhibition were not significantly associated with functional communication (ps $\geq .335$).

Table 16. Final multigroup path analysis results for expressive language on functional communication via attention. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Functional Communication was measured by the Total Reasoning Subskills standard score from the Student Functional Assessment of Verbal Reasoning and Executive Strategies test. Expressive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Expressive Language Index standard score. Attention was measured by the Flanker Inhibitory Control and Attention standard score from the National Institutes of Health Toolbox.

ATTENTION	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	5.711 (3, 60)	.127	.890	.174	.274
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Expressive Language on Attention	--	--	--	--	--
AE*	.200	.081	.380	.136	.005
CON*	.200	.081	.229	.103	.025
Attention on Functional Communication	--	--	--	--	--
AE	.085	.200	.045	.106	.673
CON	.085	.200	.053	.125	.672
Expressive Language on Functional Communication	--	--	--	--	--
AE*	.598	.133	.601	.118	< .001
CON*	.598	.133	.428	.098	< .001

Table 17. Final multigroup path analysis results for expressive language on functional communication via inhibition. Groups included adolescents with heavy prenatal alcohol exposure (AE) and non-exposed controls (CON). *Note:* * $p < .05$ level, df = degrees of freedom, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual, SE = Standard Error, β = standardized coefficients, B = unstandardized coefficients. Functional Communication was measured by the Total Reasoning Subskills standard score from the Student Functional Assessment of Verbal Reasoning and Executive Strategies test. Expressive Language was measured by the Clinical Evaluation of Language Fundamentals – Fifth Edition Expressive Language Index standard score. Inhibition was measured by the Inhibition Total Errors scaled score from the Delis-Kaplan Executive Function System Color-Word Interference Test.

INHIBITION	**χ^2 (df, *N*)**	***p***	**CFI**	**RMSEA**	**SRMR**
Overall	3.951 (3, 60)	.267	.967	.103	.175
PATH COEFFICIENTS	**B**	**SE**	**β**	**SE**	***p***
Expressive Language on Inhibition	--	--	--	--	--
AE*	.103	.029	.402	.106	<.001
CON*	.103	.029	.458	.129	<.001
Inhibition on Functional Communication	--	--	--	--	--
AE	.507	.530	.130	.134	.335
CON	.507	.530	.081	.085	.339
Expressive Language on Functional Communication	--	--	--	--	--
AE*	.576	.133	.575	.120	< .001
CON*	.576	.133	.410	.096	< .001

Discussion

Overall, this study aimed to identify the profile of language (receptive, expressive, speech) and communication (social, functional) abilities among adolescents with heavy prenatal alcohol exposure and how these abilities differ from non-exposed controls. Further, we aimed to delineate cognitive bases (attention, working memory, inhibition) of these language abilities and determine the relation between language, communication, and cognitive variables.

Specific Aim 1

In terms of language abilities, our hypotheses were partially supported as the AE group performed below the CON group on all measures examined (Receptive Language, Expressive Language, Speech, Parent-Report of General Language) although these differences were only statistically significant on receptive language and parent-report. Furthermore, receptive language did not significantly differ from expressive language abilities within either group. These findings differ from previous studies that showed significant differences in both receptive and expressive language between AE and CON as well as stronger receptive than expressive language skills (McGee et al., 2009). The lack of group differences on expressive language in the current study may be attributable to the inclusion of a heterogeneous comparison group as follow-up analyses showed that in removing the CON subjects who met research criteria for ADHD, the groups significantly differed on expressive language abilities as well, though there were still no within-group differences between expressive and receptive language. Furthermore, the current study investigated these abilities among adolescents whereas previous studies have focused on younger children (e.g., 3-9 years of age) with prenatal alcohol exposure.

