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Are language production problems apparent in adults who no longer meet diagnostic criteria for Attention-Deficit/Hyperactivity Disorder?

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Abstract

In this study, we examined sentence production in a sample of adults ($N = 21$) who had Attention-Deficit/Hyperactivity Disorder (ADHD) as children, but as adults, no longer met DSM-IV diagnostic criteria (APA, 2000). This “remitted” group was assessed on a sentence production task. On each trial, participants saw two objects and a verb. Their task was to construct a sentence using the objects as arguments of the verb. Results showed more ungrammatical and disfluent utterances with one particular type of verb (i.e. participle). In a second set of analyses, we compared the remitted group to both control participants, and a “persistent” group, who had ADHD as children and as adults. Results showed that remitters were more likely to produce ungrammatical utterances and to make repair disfluencies compared to controls, and they patterned more similarly to ADHD participants. Conclusions focus on language output in remitted ADHD, and the role of executive functions in language production.

Keywords

ADHD; language production; conceptual accessibility; grammatical encoding; partial remission; response inhibition

Attention-Deficit/Hyperactivity Disorder (ADHD) is a self-regulatory disorder associated with hyperactivity, impulsivity, and/or inattention. With a 6% incidence rate, it is one of the most commonly diagnosed childhood disorders and often persists into adolescence and adulthood, with an estimated 4% of adults affected in the United States (Barkley, Fischer, Smallish, & Fletcher, 2002; Barkley, Murphy, & Fischer, 2008; Kessler et al., 2006). Based on the constellation of symptoms of the disorder, three subtypes are recognized: primarily-inattentive (ADHD-PI), primarily-hyperactive/impulsive (ADHD-PH), and combined (ADHD-C). Research seems to be converging on the idea that the primary functional deficit in ADHD relates to response inhibition (Barkley, 1997; Casey et al., 1997; Nigg, 2001; Pennington & Ozonoff, 1996).

Children with ADHD often have co-occurring language problems. These can include both expressive and receptive language delays, poor performance on standardized tests, and pragmatic problems, such as difficulty managing dialogue (August, & Garfinkel, 1990; Cantwell, 1996; Cohen, Davine, Horodezky, Lipsett, & Isaacson, 1992; Hinshaw, 1992;

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Nigg, Hinshaw, Carte, & Treuting, 1998; Redmond, 2004; Tannock, Purvis, & Schachar, 1993; Willcutt et al., 2001). Estimates of the comorbidity between ADHD and language impairments typically ranges from 30% – 50% (Beitchman, Hood & Inglis, 1990; Tirosh & Cohen, 1998). Formal learning disabilities are also prevalent in ADHD, and the most common of these is reading disability, which co-occurs at a rate of 15% – 30% with ADHD (Dykman & Ackerman, 1991; Willcutt & Pennington, 2000).

In the current study, our focus is on language production, and several symptoms of ADHD specifically relate to inappropriate speech output. Problematic issues include (1) talking excessively, (2) blurting out answers in class, (3) frequently interrupting other people, (4) intruding on conversations, and (5) initiating conversations at inappropriate times (APA, 2000). With respect to language production in children with ADHD, there are two primary experimental paradigms that have been used. The first is story re-telling. In this task, participants are told a story, which they must memorize and then recall. Purvis and Tannock (1997) showed that participants with ADHD had overall organizational problems related to event sequencing compared to control participants. The ADHD children also made more ambiguous references (for similar findings, see Oram, Fine, & Tannock, 1999; Tannock et al., 1993).

The second method for assessing language production is to record naturalistic conversations, and to analyze them for factors such as number of interruptions, grammatical errors, etc. Studies using this type of task have produced mixed results. Barkley, Cunningham, and Karlsson (1983) reported similar numbers of utterances and syllables per utterance in ADHD children compared to controls. However, Tannock and Schachar (1996) reported that children with ADHD produced more off topic speech and made more interruptions compared to control children. In summary, studies of language production suggest that (1) the narrative speech of children with ADHD is marked by disorganization and poor cohesion, and (2) children with ADHD produce more off topic speech and tend to interrupt other people (Hamlett, Pellegrini, & Conners, 1987; Purvis & Tannock, 1997).

