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Research Note

Linguistic Maze Production by Children and Adolescents With Attention-Deficit/Hyperactivity Disorder

Katherine J. Bangert[a] and Lizbeth H. Finestack[a]

Purpose: Previous investigations reveal that children with attention-deficit/hyperactivity disorder (ADHD) produce elevated rates of linguistic mazes (i.e., filled pauses, repetitions, revisions, and/or abandoned utterances) in expressive language samples (Redmond, 2004). The current study aimed to better understand maze use of children and adolescents with ADHD with a focus on the specific maze types produced in different language sampling contexts based on the Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2012).
Method: Participants included twenty-five 4- to 13-year-olds with a confirmed diagnosis of ADHD. Each participant completed the ADOS to provide narrative and conversational language samples. Research assistants transcribed at least 100 utterances from the ADOS using Systematic Analysis of Language Transcripts (Miller & Chapman, 2000) conventions. Dependent variables included the rates of repetitions, revisions, filled pauses, content mazes (Thordardottir & Ellis Weismer, 2002), and stalls (Rispoli, 2003; Rispoli, Hadley, & Holt, 2008) produced in narrative and conversational portions of the ADOS.
Results: In the full sample, participants produced a significantly greater rate of revisions than filled pauses ($p = .01$) and repetitions ($p < .01$). Participants also produced a significantly lower rate of filled pauses than content mazes ($p < .01$). Across contexts, participants produced a higher rate of filled pauses in conversational versus narrative contexts. Age was positively correlated with revisions and content mazes. Mean length of utterance was positively correlated with revisions, repetitions, and context mazes. Expressive language ability was positively correlated with filled pauses and stalls.
Conclusion: The children and adolescents in our sample demonstrated a unique profile of maze use. Sampling context had a limited influence on maze use, whereas maze use was impacted by age, mean length of utterance, and expressive language ability. Study findings highlight the importance of analyzing maze types separately rather than as a single category.

Child and adult speakers commonly produce linguistic mazes or disruptions in speech flow. These disruptions include long and filled pauses (e.g., "I want...to go," "Where is the, um, balcony?"); repetitions of sounds, syllables, words, and phrases (e.g., "C-come with me," "I want the ball-balloon," "I, I want the ball," "I want, I want the ball"); revisions of previous produced speech (e.g., "I want, I went to the store"); and orphans, or abandoned utterances in which a verbal expression is not completed (e.g., "I went to…"). The direct cause or purpose of maze production is unknown, but elevated maze production has been associated with weaknesses in language processing and/or executive functioning (Boscolo, Ratner, & Rescorla, 2002; Dollaghan & Campbell, 1992; Guo, Tomblin, & Samelson, 2008; Nettelbladt & Hannaon, 1999; Rispoli & Hadley, 2001; Thordardottir & Ellis Weismer, 2002; Wetherell, Botting, & Conti-Ramsden, 2007).

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common childhood neurodevelopmental disorders diagnosed, with current estimates at 8.4% of children in the United States (Danielson et al., 2018). According to the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (American Psychiatric Association, 2013), ADHD is characterized by symptoms of inattention and/or hyperactivity and impulsivity that interferes with development. The profiles of children with ADHD include weaknesses in cognitive processing, especially in the executive functioning domain of inhibition (Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004; Oram, Fine, Okamoto, &

[a]Department of Speech-Language-Hearing Sciences, University of Minnesota, Minneapolis

Correspondence to Katherine J. Bangert: bange017@umn.edu

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Tannock, 1999; Schachar, Mota, Logan, Tannock, & Klim, 2000). Children with ADHD are also at an increased risk for deficits in language, learning, and reading (Oram et al., 1999; Purvis & Tannock, 1997; Tirosh, Cohen, & Child, 1998). Investigators have found heightened maze use by individuals with ADHD compared to individuals without ADHD and individuals with other developmental disorders (Engelhardt, Ferreira, & Nigg, 2011; Redmond, 2004).

Elevated maze use may represent underlying weaknesses in language formulation and/or processing. Speech fluency has been shown to be strongly correlated with both language ability (Boscolo et al., 2002; Dollaghan & Campbell, 1992; Guo et al., 2008; Nettelbladt & Hannaon, 1999; Thordordottir & Ellis Weismer, 2002; Weber-Fox, Hampton Wray, & Arnold, 2013; Wetherell et al., 2007) and executive functioning (Turkstra, Fuller, Youngstrom, Green, & Kuegeler, 2004). Difficulties in either or both domains may underlie the increase in maze use by individuals with ADHD. The purpose of the current study was to examine the different types of mazes produced by children and adolescents with ADHD and investigate relationships between maze use, language context, and participants' language, cognitive, and behavioral profiles.

Defining and Categorizing Linguistic Mazes

Researchers generally define mazes as disruptions in speech flow most commonly characterized as pauses, repetitions, revisions, and orphans (Dollaghan & Campbell, 1992). Silent pauses include a period of silence lasting 2 s or more that interrupts the utterance. Filled pauses are interjections of words that are meaningless to the conveyed message ("uh," "like," "ya know"). Repetitions are characterized as linguistic units repeated verbatim in succession at the sound, word, phrase, and sentence levels ("I (I) went to the store"). Revisions consist of modifications of an utterance already produced by the speaker to add, remove, or somehow change the previous utterance ("I went to the store (yesterday) the day before yesterday"). Orphans include expressed thoughts that are not finished—the utterance is abandoned before the speaker finishes the message ("I went to the…"). Studies investigating linguistic mazes vary in how they categorize maze types. Investigators have proposed taxonomies that include dichotomous categorizations based on formulation difficulties, such as lexical retrieval or syntactic difficulty (e.g., Rispoli et al., 2008; Thordardottir & Ellis Weismer, 2002).