The patterns of language performance in previous studies and the current study suggest interesting developmental trends although longitudinal studies are needed to confirm crosssectional observations. While young children demonstrated better receptive than expressive language skills across groups, the level of performance in the AE group was similar on the two language measures (Expressive Language: M = 92.16; Receptive Language: M = 93.44; McGee et al., 2009). Differences between expressive and receptive language appeared to be driven more by the controls (Expressive Language: M = 102.54; Receptive Language: M = 109.62; McGee et al., 2009) although the Group x Test interaction was not significant. Similarly, findings from the current study suggest impaired receptive language abilities in the AE group as compared to the CON group, though again, receptive and expressive language scores did not significantly differ within the AE group (Expressive Language: M = 90.3; Receptive Language: M = 87.8; see Table 2). Longitudinal studies among non-exposed individuals with developmental language disorders show a similar pattern of impaired but stable language abilities over time (Johnson et al., 1999) although certain skills appear to plateau as individuals continue to fall behind as compared to their peers (Stothard et al., 1998). Taken together, results from the current study and those from previous studies highlight the need for longitudinal studies among individuals with prenatal alcohol exposure to clarify the developmental trajectories of these important language skills.

In addition to the differences in statistical significance, examination of effect sizes (see Table 4) suggests that receptive language (partial η^2 = .107) is more strongly related to group membership than expressive language (partial η^2 = .053) highlighting the importance of receptive language abilities among adolescents with prenatal alcohol exposure. The clinical implications of language disorders, characterized by impaired receptive and/or expressive language, are clear. Language disorders can impact long-term functioning in terms of academic functioning, occupational functioning, and socialization skills (American Psychological Association, 2013). In terms of academic functioning, components of receptive language such as sentence comprehension and understanding spoken passages have been implicated in reading disorders (Shankweiler & Crain, 1986). Indeed, smaller studies have shown worse receptive than expressive language abilities among youth with reading disorders (Stojanovik & Riddell, 2008).

Among individuals without a history of prenatal alcohol exposure, early language disorders predict significant social maladaptations in later life as well as increased risk for psychiatric disorders (Clegg et al., 2005). Notably, the prognosis for receptive language disorder is worse than that for expressive language disorder and early intervention is key in addressing these difficulties (Clark et al., 2007). In addition, individuals with a pure language disorder in the absence of speech impairments are at a high risk of developing psychiatric illness (Prizant et al., 1990) likely due to these underlying difficulties not being identified or intervened upon. Findings from the current study show intact speech abilities among adolescents with prenatal alcohol exposure highlighting the risk of these individuals developing psychiatric or functional issues due to underlying language disorders and potential for these language disorders to go unidentified.

Given the implications for impaired receptive language, findings suggest interventions targeted at improving receptive language abilities may be most beneficial in ameliorating language deficits among youth with prenatal alcohol exposure given the statistical significance and effect size of receptive language on group membership. Furthermore, receptive language (Pearson's $r = .804$) showed a stronger relation with FSIQ than expressive language (Pearson's $r = .575$) though both were significantly correlated with FSIQ. Limited research has investigated language and literacy interventions to improve academic functioning among youth with FASD in South Africa and has shown promising results on select measures of language and early literacy skills (Adnams et al., 2007). However, these interventions were not specifically targeted to receptive language skills. Among other neurodevelopmental disorders, limited research has investigated the responsiveness of language disorders to targeted intervention and findings suggest minimal improvement in receptive language abilities although earlier and longer term (i.e., more than 8 weeks) therapy provided better clinical outcomes (Law, Garrett, & Nye, 2004). As such, current results highlight the importance of early identification of language difficulties among youth with prenatal alcohol exposure to provide intervention as early as possible to improve deficits still evident in adolescence.

Another component of this study was to investigate the cognitive bases (attention, working memory, inhibition) of receptive and expressive language and how these relations may differ between groups (see Tables 5 and 6). Once again, our hypotheses were partially supported. Attention and inhibition significantly related to expressive language across groups with inhibition (B = 1.404) showing the strongest relation follow by attention (B = .442). As hypothesized, all cognitive domains tested significantly related to receptive language regardless of group with inhibition (B = 1.111) showing the strongest relation, followed by working memory (B = .367) and then attention (B = .285). Notably, the initial interaction effect of group with attention was trending towards significance though the current study was likely underpowered to detect a significant interaction effect. Follow-up analyses examining these relations without CON subjects that met research criteria for ADHD revealed significant main effects of group and working memory on receptive language, highlighting the significant group differences in receptive language as well as the importance of working memory abilities on receptive language skills. In addition, attention and working memory significantly related to expressive language abilities. The results regarding cognitive bases of language support the theoretical models posed emphasizing the role of working memory and attention in language function (Baddeley & Hitch, 1974). Specifically, the phonological loop subsystem of working memory has been implicated in language acquisition and development along with the central executive subsystem operating as an attentional control mechanism (Baddeley, 2003). The central executive subsystem relies heavily on frontal lobe function which similarly implicates the importance of other executive functions (e.g., inhibition) in language abilities. Thus, current findings suggest that deficient executive function processes (e.g., working memory, attention, inhibition) may be disrupting central aspects (i.e., phonological loop) of receptive and expressive language abilities and that group membership relates to receptive and expressive language above and beyond these cognitive processes.