Developmental Changes in ADHD

Over the course of development, significant changes occur in the organization of certain cognitive control processes that could influence the progression of ADHD with age. One of these is the relatively late maturation of the prefrontal cortex, which is important because the prefrontal cortex may contribute to an increasing ability to suppress inappropriate responses over time (Castellanos & Tannock, 2002; Giedd et al., 1999). Furthermore, because overall activity-levels tend to decrease with age, there is reason to believe that hyperactive/impulsive symptoms may naturally wane over the course of development from adolescence to adulthood (Barkley et al., 1990; Beiderman & Farone, 2000; Hart, Lahey, Loeber, Applegate, & Frick, 1995). Whether the alleviation of ADHD symptoms with age reflects improvement of underlying deficits or the acquisition of compensatory mechanisms remains unresolved (cf. Shaw, Gogtay, & Rapoport, 2010). However, there is currently a body of work looking at the performance of adults with ADHD, and these studies have shown that certain impairments persist across development (e.g. Murphy & Barkley, 1996; Nigg et al., 2005).

For example, Carr, Nigg, and Henderson (2006) found that performance on the anti-saccade task was impaired in adults with ADHD compared to controls. In this task, participants must fixate on a central dot, and when a flash of light is briefly presented, participants must move their eyes in the opposite direction. Adults with ADHD were poorer at both holding fixation on the dot and ignoring the flash of light. Carr et al. (2006) also looked at a group of participants who had ADHD as children, but then as adults no longer met the diagnostic

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criteria (APA, 2000). This "remitted" group was not different from controls in the number of directional errors (an index of response inhibition), but they patterned more similarly to the ADHD group in anticipatory errors (an index of attention). Carr et al. argued that the deficits that persisted in the remitted group were more likely to be core issues in ADHD, whereas symptoms that remitted were more likely to be epiphenomenal or secondary consequences of ADHD (see also Halperin, Trampush, Miller, Marks, & Newcorn, 2008).

Language Production in Adult ADHD

Recent research has begun to focus on language output problems in adult ADHD. For example, Engelhardt, Ferreira, and Nigg (2009) hypothesized that impairments in response inhibition would lead to more ungrammatical utterances in a sentence production task. In order to test this hypothesis, they utilized a psycholinguistic task that takes advantage of the incremental nature of grammatical encoding, that is, the word-by-word integration of distinct concepts into a well-formed sentence (Bock, 1982; Bock & Levelt, 1994; Bock & Warren, 1985; Christianson & Ferreira, 2005; de Smedt, 1996; Ferreira, 1994; Kempen & Hoenkamp, 1982; Levelt, 1989; van Nice & Dietrich, 2003).

In this task, participants saw two sequentially presented objects followed by a conjugated verb, and they were asked to construct a sentence with one of the objects as the subject of the sentence and the other as the object of the sentence. Processing demands tend to bias speakers to use the first object presented as the subject of the sentence and the second as the direct object (Bock, 1987; Ferreira & Engelhardt, 2006). Because of this bias, the difficulty of the task can be manipulated by varying the animacy of the first object presented. If the first object is animate, speakers should be more likely to produce an active sentence (Ferreira, 1994). In contrast, if an inanimate object is presented first, participants should be more likely to produce a passive sentence. In addition to manipulating object order, syntactic complexity can also be varied by presenting different types of verbs. One type, which we refer to as "optional" (e.g. *moved*), allow for multiple syntactic constructions; whereas, past-participle verbs (e.g. *ridden*), have fewer syntactic options and tend to appear in passive sentences (e.g. *The bicycle was ridden by the girl.*). Resolving these competing biases and syntactic demands requires cognitive control in order to produce a well-formed sentence that does not contain online revisions or hesitations.

Results from this task showed that adolescents and adults with ADHD produced more ungrammatical sentences, especially in the condition in which an animate object was presented first and the verb was a participle (Engelhardt et al., 2009). This finding suggests that participants with ADHD experienced greater difficulty when task demands were high. The processing difficulty was greatest for the ADHD-C group compared to the ADHD-PI group and controls. This pattern suggests that language production may be problematic only for individuals who have hyper-active/impulsive symptoms or a combination of inattention and hyper-activity/impulsivity.[1] In addition, there was no evidence of attenuation over the course of development, which suggests that language output problems are persistent.