For children who are developing typically, it is believed that the production of linguistic mazes is related to syntactic development (see Gou, Tomblin, & Samelson, 2008, for a review; Rispoli & Hadley, 2001). Rispoli and colleagues (Rispoli, 2003; Rispoli & Hadley, 2001; Rispoli et al., 2008) examined the relationship between linguistic mazes and the length and complexity of sentences produced by children developing grammar, drawing from an adult-based theory of incremental, hierarchical encoding. Incremental encoding allows speakers to begin a message before it is fully formed, which speeds up the process of speech production. As a sentence is being produced, it is broken into increments. The first increment is grammatically encoded and sent to the next level of production—phonological encoding. As this happens, the second increment of the sentence is grammatically encoded and then is phonologically encoded as the first increment is sent to the final level of production—articulation. When a disruption or "glitch" arises at the grammatical encoding level, it causes an interruption in the flow of information that is inherited by the successive phonological and articulatory levels of encoding, eventually surfacing as a sentence disruption or maze. Specifically, encoding glitches are likely to manifest as mazes characterized as a silent or filled pause or a repetition according to Rispoli and colleagues (Rispoli, 2003; Rispoli et al., 2008).

Rispoli and colleagues (Rispoli, 2003; Rispoli et al., 2008) attribute mazes characterized as revisions to the monitoring process of the speaker, which compares the speech output to the intended message. If there is an unacceptable discrepancy between the output and the intent, the speaker revises the utterance. Rispoli (2003) and Rispoli et al. (2008) investigated if changes could be detected in the types of disfluencies that occurred in typically developing children's speech productions. They proposed a maze taxonomy that separates sentence disruptions into a dichotomy of either stalls or revisions, each with distinct underlying causes. Under their framework, the production of long pauses, filled pauses, and repetitions that do not contribute to the meaning of the overall message arises from glitches in the encoding process. These glitches are thought to be necessary to allow for further processing of the message. Rispoli et al. characterize these types of mazes as "stalls," as the speaker is stalling to wait for the internal incremental syntactic and phonological encoding processes to complete the message. If the speaker reaches the end of the articulation program before the next increment is sent, the speaker must stall, disrupting the flow of speech (Rispoli, 2003). In contrast, they link the production of revisions to a central monitoring system that compares the speaker's intended message to the linguistic output. They consider revision use as an overt manifestation of grammatical knowledge. When external monitoring occurs, if there is a discrepancy in the intended message and the message output, the speaker revises the utterance, creating a maze revision. Rispoli and Hadley (2001) found that, in typically developing preschoolers, maze use increased with syntactic complexity. Furthermore, when examined separately, revisions were produced at a higher rate as syntactic complexity increased, whereas stalls were not in children aged 1–4 years (Rispoli, 2003). Studies utilizing a framework of stalls versus revisions have been useful for examining syntactic development, especially in young children. However, there are other categorizations of maze types by other researchers for different age groups and/or diagnoses.

Another way of investigating mazes was proposed by Thordardottir and Ellis Weismer (2002). They examined mazes by combining repetitions and revisions into a category that they characterized as "content mazes." They posited that content mazes represent processing difficulties in producing a message, while filled pauses serve a pragmatic function. Thordardottir and Ellis Weismer compared maze use in the narratives of children with specific language impairment (SLI; n = 50) to children with typical language development (TD; n = 50), all between the ages of 5 and 9 years. They hypothesized that high frequencies of mazes could be indicative of a processing conflict during speech production. Given the processing and working memory limitations associated with children with SLI, they expected a higher frequency of both types of mazes in this population. They also proposed that, as overall language complexity increased, so would the frequency of mazes, especially in children with SLI. Maze measures, based on narrative language samples, included the number of mazes (both content mazes and filled pauses), the number of filled pauses, and the number of content mazes. They found that the children with SLI produced significantly fewer filled pauses than age-matched children with TD, but there was no difference in content maze use across groups. Within the diagnostic group, the children with SLI produced significantly fewer filled pauses than content mazes, and the children with TD did not have significant differences between the two maze types. These findings suggest that the two maze types are not influenced or manifested by the same processes.

In a follow-up analysis, Thordardottir and Ellis Weismer (2002) formed subgroups of children matched on MLU. The subgroup of children with SLI (n = 25, M_{age} = 8.4 years) had a higher mean MLU than the larger age-matched SLI group. Thus, this group included the children with SLI who had relatively higher language abilities. Between diagnostic groups, the children with SLI used significantly more content mazes than the children with TD (n = 25, M_{age} = 7.0 years). Similar to findings with the larger age-matched sample, the children with SLI produced significantly fewer filled pauses. Within groups, children with SLI produced fewer filled pauses than content mazes. There were no significant differences across maze types for the TD group. The authors concluded that content mazes are susceptible to processing factors (i.e., utterance length), but filled pauses are not. They further speculated that filled pauses might be influenced by pragmatic factors independent of utterance length. Thus, filled pauses may serve the function of indicating that the speaker still holds the floor when they encounter a speech or language processing difficulty.

In summary, linguistic mazes are thought to be indicative of underlying processes related to external monitoring and repair (i.e., revisions), pragmatics (i.e., filled pauses), and/or motor programming arising from difficulties in lexical retrieval or in syntactic processing. Classification of maze types differ across studies, based on which linguistic process is disrupted. Thordardottir and Ellis Weismer did not separate revisions from repetitions, attributing filled pauses to a pragmatic function and content mazes (repetitions, revisions) to a linguistic processing/motor programming difficulty. Rispoli et al. did not separate filled pauses from repetitions, attributing them both to processing/programming difficulty, and revisions representing self-monitoring and repair that is closely tied to syntactic ability. For the current study, we investigated each maze type separately, and also according to each framework introduced above, to determine if our population of children and adolescents with ADHD has a unique profile of maze behaviors or one more similar to typically developing children or children with SLI. We also examined the relationships between maze use, age, ADHD symptomology, cognitive ability, and language ability.