Findings regarding cognitive bases of language abilities are similar to the relations between cognitive variables and language shown among children with SLI (Finneran, Francis, & Leonard, 2009; Im-Bolter, Johnson, & Pascual-Leone, 2006; Spaulding, Plante, & Vance, 2008). Notably, these relations are evident even when accounting for group, which included non-exposed subjects meeting research criteria for ADHD. As such, while receptive language abilities differed between groups, the cognitive bases contributing to receptive language abilities did not differ between groups and these cognitive variables related to receptive language ability above and beyond group membership. Similarly, cognitive bases contributing to expressive language abilities did not differ between groups. Findings suggest that interventions shown to be effective in treating language disorders of children with SLI (Goorhuis-Brouwer & Knijff, 2002) may be similarly helpful in treating language difficulties evidenced among youth with FASD. Furthermore, interventions targeting working memory, inhibition, and attention in combination with speech-language therapy may improve receptive language abilities of adolescents with prenatal alcohol exposure, while interventions focused on attention and inhibition may help improve expressive language abilities.

Overall, findings regarding the cognitive bases of language difficulties highlight the importance of comprehensive evaluation to identify individual strengths and weaknesses as intervention providers should be aware of cognitive limitations when working with youth with histories of prenatal alcohol exposure. Furthermore, such information will provide additional information regarding ways to individualize interventions and accommodations. For example, several interventions exist for improving or compensating for working memory deficits including classroom interventions, direct therapy, and environmental accommodations (Holmes, Gathercole, & Dunning, 2010). Youth with impaired working memory may require materials presented in smaller chunks of information with numerous repetitions and opportunities to practice skills. Interventions targeting executive functions (e.g., attention, working memory, inhibition) as a whole have also shown promise in improving functioning of young children with ADHD (Re, Capodieci, & Cornoldi, 2015) suggesting these interventions may be helpful for youth with prenatal alcohol exposure as similar cognitive bases are targeted. Similarly, youth with lower cognitive functioning may require presentation of concrete skills, rather than abstract, with real-world applications and explicit connection to previously learned material. Understanding the individual's cognitive strengths and weaknesses will allow for individualized and targeted interventions. Multidisciplinary and comprehensive intervention will likely provide the most benefit and opportunity for functional improvement of language skills for adolescents with prenatal alcohol exposure (Millians, 2015).

Specific Aim 2

Regarding communication abilities, our hypotheses were once again partially supported as groups did not significantly differ on a direct measure of functional communication (the S-FAVRES) but did significantly differ on a measure of social communication (SSIS). However, the average functional communication score of the AE group fell more than one standard deviation below average (M = 79.0) while the CON group was within the low end of the average range (M = 85.8) and parents of exposed youth reported difficulties in social communication on the SSIS. In addition, follow-up analyses that removed CON subjects meeting research criteria for ADHD lead to an increase in functional communication scores in the CON group (M = 89.9) and the difference between functional communication scores of the AE and CON groups becoming significant. The current study may have been underpowered to detect a statistically significant difference in functional communication with a heterogeneous control group. However, follow-up analyses highlight the significant impairment in communication among adolescents with prenatal alcohol exposure. Importantly, the S-FAVRES was designed to discriminate typical or average performance from below average performance. Based on descriptors provided by test manufacturers, the AE group performed in the below average range while the CON group performed in the low average range (MacDonald, 2013) highlighting the significant communication difficulties among the AE group. Social and functional communication abilities of the AE group were generally comparable and did not significantly differ.