The current study aims to add to the literature concerning the clinical profile of adult ADHD. Like Carr et al. (2006), we tested adults who met criteria for ADHD as children, but then no longer met diagnostic criteria as adults (APA, 2000). We refer to this group as "partially remitted" or "remitters". Across a series of studies, Engelhardt and colleagues have reported three main findings with respect to language production difficulties in ADHD. The first is that sentences with participle verbs are more likely to be ungrammatical

[1]The ADHD-PH group is infrequent past adolescence and some even argue that this group does not exist in adults (Hart et al., 1995; Lahey, Pelham, Loney, Lee, & Willcutt, 2005; Milich, Balentine, & Lynam, 2001).

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compared to sentences with the more flexible optional verbs (Engelhardt et al., 2009). The second main finding relates to disfluencies. Significant differences were observed in repair disfluencies, which occur when a speaker stops speaking and restarts with a new word or phrase (Engelhardt, Corley, Nigg, & Ferreira 2010). Again, the combined subtype produced more disfluencies compared to both controls and the inattentive subtype. Finally, in a network description task, Engelhardt, Ferreira, and Nigg (2011) reported that adult ADHD participants (both ADHD-PI and ADHD-C) were more likely to make unfilled (or silent) pauses and repetitions when compared to controls.[2] Therefore, summing over the existing literature, participants with the inattentive subtype were mixed: In some cases they patterned more like controls, and in other cases patterned more like the combined subtype. In contrast, the combined subtype shows more consistent differences from controls, especially as task demands increase.

Current Study

In the current study, we tested 21 participants who met diagnostic criteria for ADHD as children, but then no longer met criteria as adults. In the first set of analyses, we tested these participants on the sentence production task from Engelhardt et al. (2009). In the second set of analyses, we compared the sample of remitted participants to the adults from previously published work. In those studies, there were 20 control participants (i.e. never had ADHD), 22 ADHD-PI, and 22 ADHD-C. (All of the ADHD participants had a consistent diagnosis from childhood to adulthood.) We expect the second set of analyses to reveal whether remitters pattern more like controls or ADHD participants in terms of the number of ungrammatical and disfluent utterances. Participants in the study also completed a battery of neuropsychological tests, including assessments of executive function (i.e. inhibition and set shifting). Therefore, a secondary goal of the study was to investigate the link between executive function abilities and language output problems.

Method

Participants

Participants were 85 adults between the ages of 18 and 35 (M = 23.38, SD = 4.49). Table 1 shows the demographic data for the remitted group and the other (adult) participants that comprised the comparison groups for the second set of analyses. P-values presented on the right hand side of the table show that the groups were fairly well matched on age, gender, and IQ.

Participants were recruited from the community via widespread public advertisements designed to access as broad and representative a sample as possible. Participants were evaluated in a multistage screening and diagnostic evaluation procedure. Prospective participants contacted the project office, at which point key rule-outs were checked (i.e., no sensory-motor handicap, no neurological illness, and no non-stimulant psychiatric medications). Eligible participants were scheduled for a diagnostic visit wherein they completed a semi-structured clinical interview and assessment of IQ (Wechsler, 1997). IQ was estimated using a reliable and valid five subtest short form of the WAIS-III. The subtests were picture completion, vocabulary, similarities, arithmetic, and matrix reasoning. Participants also completed the Wide Range Achievement word pronunciation test (Wilkinson, 1993), and so, the dataset included a standardized reading score.

In the case of adults, assessment of ADHD requires retrospective assessment of their childhood ADHD status to establish childhood onset, in turn, mandating the inclusion of

[2]Repetitions are cases in which a speakers stops speaking and then repeats something s/he has just said.

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informant interviews to verify symptoms (Wender, Wolf, & Wasserstein, 2001). A retrospective Kiddie Schedule for Affective Disorders and Schizophrenia (*K-SADS*; Puig-Antich & Ryan, 1986) was administered by a masters-level clinician with extensive training, following previously published procedures for assessing adults (Biederman, Faraone, Keenan, Knee, & Tsuang, 1990). This procedure assessed the adult's childhood ADHD, Conduct Disorder, and Oppositional Defiant Disorder symptoms and impairment. Because self-reported recall of these symptoms by adults with ADHD may lead to under-reporting (Murphy & Barkley, 1996), an informant who had known them as a child (usually a parent) reported on the participant's childhood behaviors via an ADHD Rating Scale and a retrospective K-SADS ADHD module adapted to be appropriate for an informant.