Context and Maze Use

As the demands of communicative tasks increase, so do the production of linguistic mazes (Oomen & Postma, 2001; Postma, Kolk, & Povel, 1990). For example, in narrative language contexts, which tend to elicit more grammatically complex language, children and adults produce mazes at a higher frequency than in conversational language contexts (MacLachlan & Chapman, 1988; Navarro-Ruiz & Rallo-Fabra, 2001; Wagner, Nettelbladt, Sahlén, & Nilholm, 2000; Wetherell et al., 2007). Wagner et al. (2000) compared the language use of 5-year-old children with SLI in narrative and conversational contexts. They found higher MLU and maze use (examining all mazes as a single category) in the narrative context than in the conversational context. In an exploratory study, Navarro-Ruiz and Rallo-Fabra (2001) compared disfluencies in four typically developing children and four children with SLI between the ages of 6 and 8 years. They classified mazes into three categories: mazes related to fluency (i.e., hesitations and repetitions), mazes related to channel of communication and turn of talk (i.e., filled pauses), and mazes related to self-repair (i.e., revisions). Both the children with TD and the children with SLI produced more mazes overall in narrative discourse than in conversational discourse, with fluency-type mazes (repetitions, silent pauses) occurring most frequently. Children with TD produced more filled pauses than children with SLI in both contexts. Additionally, the children with SLI produced significantly more silent pauses and more abandoned utterances than the typically developing children in both contexts. In the current study, we compared mazes produced in narrative and conversational contexts to better understand the influence of language sampling context on maze production.

Maze Use by Individuals With ADHD

Investigators have found heightened maze use by individuals with ADHD compared to those without ADHD and individuals with other developmental disorders, which could represent difficulty in language formulation and/or executive functioning in this population (Engelhardt et al., 2011; Redmond, 2004). Redmond (2004) compared language measures derived from conversational samples of children with ADHD, SLI, and TD who were between the ages of 5 and 8 years. Conversation samples were collected during

30 min of free-play with an examiner and age-appropriate toys. In Redmond's analyses, revisions, filled pauses, and repetitions were categorized together as a single variable of maze use. Pairwise comparisons across groups did not reveal statistically significant differences between children with ADHD and children with TD on measures of lexical diversity or morphosyntax. However, children with ADHD produced significantly more words per maze and a greater percentage of total words mazed than both children with SLI and children with TD. Redmond hypothesized that fluency difficulties were caused by limitations in executive function.

A subsequent study of adults with ADHD by Engelhardt et al. (2011) suggests that difficulty with utterance formulation in children with ADHD may persist into adulthood. Analysis of language produced by 44 adults with ADHD and 31 controls revealed that the ADHD group produced significantly more repetitions and silent pauses than those without ADHD when describing pictures of a colored network of dots. Thus, there is evidence that children with ADHD produce more mazes than their typically developing peers and that this pattern persists into adulthood.

In a study of incarcerated adolescents (aged 13–17 years) with and without conduct disorder, Turkstra et al. (2004) found a strong association between maze use in conversational language samples and executive functioning abilities as measured by parent questionnaires. In their sample, maze use increased as executive functioning ability diminished. Executive functioning deficits are also well documented in individuals with ADHD, especially in the domain of inhibition (Pennington & Ozonoff, 1996; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). In a study of children between the ages of 6 and 12 years, Guerts, Verte, Oosterlaan, Poeyers, and Sergeant (2004) found children with ADHD performed significantly worse than typically developing peers on executive functioning tasks of inhibiting a prepotent response (e.g., suppressing an automatic response) and verbal fluency (e.g., naming examples in a category when given 1 min). Other domains compared included working memory, planning, and flexibility. There were no differences across ADHD or TD groups in those domains. Executive functioning difficulties in the area of verbal fluency (e.g., word retrieval) could potentially be causing lexical retrieval slowdowns during linguistic processing of the message. This would cause a glitch in the flow of processing, eventually manifesting as a maze. Furthermore, difficulty with inhibiting a prepotent response could cause children with ADHD to produce mazes related to self-repair. An increased understanding of the types of mazes used by children and adolescents with ADHD may provide further insight regarding why mazes occur and how they are influenced by language and cognitive processes.

Current Study

In the current study, we aimed to expand upon the work of Redmond (2004), examining mazes produced by children and adolescents with ADHD. We used a within-subject design to examine the maze types produced by children and adolescents with ADHD. Unique to this study, we analyzed specific maze types, mazes grouped according to underlying functions, and mazes produced in different contexts. We also examined the relationship between maze use and language ability. We included a larger age range of children that overlap with the ages of children included in the studies of Rispoli (2003), Thordardottir and Ellis Weismer (2002), Navarro-Ruiz and Rallo-Fabra (2001), and Redmond (2004) to shed light on potential developmental changes in maze use. In an effort to better understand the language profiles of children with ADHD, our specific research questions were the following:

1. What are the maze profiles of children and adolescents with ADHD when maze types are examined individually (revisions, repetitions, filled pauses) and when grouped by function (i.e., content mazes or stalls)?
2. Do the rates of mazes produced by children and adolescents with ADHD differ based on language sampling context (i.e., narrative and conversation)?
3. What are the relationships between the rates of mazes produced and the language and cognitive skills as well as ADHD symptom severity of children and adolescents in this population?

Given findings that children with ADHD may have weaknesses in language similar to children with SLI, and consistent with Rispoli et al.'s framework, for Research Question 1, we predicted that the children and adolescents with ADHD in our sample would produce fewer revisions than stalls (repetitions and filled pauses). Based on Thordardottir and Ellis Weismer's taxonomy, we predicted that our participants with ADHD would produce fewer filled pauses than content mazes (repetitions and revisions combined) and more filled pauses in the conversational context. However, we were cautious in these predictions because evidence suggests that inhibition and verbal fluency (e.g., word retrieval) are documented areas of executive functioning deficit in children with ADHD. We also posited that these may cause different types of mazes. The lack of inhibition of a prepotent response could cause an increase in revisions in this population. Difficulty with word retrieval could cause an increase in filled pauses or stalls (filled pauses and repetitions).