Our hypotheses regarding relations between language and communication via cognitive variables were partially supported as expressive language related to social and functional communication more so than receptive language. Significant cognitive variables related to receptive or expressive language (see Tables 5 and 6), although these variables did not in turn show a mediation effect on functional or social communication in the multigroup path analyses (see Tables 8-17). In addition, receptive language significantly related to attention abilities in the control group but not the alcohol-exposed group despite earlier findings that showed a significant relation across groups (Aim 1b). As such, in combination with findings from Aim 1b, these results reinforce the importance of executive processes (i.e., working memory, inhibition, attention) in relation to receptive and expressive language skills of adolescents with prenatal alcohol exposure though attention does not appear to be significantly related to receptive language when also considering communication (both functional and social). These findings again highlight the importance of comprehensive evaluation and reinforce the potential efficacy of existing language interventions for youth with prenatal alcohol exposure given similar cognitive bases and suggest potential modifications to such interventions.

Consideration of cognitive domains is important in evaluating basic language skills but these domains do not appear to mediate the relation between language and communication. Rather, when considering the cognitive domains included in the current study, language appears to show a significant direct relation to communication highlighting the importance of basic language skills in higher-level communication abilities. Expressive language predicted both functional and social communication abilities whereas receptive language predicted functional communication abilities only. Although we are unable to determine causal relationships, this is the first known study to highlight a link between basic language skills and higher-level communication abilities among individuals with prenatal alcohol exposure. As such, improving receptive language skills may lead to improved functional communication, while improving expressive language skills may lead to overall improved communication (functional and social) abilities. A link has been shown between communication, emotional, and behavioral disorders

(Prizant et al., 1990) which are commonly occurring disorders among this population (Akbarian, 1992; Crocker et al., 2009; Fryer et al., 2007) emphasizing the need of comprehensive evaluation of language and communication abilities to help improve behavioral and emotional functioning of these individuals. Results from the current study suggest that improving communication abilities, in turn, may lead to better adaptive and behavioral functioning of youth with prenatal alcohol exposure.

The clinical implications of language and communication difficulties are clear and findings show previously unknown bases of language and communication impairment among adolescents with FASD. Therefore, common behavioral and psychiatric interventions (e.g., psychotherapy, medication, social skills) alone may not provide robust results in treating functional and social communication difficulties evident among youth with prenatal alcohol exposure given the significant relations between language skills and communication abilities. Additional components of speech-language therapy may provide added benefit and improve clinical outcomes. As highlighted above, intact speech abilities among this population also increases the risk for long-term functional impairment in the presence of underlying language and communication disorders and lack of identification (Prizant et al., 1990). Results again highlight the need for early identification in combination with comprehensive and multidisciplinary treatment to improve academic, social, and overall well-being of youth with prenatal alcohol exposure.

Limitations and Future Directions

Findings from the current study should be considered within the context of several limitations. First of all, while several interesting results were shown, we were limited in attainment of proposed study sample size ($N = 80$) which may have restricted statistically significant results. As such, we may have not had adequate power to detect relations with smaller effect sizes. Given observed effect sizes ranging from $.041 < partial\,\eta^2 < .169$ for MANOVA, post hoc power analyses showed required sample sizes ranging from 69 to 270 in order to detect significant special effects of interest. Despite this limitation, several significant results were revealed, and effect size estimates provide additional information for potentially significant findings. In evaluating effect size estimates, we are able to weigh practical as well as statistical significance. Along those lines, we were limited in the adolescent age range we were able to investigate (i.e., 12-17 years) based on normative age ranges for the chosen measures. In our study, 3 of the 8 AE subjects with parent-reported delayed language continued to show language impairment on our measures while 2 of the 4 CON subjects with delayed language continued to show impairment. Future studies should expand upon this age range and consider longitudinal examination to elucidate developmental trajectories of language and communication abilities. Further, longitudinal studies can help to clarify causal relationships between observed variables.