Current adult ADHD symptoms were assessed by self-report and by interview with a second informant who currently knew the participant well (Wender et al., 2001), typically a spouse, roommate, or close friend. We again used K-SADS ADHD questions worded appropriately for current adult symptoms (Biederman et al., 1990). This interview was supplemented with Barkley and Murphy's (2006) Current ADHD Symptoms rating scale (as recommended by Weiss, Hechtman, & Weiss, 1999). To ensure that ADHD participants exceeded normative cutoffs for ADHD symptoms, adult participants also completed the Conners, Erhart, and Sparrow (1999) Young Adult ADHD Rating Scale, Achenbach (1991) Young Adult Self Report Scale, and the Brown (1996) Adult ADHD rating scale. Their peer informants completed the Conners et al. (1999) peer rating form, as well as Barkley and Murphy peer ratings on adult symptoms, and a brief screen of antisocial behavior, and drug and alcohol use. The informant also completed a structured interview about the participant's current ADHD symptoms, using the modified K-SADS for current symptoms. All informant interviews were conducted by clinically trained interviewers via telephone after appropriate consent procedures.

Best Estimate Diagnosis for ADHD—For all participants, a diagnostic team comprised of a licensed clinical psychologist and a board certified psychiatrist arrived at a “best estimate” diagnosis (Faraone et al., 2000). The same team evaluated all cases. Each member independently reviewed all available information from all interviews and all self and informant rating scales (including staff notes and observations) to arrive at a clinical judgment about ADHD present or absent, ADHD subtype, and comorbid disorders. They considered the option of using an “or” algorithm to reach a count of six symptoms, in cases in which there were at least four symptoms from each informant and there was clear evidence of cross-situational impairment. This is in line with the practice in the DSM-IV field trials. Because there is no agreement on age-appropriate cutoffs for adolescents and adults, the team conservatively followed DSM-IV criteria by requiring the six symptoms that DSM-IV specifies. This ensured minimal “false positives” in the ADHD group. False negatives (ADHD cases ending up in the control group) were minimized by requiring four or fewer symptoms of ADHD, no past history of ADHD diagnosis, and rating scale data not in the clinical range for any of the ADHD scales. The DSM-IV criteria regarding comorbidity were carefully followed, so that although comorbid disorders were diagnosed when present, the participant was excluded from the study if the clinicians agreed that ADHD symptoms were better explained by another disorder (APA, 1994). This provided some control against obtaining a sample with extreme levels of comorbid disorders while still representing true cases of ADHD. Clinical interviewers rated and noted evidence of impairment (i.e. a rating of at least “moderate” on the KSAD rating scale), and the diagnostic team required such evidence to make the ADHD diagnosis.

Inter-clinician agreement on presence or absence of ADHD was satisfactory ($k = .80$), and agreement on ADHD subtype was also adequate, ranging from $k = .74$ to .90. Diagnostician reliability for comorbid disorders was excellent (past major depression, $k = .96$; any current

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anxiety disorder, $k = 0.98$; antisocial personality disorder, $k = 0.93$; substance or alcohol dependence, $k = 0.97$). Disagreements were handled by conference of the clinicians. It happened that consensus was readily achieved in all cases; had it not been, that case would have been excluded.

Exclusionary Criteria—Potential participants were excluded from all groups if they had a current major depressive or manic/hypomanic episode; current substance dependence preventing sober testing; history of psychosis; history of autism; history of head injury with loss of consciousness greater than 1 minute, sensory-motor handicap, neurological illness; currently prescribed anti-psychotic, anti-depressant, or anti-convulsant medications. We also ruled out participants with an IQ < 75, in keeping with the field's consensus definition of mental impairment.

Medication washout—Participants prescribed psychostimulant medications (Adderall, Ritalin, Concerta, & Focalin) were tested after a minimum of 24 hr (for short acting preparations) and after 48 hr (for long acting preparations); actual mean washout time was from 24 to 176 hrs. This degree of washout is considered sufficient to minimize medication effects on results.

Executive Function Tasks

Wisconsin Card Sorting Test—A computerized version of the Wisconsin Card Sorting Test was administered to all participants. The task requires participants to match a card to one of four other cards based on one of four attributes (shape, color, quantity, or design). Participants were given feedback after every decision. After 10 correct decisions, the correct match attribute changed. The dependent measure was number of perseveration errors, that is, the number of incorrect decisions based on the previous match attribute. More errors indicate poorer set-shifting or flexibility in the face of changing task requirements.