For Research Question 2, we predicted that, as demands of the language sample increased, so too would the production of mazes. Therefore, we predicted that participants would also produce more revisions in narrative contexts than in conversational contexts. If filled pauses indeed serve a pragmatic function, we also predicted that children would use filled pauses more in conversation than in narrative contexts because, during a narrative context, there is less need for the speaker to indicate they still hold the floor.

For Research Question 3, based on Rispolli et al., we predicted positive associations between the production of revision mazes and age, language skills, and cognitive abilities. In contrast, we predicted nonsignificant correlations between the production of stalls, age, and language skills. Investigations of maze use and ADHD symptom severity, to our knowledge, have not been done. We therefore did not have a clear hypothesis regarding maze use and associated ADHD behaviors. We cautiously anticipated that, as severity increased, children would produce more repairs and filled pauses due to limitations in inhibition and verbal fluency. Based on Redmond's (2004) findings that children with ADHD produced more mazes than children with SLI and children with TD, we also cautiously anticipated that an increase in ADHD problem behaviors would lead to greater maze use in general.

Method

Participants included 25 children and adolescents with ADHD between the ages of 4 and 13 years (17 boys, eight girls). Participation criteria included a diagnosis of ADHD by a licensed clinical psychologist using *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (American Psychiatric Association, 2013) criteria. Diagnosis was informed by observation, parent and teacher questionnaires, standardized assessments, and previous medical reports. A clinical psychologist reviewed all of the information gathered from the parent and child assessments and reviewed previous diagnostic reports to assign participants a best-estimate diagnosis of ADHD based on the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision*. Participants were part of a larger study investigating an autism spectrum disorder (ASD) screening tool (Bishop et al., 2017; Havdahl et al., 2016). Eligibility criteria for the larger study included either a clinical diagnosis of ASD or a targeted non-ASD diagnosis (i.e., ADHD, language disorder, intellectual disability, mood or anxiety disorder). Table 1 includes information on demographic characteristics of the sample.

To eliminate the chances of comorbidity of ASD in the children with ADHD, all participants completed a full ASD diagnostic assessment, including the Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2012), Autism Diagnostic Interview–Revised (Rutter, Le Couteur, & Lord, 2003), the Vineland Adaptive Behavior Scales–Second Edition (Sparrow, Cicchetti, & Balla, 2005), and cognitive testing (i.e., the Differential Ability Scales–Second Edition [DAS-II]; Elliott, 2007). Clinical psychologists with specialized training in diagnosis of ASD and other developmental disorders administered all assessments. The diagnostic sessions typically required 3–4 hr for a parent interview and 2.5–3.5 hr for the child assessments. The examiner provided the participant with breaks as needed. Additionally, parents completed several questionnaires, including the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001), the Conners' Parent Rating Scales–Revised (Conners, 2001), the Spence Children's Anxiety Scale (Parent Version; Spence, 1999), and a background history form. Children completed the Multidimensional Anxiety Scale for Children (March, 1997). To rule out hearing loss as an influence on each participant's diagnostic status, all participants completed a hearing screening, which required them to detect 20–dB HL pure tones at 1000, 2000, and 4000 Hz in both ears.

Table 1. Participant demographics.

Variable	*n*
Race	
African American	15
White	8
Biracial	1
Other	1
Income	
< $20,000	12
$21,000–$35,000	9
$36,000–$50,000	2
$66,000–$100,000	2
Maternal education	
Some college, associate, or vocational	14
4-year college degree	5
Graduate/professional	1
No response	5

Key assessments completed for the current study included the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4) Recalling Sentences subtest (Semel, Wiig, & Secord, 2003), DAS-II (Elliott, 2007), CBCL (Achenbach & Rescorla, 2001), and ADOS-2 (Lord et al., 2012). Table 2 contains participant characteristics on key study variables. For the current study, only children with a diagnosis of ADHD, with no comorbid developmental disorders, were included.

Assessments

CELF-4 Recalling Sentences Subtest

The CELF-4 (Semel et al., 2003) is a norm-referenced clinical tool for the identification, diagnosis, and follow-up evaluation of language and communication disorders. It is designed for individuals 5–21 years of age. The Recalling Sentences subtest evaluates the child's ability to listen to spoken sentences of increasing length and syntactic complexity and repeat the sentences verbatim. Language repetition tasks are common for assisting in determining if language is normal or disordered. Deficits in sentence imitation are widely accepted as a potential marker of language disorder in English-speaking children. It is thought to reflect both the linguistic knowledge and phonological working memories in children. This 32-item subtest yields a norm-referenced scaled score (M = 10, SD = 3). Due to time constraints, only 16 of the 25 children were administered this test. The participants' performance on the Recalling Sentences subtest was used as a measure of language proficiency for those 16 children.

DAS-II

The DAS-II (Elliott, 2007) was administered to all children in the study to obtain a measure of cognitive ability, specifically verbal and nonverbal IQ. The test is

Table 2. Participant characteristics (N = 25).

Characteristic	*M* (*SD*)	Min–max
Age in years	9.3 (2.6)	4.2–13.2
NVIQ SS[a]	96.81 (14.07)	74–131
VIQ SS[b]	91.92 (13.87)	74–118
MLU	4.8 (1.04)	3.21–6.56
Expressive language[c]	9.5 (2.73)	6–14
Attention[d]	69.8 (10.56)	55–93
ADHD severity[e]	67.52 (8.39)	54–80
Number of utterances		
Conversation (n = 25)	158.48 (36.55)	102–250
Narrative (n = 23)	35.65 (21.04)	8–77

Note. Min = minimum; max = maximum; NVIQ = nonverbal IQ; SS = standard score; VIQ = verbal IQ; MLU = mean length of utterance; ADHD = attention-deficit/hyperactivity disorder.