Other possible limitations include the assessments chosen to measure study constructs. While standard measures of neuropsychological and speech-language function were used, other measures may have provided additional information regarding language and communication ability. For example, the S-FAVRES was included as an objective measure of functional communication. While standardized on language impaired (i.e., adolescents with traumatic brain injury) and unimpaired subjects (MacDonald, 2013), it may be more sensitive to attention difficulties and effort as group differences were not evident with a heterogeneous control group. Furthermore, inclusion of a direct measure of social communication may be helpful to clarify or validate parent-reported concerns. Despite these limitations, the AE group performed below the average range while the CON group was within the average range, particularly when removing subjects meeting research criteria for ADHD. As highlighted above, the purpose of the S-FAVRES is to identify individuals with below average communication skills and results suggest possible use in clinical settings to delineate cognitive-communication difficulties experienced by adolescents with prenatal alcohol exposure. Future studies with larger sample sizes will help clarify this pattern. Concern may also exist in using parent-report questionnaires as parents or caregivers may be similarly impaired in language abilities. A reading level roughly equivalent to the fifth grade is required (Bishop, 2006; Gresham & Elliot, 2008) and follow-up analyses showed that caregiver education level did not significantly predict CCC-2 or SSIS scores (*p*s $\geq .139$). Therefore, it is unlikely that caregiver education levels significantly influenced results. Future studies should also expand upon the cognitive domains chosen to investigate potential underlying mechanisms of the relation between language and communication.

Additional confounds that are inherent to prenatal alcohol exposure should be considered. Other psychiatric disorders are highly prevalent among individuals with prenatal alcohol exposure and may have contributed to our findings (e.g., ADHD, depression). However, inclusion of a heterogeneous control group provides additional support for our findings above and beyond comorbid diagnoses. We also considered the contribution of ASD to our findings as the AE group had significantly more ($p = .004$) subjects with an existing ASD diagnosis ($n = 10$; 32.3%) than the CON group ($n = 1$; 3.4%) per parent report. However, accounting for existing

ASD diagnoses removes important variability inherent to group membership as some have suggested elevated rates of ASD among youth with FASD (Mukherjee, Layton, Yacoub, & Turk, 2011) and there may be a significant overlap in symptomatology, particularly impaired quality of social interactions (Bishop, Gahagan, & Lord, 2007; Stevens, Nash, Koren, & Rovet, 2013). Furthermore, we were not able to specifically recruit subjects with an ASD diagnosis and did not verify the accuracy of the diagnosis. Exploratory analyses showed that within the AE group, subjects with and without an existing ASD diagnosis, based on parent report, did not significantly differ on any language or communication variables (ps $\geq .087$). However, future studies should consider inclusion of an ASD comparison group to further investigate these relations between language and communication and clarify the profile of abilities between youth with FASD and those with ASD. In addition, information regarding medication usage during testing appointments was not available, though all subjects were asked to refrain from medication usage on the days of testing. However, potential cumulative effects due to medication usage cannot be entirely ruled out. In addition, while we screened subjects for hearing loss, studies have documented listening difficulties among individuals with FASD (McLaughlin et al., 2019). Future studies should consider a more in-depth assessment of hearing and listening abilities (e.g., multispeaker, filtering abilities) of adolescents with FASD to elucidate how these skills may related to language and communication.

Other confounds include maternal use of other substances (e.g., cocaine, nicotine, marijuana) during pregnancy. Due to the retrospective nature of this study, specific information regarding smoking or other drug use is unknown and as such we cannot account for these potentially confounding variables. We require evidence of alcohol as the primary substance of exposure for inclusion in the alcohol exposed group, though we cannot rule out the effects of other drugs of abuse. Future studies would benefit from investigating potential contribution of other substances to observed patterns of language and communication among these youth.

Conclusions

The current study is the first known comprehensive investigation of language and communication abilities of adolescents with prenatal alcohol exposure. In terms of language, the alcohol-exposed group performed below the control group on all variables though only significantly differed in receptive language skills and parent-report of general language. These findings have significant clinical implications as receptive language disorders are often difficult to identify and treat. Evaluation of cognitive bases showed that working memory, inhibition, and attention are important factors in receptive and expressive language abilities of adolescents with prenatal alcohol exposure and may provide targets for intervention.

While adolescents with prenatal alcohol exposure did not differ from heterogeneous controls on a measure of functional communication, the average scores of the alcohol-exposed group fell in the below average range identifying these subjects as experiencing clinically significant communication difficulties. Furthermore, parents of adolescents with prenatal alcohol exposure reported significantly impaired social communication skills as compared to controls. Findings highlight clinically important relations between basic language skills and higher-level communication abilities as expressive language predicted both social and functional communication while receptive language predicted functional communication. Overall, improving receptive and expressive language skills may translate to better social and functional communication. Ultimately, improving communication skills may translate to better functioning for adolescents affected by prenatal alcohol exposure in social, academic, and occupational domains.

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