Trail Making Task—The Trail Making task is a commonly used paper-and-pencil task to assess set-shifting abilities (Reitan, 1958). In part A, the participant rapidly connects a series of numbers in sequential order. In part B, the participant must rapidly draw a line between alternating numbers and letters in sequential and alphabetical order, respectively. Part B, therefore, requires the ability to rapidly shift between two mental sets (Arbuthnott & Frank, 2000). The time to complete part A was subtracted from time to complete part B, and so higher scores indicated worse performance.

Stroop Task—The Stroop task assesses interference control, that is, the ability to monitor response conflict and suppress a competing response in order to successfully execute the task requirements. Participants in the study completed a paper-and-pencil version of the Stroop Task (Golden, 1978; Stroop, 1935; van Mourik, Oosterlann, & Sergeant, 2005), in which individual trials occurred at 45 second intervals. An interference control composite score was calculated by regressing the color-word naming score on the word-reading and color-naming scores and saving the unstandardized residual. Higher scores indicated better performance.

Stop Task—The Stop task assesses response inhibition, which is the ability to suppress a prepotent motor response (Dempster & Corkill, 1999; Logan, 1994). In this task, participants saw an X or an O on a computer screen and they had to respond as rapidly as possible with one of two keys. These are called “go” trials. On 25% of the trials, a tone sounded shortly after the X or O was displayed. The tone was the signal that participants should withhold their response. These are called “stop” trials. A stochastic tracking procedure was used to calculate stop signal reaction time (SSRT), or how much warning

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each participant needed to interrupt the button response. Stop signal reaction time was calculated by subtracting the average stop signal delay from average reaction time (Logan, 1994). Higher scores indicate worse performance.

Apparatus and Materials

The sentence production experiment was programmed using E-Prime experimental software (Version 1.1). Participants completed the experiment on a Dell Optiplex GX 400 computer with a 19 in. (48.26 cm) monitor. Utterance onset times were recorded using a voice activated sound trigger. The stimulus materials consisted of 90 line drawings of easily namable objects, and 54 verbs. Half of the drawings were of animate objects and half were of inanimate objects. Eighteen of the verbs were what we refer to as “optional”. These verbs can appear in either the past tense or past participle sentences in active voice (e.g. *The man moved the chair.* vs. *The man had moved the chair.*). Eighteen of the verbs were participle (e.g. *torn*). These verbs can only appear in past participle sentences in active voice (e.g. *The man had torn the paper.*). Thus, the participle verbs are more restrictive in terms of the sentence types they can grammatically appear in. Participle verbs included both irregulars (e.g. *torn*) and -en affixes (e.g. *ridden*). Lastly, 18 of the verbs were intransitive (e.g. *melted*). These were included in the study to serve as filler trials. (A full list of stimulus materials is available in the Appendix.)

Design and Procedure

The design for the first set of analyses was 2 × 2 (object order × verb type). Both variables were within subject. Object order indicates which picture, animate or inanimate, was presented first. The animate first order should bias towards an active construction (e.g. *The man moved the chair.*), and the inanimate first order should bias towards a passive construction (e.g. *The chair was moved by the man.*). Verb type was either optional or participle. Participle verbs are biased towards passives, and are more difficult, because they allow fewer syntactic options compared to the optional verbs. The dependent variables focused on whether the sentence was grammatical and/or disfluent, and the time taken to begin speaking. (Voice onset times are important for ensuring that there are no speed-accuracy tradeoffs, as might be expected with impulsive responding.) The design for the second set of analyses was 2 × 2 × 4 (object order × verb type × group). Group was between subjects, and the levels were control, ADHD-PI, ADHD-C, and remitted.

On each critical trial, participants were presented with two objects and a verb, and their task was to produce a sentence using the objects as arguments of the verb. Example stimuli are shown in Figure 1. For this task, the objects appeared one after the other and were followed by the verb. Participant responses were recorded to audiotape, and then transcribed and coded as described below. Each trial began with a fixation cross presented in the center of the computer screen. This was the participants’ cue that s/he could press the space bar to see the first picture. After 1 s a second picture appeared, and it was followed by a verb. For trials with intransitive verbs, participants saw only one picture followed by a verb. Participants were instructed to begin speaking as soon as possible. They were given four practice trials with feedback, followed by 54 regular session trials: nine in each of the four different conditions and 18 (intransitive) fillers. The order of trials was randomly determined for each participant, and participants were tested individually. The entire experiment lasted approximately 30 min.