[a]Standard score with M = 100 and SD = 15 based on the Differential Ability Scales–Second Edition Nonverbal Cluster. [b]Standard score with M = 100 and SD =15 based on the Differential Ability Scales–Second Edition Verbal Cluster. [c]Scaled score from the Recalling Sentences subtest on the Clinical Evaluation of Language Fundamentals–Fourth Edition, n = 16. [d]T score with a mean of 50 and an SD of 10, with increases from the mean indicating increases in attention-deficit symptom severity on the Child Behavior Checklist Attention subtest, and scores of 64 or higher in the clinical range. [e]T score with increases from the mean indicating increases in ADHD symptoms severity on the Child Behavior Checklist ADHD subtest and scores of 64 or higher in the clinical range.

designed for individuals 2.5–18 years of age and includes 22 subtests that are grouped into two overlapping levels: early years and school age. The DAS-II yields separate standard scores (M = 100, SD = 15) for a verbal cluster and a nonverbal cluster. Composites for these clusters served as verbal and nonverbal IQ measures, respectively.

CBCL

Parents completed the CBCL (Achenbach & Rescorla, 2001), an empirically based scale used to determine a variety of problem behaviors in children between the ages of 6 and 18 years. Two subscales were chosen to measure ADHD symptom severity: The first is based on questions regarding difficulties with attention; the second is based on questions related to overall ADHD problem behaviors. For both subscales, T scores with means of 50 and *SD*s of 10 were used, with increases from the mean indicating increases in problem behaviors. Scores of 64 or greater are considered in the clinical range.

ADOS

The ADOS (Lord et al., 2012) is an observation of social communication and restricted and repetitive behaviors associated with a diagnosis of ASD. It consists of five modules, one of which is administered depending on the expressive language level of the participant. In the current study, all participants received Module 3, which is designed for children who regularly use complex sentences and play with toys appropriate for up to 12–16 years of age. The ADOS typically requires 45–60 min to administer.

The ADOS consists of a variety of communicative subtests, including narrative and conversational tasks. We characterized four of the ADOS tasks as narrative: (a) "Telling a Story from a Book," in which the child looks through a book with the examiner and tells the story; (b) "Demonstration Task," in which the child explains to the examiner how to brush your teeth; (c) "Cartoons," in which the child recites a story that they learn from a series of pictures; and (d) "Creating a Story," in which the child makes up a story using five random objects. We characterized all other tasks as conversational, including (a) "Construction Task," which involves the examiner and child talking about a puzzle; (b) "Make Believe Play" and (c) "Joint Interactive Play," in which the child plays with action figures and toys; (d) "Description of a Picture," in which the child is prompted to talk about a picture scene; (e) "Interview," in which the examiner asks the child questions about their lives; and (f) "Break," in which the child and examiner engage in conversation.

Transcription and Reliability

Two trained research assistants unfamiliar with the participants transcribed video recordings of the ADOS, which was initially used for diagnostic purposes. For each recording, research assistants began transcribing at the beginning of the assessment and stopped transcribing once they had included approximately 100 utterances that contained sentences with an overt subject and verb. Research assistants transcribed the samples using standard conventions of the Systematic Analysis of Language Transcripts (Miller & Chapman, 2000), including maze notations. Transcribers also inserted codes for the beginning and end of each of the ADOS communicative tasks described above. Most participants (n = 23) produced utterances for both the narrative and conversational contexts based on the 100 transcribed utterances. Two participants produced a limited number of utterances (i.e., less than 25 words, overall) in the narrative portions of the ADOS. For these children, the first 100 utterances of their sample occurred almost entirely during the conversation subtests of the ADOS. Their data were excluded in all analyses of narrative language. On average, participants completed 4.5 conversational subtests, which yielded a mean of 158.48 utterances and 1.7 narrative subtests, which yielded a mean of 35.65 utterances. The mean number of utterances in conversation is well over 100 because the transcriber stopped only after 100 utterances with a subject and a verb. It is likely that the conversational context had more utterances that were not complete sentences.

Rate of each maze type per utterance was calculated by dividing the number of each maze type produced by the total number of utterances to derive the number of filled pauses per utterance, the number of repetitions per utterance, and the number of revisions per utterance. Filled pauses included interjections that did not contribute to the overall message, such as "um" or "uh." Repetitions were utterances that were exact replications of the previous utterance at the phoneme, syllable, word, phrase, or sentence level. Revisions were modifications made by the child to clarify or revise errors in previous utterances. We also calculated mean length of utterance (MLU) as a proxy measure for comparison of syntactic complexity across narrative and conversational contexts. MLU has been found to differ across language sampling contexts, with narration often yielding more complex utterances than conversational contexts (Abbeduto, Benson, Short, & Dolish, 1995).

Researchers independently double transcribed 20% of the ADOS video recordings for reliability purposes. To calculate reliability, the number of agreements between transcripts was divided by the sum of agreements and disagreements. Agreement in segmenting utterances into C-units was 83%, and agreement of morphemes per line was 87%.

Initial transcription yielded low reliability for the maze variables (range: 28%–67%). Given this low reliability, two new transcribers independently checked the original transcripts for maze coding while viewing the videos. Together, they developed a consensus transcript. Then, a third transcriber independently checked maze coding using the original sample. Approximately 30% of samples were compared to the consensus with the third reliability coder. Percent agreement for items coded were as follows: repetitions = 93%, filled pauses = 90%, revisions = 78%, and all mazes combined = 88%.

Statistical Analyses

We used a within-subject research design to compare the maze types produced by the participants with ADHD in conversational and narrative contexts. Due to the small sample size, for Research Questions 1 and 2, we completed nonparametric, related-samples Wilcoxon signed-ranks tests. We calculated effect sizes (r) by dividing the standardized test statistic (Z) by the square root of the number of observations. Criterion for medium and large effect sizes is .3 and .5, respectively. For Research Question 3, we computed Kendall's rank correlation coefficients. We used a conservative p value of .01 to determine significance due to the large number of comparisons completed for all three research questions.

Results

For Question 1, we first compared the maze types separately (repetitions, revisions, filled pauses). Table 3 includes the total number of each maze type per utterance produced by each participant. Table 4 includes the means and standard deviations of the different maze types per utterance produced. For the full ADOS sample, there were no significant differences between the rates of filled pauses and repetitions ($Z = -1.4$, $p = 0.17$, $r = .27$) within participants. Participants did produce a greater rate of revisions per utterance than both repetitions ($Z = -4.12$, $p < .01$, $r = -.82$) and filled pauses ($Z = 2.5$ $p = .01$, $r = .49$).

We next compared maze use based on Rispoli et al.'s categories, which comprised stalls (i.e., repetitions and filled pauses combined) and revisions. This comparison did not yield a significant difference between revisions and stalls ($Z = -0.47$, $p = .63$, $r = .09$). Using Thordardottir and Ellis Weismer (2002) categories, we compared the rate of content mazes (i.e., repetitions and revisions combined) and filled pauses. Participants produced a significantly lower rate of filled pauses than content mazes ($Z = -3.64$, $p < .01$, $r = .73$).

For Question 2, we compared maze rates produced in the narrative and conversational contexts. We first investigated differences in MLU with Wilcoxon signed-ranks tests and found a significant difference, with a higher MLU in the narrative context compared to the conversational context ($Z = -5.04$, $p < .01$, $r = 1.05$). For mazes, there was not a significant difference between rates of filled pauses in the conversational and narrative contexts ($Z = -2.17$, $p = .02$, $r = .45$), but the comparison was associated with a large effect size. There were no other significant differences across contexts (all ps > .05). There were no significant differences in the rates of stalls or content mazes between contexts (all ps > .1). We next analyzed use of each maze type within each context. Within the narrative context, participants, on average, produced a greater rate of revisions than repetitions ($Z = -2.01$, $p = .04$, $r = .42$) and filled pauses ($Z = -1.94$, $p = .05$, $r = .4$). These comparisons were not statistically significant at the .01 level but were associated with medium-to-large effect sizes. There was also not a significant difference between the rates of repetitions and filled pauses ($Z = -0.18$ $p = .85$, $r = .38$).

This pattern of results was similar within the conversational context, with a significantly greater rate of revisions than repetitions and a corresponding large effect size ($Z = -2.3$, $p < .01$, $r = -.47$). Revisions also occurred more than filled pauses on average with a medium effect size ($Z = -1.69$, $p = .02$, $r = .35$); however, this was not statistically significant at the .01 level. There was not a significant difference between the rates of filled pauses and repetitions ($Z = -1.69$, $p = .09$, $r = .35$). Similar to findings in Question 1, participants produced a greater rate of content mazes than filled pauses in both contexts (conversations: $Z = -3.24$, $p < .01$, $r = .68$; narrative: $Z = -3.19$ $p < .01$, $r = .67$), and there was no difference between stalls and revisions (conversations: $Z = -0.41$, $p = .68$, $r = .09$; narrative: $Z = -0.66$, $p = .51$, $r = .13$).

For Question 3, we calculated Kendall's correlation coefficients to examine the relationships between each type of maze use, age, language skills (verbal IQ, MLU, and Recalling Sentences), cognitive ability (nonverbal IQ), and ADHD symptom severity and attention deficits on the entire ADOS sample (i.e., narrative and conversational portions combined). The correlations are included in Table 5. We found statistically significant positive correlations between

Table 3. Number of mazes per utterance by type.

Participant	Filled pauses	Repetitions	Revisions	Stalls	Content mazes
1	0.000	0.035	0.160	0.035	0.194
2	0.055	0.032	0.083	0.087	0.115
3	0.030	0.025	0.035	0.055	0.060
4	0.006	0.030	0.098	0.037	0.128
5	0.106	0.011	0.045	0.117	0.056
6	0.069	0.059	0.101	0.128	0.160
7	0.025	0.031	0.119	0.056	0.150
8	0.017	0.009	0.047	0.026	0.055
9	0.026	0.040	0.073	0.066	0.113
10	0.000	0.034	0.020	0.034	0.054
11	0.000	0.017	0.012	0.017	0.029
12	0.139	0.052	0.087	0.191	0.139
13	0.078	0.012	0.025	0.090	0.037
14	0.058	0.029	0.050	0.087	0.079
15	0.018	0.009	0.036	0.027	0.044
16	0.047	0.095	0.095	0.142	0.189
17	0.037	0.011	0.074	0.048	0.085
18	0.094	0.031	0.193	0.125	0.224
19	0.000	0.020	0.061	0.020	0.082
20	0.067	0.005	0.104	0.073	0.109
21	0.029	0.032	0.243	0.061	0.275
22	0.063	0.016	0.037	0.079	0.053
23	0.166	0.049	0.117	0.215	0.166
24	0.043	0.136	0.207	0.179	0.342
25	0.027	0.007	0.156	0.034	0.163

age and the rate of revisions and content mazes, both increasing with age. MLU was significantly positively correlated with revisions, repetitions, and content mazes. Performance on the CELF-4 Recalling Sentences subtest was significantly and strongly positively correlated with the use of filled pauses and stalls. However, verbal IQ and nonverbal IQ were not significantly correlated with any of the maze variables. ADHD symptom severity also was not correlated with maze variables.