Coding—Active sentences with optional verbs could be either past tense or past participle (e.g. *The man moved the chair.* or *The man had moved the chair.*). However, the vast majority of sentences with optional verbs resulted in past-tense constructions. For participle verbs, only the past participle form is available for active sentences (e.g. *The girl had ridden*

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the bicycle.). Passive sentences have the inanimate object in the subject position (e.g. *The bicycle was ridden by the girl*). Sentences were coded as *ungrammatical/other,* if the tense of the verb was changed or if the utterance was ungrammatical. In addition, some of the participle verbs can be used as an adjective modifier (e.g. *The dog found the hidden bone*.). These constructions were also included in the *other* category; however, this type of construction was relatively rare.

Four types of disfluencies were examined: filled pauses (i.e. *uh, um*, & *er*), unfilled pauses, repetitions, and repairs. Unfilled pauses were coded as a disfluency only if they lasted for longer than one second (to rule out ordinary prosodic pauses). Repetitions refer to unintended repeats of a word or a string of words (e.g. *The ball... the ball was dropped by the boy)*. Repairs occur when a speaker suspends articulation, and then starts over with some new word or phrase (e.g., *The ball...the boy dropped the ball)*. The data were transcribed and coded by two trained research assistants. Inter-rater reliability on a sample of the data was excellent: 95.2% agreement. The few disagreements that did exist were re-evaluated and resolved. Each research assistant then coded approximately half of the remaining data. Table 2 contains example utterances coded for both grammaticality and disfluencies.

Analyses

Results were analyzed using logit mixed effects models in cases where the dependent variable was binomial (Baayen, Davidson, & Bates, 2008; Barr, 2008; Jaeger, 2008). Logit mixed models have been recently advocated as more appropriate for binomial data than are ANOVAs over transformed proportions (Jaeger, 2008). These models also permit multiple random factors, so we included both subjects and items as random factors.

For each analysis, we first created a baseline model, which included an intercept and the two random factors (i.e. subjects and items). This model was then compared to successive models that included an additional predictor. If the inclusion of additional factors significantly improves fit over the baseline, then we can conclude that it accounts for a significant amount of variation in the data. In the first set of analyses, the variables were entered one after the other, and a third model tested the interaction. In the second set of analyses, we tested three-way interactions by comparing the fully saturated model to a model that contained the three main effects and the three two-way interactions. If the three-way interaction was not significant, then we tested each of the two-way interactions separately.

We assessed model improvement via log-likelihood ratio tests using the R statistical package (Bates, Maechler, & Dai, 2008). This test compares models using a χ^2 test which determines whether an additional predictor significantly improves model fit. Each model includes an intercept and slopes representing the effects of each of the factors in the model. In cases where a predictor significantly improved fit, the Wald statistic was used to show that coefficients differed significantly from zero (Agresti, 2002). Finally, in cases where the dependent variable was linear, we used standard ANOVAs with participants (*F1*) and items (*F2*) as random effects.

Results

For all of the following analyses, the data were screened for outliers. Individual participant means that differed from the condition mean by more than 3.0 standard deviations were replaced with the mean for that group in that condition. This never affected more than 2.5% of the data for any one variable. We then applied transformations to the skewed variables in the dataset (i.e. stop-signal reaction time: logarithm, trails B – A: logarithm, perseveration errors: inverse). Overall, there were 48 utterances that were lost due to problems with the

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audio recording equipment and/or the sentence being inaudible. There were 719 disfluencies (149 filled pauses, 364 unfilled pauses, 48 repetitions, 158 repairs). The means for the executive function measures are shown in Table 3, and correlations are shown in Table 4.

Remitted Participants

Grammaticality—To evaluate the relative difficulty of the four conditions, we first analyzed the distribution of ungrammatical utterances. Results showed that model fit was improved only with the inclusion of verb type $\chi^2(1) = 12.83$, $p < .001$. There were more ungrammatical utterances when the verb was participle compared to when it was optional (see Figure 2, panel A). Model fit was not improved by object order or the interaction. However, there was a trend for more ungrammatical sentences in the animate-participle condition compared to the inanimate-participle condition (.22 vs. .18), which is consistent with the prediction that the animate-participle condition is the most difficult.