Although it was not a specific research question for this study, we were also interested in whether our sample of children and adolescents with ADHD produced mazes at a similar rate as the participants with ADHD in the Redmond (2004) study. Redmond compared mazed words as a percentage of total words. In children with ADHD, 8.5% of total words produced were mazes, whereas the children with SLI and TD produced mazes at a rate of 6.0% and 5.8%, respectively. In our sample, children mazed 6.2% of words. We conducted single-sample nonparametric *t* tests comparing the rate of mazes reported in these populations and the rate of mazes in ours. There was a significant difference; children with ADHD in the Redmond study used mazes at a higher rate than our sample ($Z = -3.27$, $p = .01$). We then compared the rate of mazes in our group versus the rate of mazes in children with TD and SLI reported by Redmond. There were no significant differences.

Table 4. Mean and standard deviation of maze types per utterance ($N = 25$).

Maze variable	Complete ADOS *M*	Complete ADOS *SD*	Conversation *M*	Conversation *SD*	Narrative *M*	Narrative *SD*
Percent words mazed	6.4%	0.03	4.0%	0.02	3.0%	0.02
Rate of revisions	0.09	0.06	0.09	0.06	0.1	0.1
Rate of repetitions	0.03	0.03	0.03	0.03	0.04	0.06
Rate of filled pauses	0.05	0.04	0.05	0.05	0.03	0.05
Rate of stalls	0.08	0.05	0.08	0.06	0.08	0.08
Rate of content mazes	0.12	0.07	0.12	0.08	0.14	0.09

Note. ADOS = Autism Diagnostic Observation Schedule.

Discussion

The purpose of the current study was to examine whether there were significant differences in the types of mazes produced by 4- to 13-year-olds with ADHD based on language produced during the ADOS. Redmond (2004) found an elevation in maze production by 5- to 8-year-olds with ADHD compared to children with TD and children with SLI of similar age based on language produced during free-play with an examiner. The maze types in the Redmond study, however, were analyzed collectively, with revisions, filled pauses, and repetitions grouped together. We compared our sample's rate of mazes with maze types collapsed. Our sample did not produce mazes at the same rate as children with ADHD in Redmond's study. This could be due to the large age range of our sample. Our sample included 4- to 13-year olds, compared to Redmond's sample of 5- to 9-years-olds. We found that the percentage of words mazed was significantly correlated with age. While that might indicate that our sample should have had a greater number of percentage of words mazed, our study also included

Table 5. Correlations between maze use and participant characteristics: Kendall's tau (*N* = 25).

Measure	Revisions	Repetitions	Filled pauses	Content mazes[a]	Stalls[b]
Age	.39*	.21	.11	.44*	.18
Nonverbal IQ	.07	.23	.09	.15	.15
Verbal IQ	.06	.14	.25	.13	.28
MLU	.55*	.41*	.11	.63*	.27
Attention	−.16	−.31	−.08	−.22	−.08
ADHD severity	−.05	−.27	−.10	−.09	−.02
Expressive language[c]	.12	.47	.57*	.26	.88*

Note. MLU = mean length of utterance; ADHD = attention-deficit/hyperactivity disorder.

[a]Revisions + repetitions. [b]Repetitions + filled pauses. [c]*n* = 16.

*Correlation is significant at the .01 level.

children in a younger range, which could have confounded this finding. Another potential reason why maze rates were different across studies could be the language sampling context. In the Redmond study, the sampling context was a free-play interaction between the examiner and the child, during which the examiner provided prompts and asked the child questions. Participants in our study were administered the ADOS from which our language samples were taken. The ADOS is more structured than a free-play interaction. It is plausible that the different contexts that each procedure yielded could have influenced the participants' maze behaviors.

For Research Question 1, we compared the rates of different maze types. When we examined maze type separately, we found that the participants in our study produced revisions at a higher rate than both repetitions and filled pauses. Rispoli et al. (2008) and Rispoli (2003) found that, in very early years, revision rates tended to be lower than rates of the other maze types. Our increase in revision rate could reflect that, as the children move through the school-age developmental period, they are developing more complex grammatical structures and therefore use revisions more frequently than the other maze types. Indeed, in our sample, age and MLU were positively correlated with revision rate. However, it was not significantly correlated with language ability on other measures, including the CELF Recalling Sentences and verbal IQ, which could suggest that revision rate is not associated with language ability. However, due to the reduced sample size, it is possible that there was not enough power to detect a relationship between CELF Recalling Sentences and revision rate. Revision rate could therefore be attributed to the older age range and thereby more advanced language ability of our sample and perhaps weaknesses in word retrieval and/or inhibition associated with ADHD.

In a study of adult speakers with ADHD in which maze types were analyzed separately, Engelhardt et al. (2011) found that adults with ADHD produced more repetitions than adults without ADHD. Our sample included children and adolescents aged 4–13 years; thus, the elevated revision rate could indicate that the maze types used in this population change with age. In fact, revisions were the only single maze variable positively correlated with age in our sample. Although not corroborated with our correlational analysis, perhaps as children age into adolescence and grammatical structures are mastered, revision rates abate in this population.

In other investigations of mazes, Rispoli (2003, 2018), Rispoli et al. (2008), and Thordardottir and Ellis Weismer (2002) found differences in the types of mazes produced by children utilizing different maze taxonomies. Across Rispoli's studies, the mean revision rate was much lower than the mean stall rate in typically developing children. In our sample, we found that there were no significant differences in the production of stalls and revisions. However, the children included in the Rispoli (2003, 2018) and Rispoli et al. (2008), studies were typically developing and very young. A distinct relationship between revisions and development were found in all three studies, and it is possible that our group of older children with ADHD demonstrated a different pattern of maze use either because they represent a different period of development or because of their diagnostic status. In our correlation analyses, we found that the stall rate was significantly positively correlated with our expressive language measure. Revisions and repetitions were positively correlated with MLU.

We also investigated maze production according to Thordardottir and Ellis Weismer's taxonomy. They found that, regardless of age or language ability, children with SLI between the ages of 5 and 9 years consistently used fewer filled pauses and more content mazes compared to children with TD. Therefore, we examined whether the children with ADHD in our sample produced maze profiles comparable to the profile of children with TD or children with SLI. When we collapsed repetitions and revisions into a content maze category, we found the children produced a statistically higher rate of content mazes than filled pauses. This is consistent with the maze profiles of children with SLI. The decreased rate of filled pauses may indicate that children with ADHD have a weak mastery of pragmatic aspects of language related to channel of talk and turn-taking.

Research Question 2 examined differences in mazes produced in narrative and conversational contexts. We had anticipated that the narrative context would give rise to more mazing due to the potentially more challenging nature of this context. Narrative language samples tend to have more complex language, and thus we predicted an increase in maze use due to processing difficulties in formulating more complex utterances. We did in fact find that MLU was significantly greater in the narrative context. We further anticipated an increase in filled pauses in the conversation samples because of the transactional nature of a conversational context. If filled pauses fulfill a pragmatic function to indicate the speaker still wishes to hold the floor, we might see an increased use of filled pauses in a conversational compared to a narrative context. Our predictions regarding filled pauses, while not significant at the .01 level, did trend toward an increase in conversation, with a large effect size. Contrary to our predictions, there were no differences in revisions across contexts—maze use did not seem to be impacted by the context of the language sample. More sensitive language complexity measures are needed to make firmer conclusions.

Research Question 3 investigated the relationship between the frequency and rates of mazes produced, age, language and cognitive ability, and ADHD symptom severity. Age was positively correlated with the use of revisions, expressive language was positively correlated with the use of filled pauses and stalls, and MLU was positively correlated with revisions, repetitions, and content mazes. ADHD symptom severity, verbal IQ, and nonverbal IQ were not associated with any maze variables.

Based on the findings of Rispoli et al. (2008) and Rispoli (2003), we had predicted positive associations between the production of revision mazes and age, language skills, and cognitive abilities in our sample of children with ADHD. In contrast, we predicted nonsignificant correlations between the production of stalls and age, cognitive abilities, and language skills. Our predictions were only partially accurate. Revisions in our sample increased with age. Stalls, however, increased with expressive language but not age. This lends support to our conclusions above that revision rate increases as children mature.

We also examined correlations using Thordardottir and Ellis Weismer's taxonomy. Because the children with SLI in their study produced more context mazes and fewer filled pauses than typically developing peers, we predicted that content mazes would be negatively correlated with language ability and filled pauses would not be correlated with language ability. Contrary to our predictions, filled pauses were positively correlated with expressive language ability, whereas content mazes were not. Perhaps, children with higher verbal IQs in our sample had a better grasp on pragmatic aspects of spoken language, regardless of their age. Finally, contrary to our tentative predictions, ADHD symptom severity was not associated with any maze variables.

Limitations and Future Directions

This study must be qualified in several ways. First, the children in our sample represented a wide age range, and the majority of children were African American or Caucasian. Future studies should include a larger, more diverse sample of children to better represent the population. An age- and/or IQ-matched control group of typically developing children would be useful in identifying whether children with ADHD have a unique profile regarding the types of mazes used. If this were true, linguistic maze use could be used as a supplemental diagnostic tool in identifying children with ADHD. Due to the nature of the parent study for which these data were collected, we were unable to compare this group to a control of typically developing children. Thus, all comparisons were within subject, and inferences were based on previous findings. Research in this area should continue to include children who are typically developing and with other developmental disabilities so direct comparisons can be made to better understand maze use and function. Due to the possible changes in maze use across the developmental span, a longitudinal comparison of maze use in this population would also provide useful information regarding linguistic profiles.

We also investigated only the maze types of repetitions, filled pauses, and revisions. We did not investigate the mazes characterized as orphans or silent pauses because they were not compared in the majority of studies we reviewed while formulating our hypotheses. We acknowledge that these maze types could also reflect unique traits in children with ADHD and/or individual or developmental changes in children's linguistic profiles. Both should be considered in future research.

Future research should also continue to examine maze use in different contexts. The differing contexts between our study and Redmond's (2004) study could have been the reason for different outcomes in maze frequency across studies. Our investigation examined narrative and conversational portions within the ADOS. More traditional narrative and conversational contexts that yield longer transcripts should also be examined. Other contexts, such as expository contexts, should be examined, particularly for older children and adolescents.

Finally, only 16 of our children had CELF-4 Recalling Sentences scores for one of our expressive language measures. More robust measures of expressive language are needed that include other aspects of language development such as both expressive and receptive vocabulary, syntactic development, and pragmatics.

Conclusions

We found evidence that this sample of children and adolescents with ADHD produced the maze type of revisions at a greater rate than other maze types and of filled pauses at the lowest rate. We also found significant positive correlations between rate of revisions and age in our sample, which may indicate that children with ADHD have relatively intact external monitoring of their speech production. In contrast, this group of children produced filled pauses at a lower rate than revisions and repetitions combined (content mazes) and demonstrated a profile more similar to children with SLI than children who are typically developing. This suggests that the pragmatic abilities of children with ADHD may not be as developed as those of children with TD. By analyzing the maze types separately, we revealed a unique pattern of maze use in this population. When examining the use of linguistic mazes, in children with ADHD or other developmental disabilities, maze types should be examined as separate entities. This finding warrants further investigation into maze use and categorization in this population and others. If maze use is caused by language processing and/or executive functioning difficulties unique to this population, it has the potential to be used as a diagnostic marker. This means language sampling and maze analyses could be used to aid in diagnosis. We also found that maze use varied by context, with conversations yielding more filled pauses than a narrative context; thus, careful consideration should be given to the type of language sample administered when investigating mazes. Finally, an increase in knowledge regarding the types of mazes produced by children with ADHD could be utilized by clinicians. With a clear linguistic profile of mazes, clinicians could potentially target mazes specifically or underlying weakness such as lexical retrieval to improve discourse ability.

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