Disfluency—The proportion of trials with a disfluency also showed that model fit was significantly improved when verb type was included $\chi^2(1) = 9.05$, $p < .01$, and again, the pattern was for there to be more disfluencies when the verb was a participle (see Figure 2, panel B). We also conducted the same analysis using each type of disfluency as a dependent variable. Three out of the four showed a main effect of verb type: unfilled pauses $\chi^2(1) = 7.89$, $p < .01$, repetitions $\chi^2(1) = 7.32$, $p < .05$, and repairs $\chi^2(1) = 7.31$, $p < .01$.

In summary, across both the grammaticality and disfluency measures, we observed a strong effect of verb type in which the participle verbs resulted in more production difficulty compared to the optional verbs. There was little effect of object order, and no interactions between the two variables.

Between Groups Comparisons

The purpose of this set of analyses was to determine how remitted participants compared to both typically-developing controls and participants who had ADHD as children and as adults.

Grammaticality—To assess the remitted group compared to ADHD and controls, we used a 2 × 2 × 4 (object order × verb type × group) mixed design. Group was between subjects, and was control, ADHD-PI, ADHD-C, and remitted. Verb type and picture order were both within subject. Results showed a significant effect of verb type $\chi^2(1) = 37.07$, $p < .001$, in which participle verbs resulted in more ungrammatical utterances compared to the optional verbs. There was also a marginal effect of group $\chi^2(1) = 7.43$, $p = .059$, and a significant two-way interaction between group and verb type $\chi^2(1) = 20.36$, $p < .001$.[3] The means for this interaction are shown in Figure 3, panel A. The interaction is primarily driven by the group differences observed with the optional verbs $\chi^2(3) = 14.13$, $p < .01$. Results showed that the remitted group produced significantly more ungrammatical utterances compared to both controls and ADHD participants (all *p's* < .05). For the participle verbs, there were no omnibus group differences ($p > .05$). However, the remitted group was again significantly different from controls ($p = .05$), and in this case, they patterned similarly to the ADHD-C group. Thus, the remitted group produced substantially more ungrammatical utterances with the optional verbs, which are the easier task conditions. In contrast, in the more difficult conditions, the remitted group patterned similarly to the combined subtype.

As a follow-up, we conducted a multiple regression in order to explore which variables in our dataset predict the number of ungrammatical utterances. We included the variables from

[3]This interaction remains significant when both education and reading standard score are covaried.

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Tables 1 and 2, and used backwards elimination to test for significant predictors. For ungrammatical utterances with participle verbs, there was only a single predictor retained in the final model, and it was reading standard score $t(84) = -3.67$, $p < .01$, $R^2 = .14$, $\beta = -.38$. For the proportion of ungrammatical utterances with optional verbs, there were no significant predictors retained. The high proportion of ungrammatical sentences produced by the remitted group with participle verbs makes sense because their reading score was similar to the combined subtype (see Table 1). As for the high number of ungrammatical utterances with optional verbs, that variance remains unexplained at this point. There are no obvious explanations in terms of demographic variables, symptom severity scores, or the executive function measures, as the remitted group tended to pattern in between the controls and the ADHD-C group. The exception was the trials task. In this task, the remitted group was nearly identical to the ADHD-C group. We return to these issues in the General Discussion.

Disfluency—We again used a 2 × 2 × 4 (object order × verb type × group) mixed design. Object order and verb type were within subject, and group was between subjects. The first analysis looked at all disfluencies summed together, and the second set looked at each of the four disfluency types separately (i.e. filled pauses, unfilled pauses, repetitions, and repairs). For the total disfluencies, there was only a main effect of verb type $\chi^2(1) = 19.42$, $p < .001$. The participle verbs resulted in more disfluencies compared to the optional verbs.

For the individual disfluency types, the filled and unfilled pauses showed only a main effect of verb type $\chi^2(1) = 7.81$, $p < .01$ and $\chi^2(1) = 19.92$, $p < .001$, respectively. For repetitions, there were no significant differences. Repairs showed significant main effects of verb type $\chi^2(1) = 18.53$, $p < .001$ and group $\chi^2(1) = 9.16$, $p < .05$. In addition, the three-way interaction between object order, verb type, and group was significant $\chi^2(3) = 12.32$, $p < .01$ (see Figure 3, panel B).[4] In order to decompose the three-way interaction, we focused on the group differences within each of the four within subjects conditions. Results showed significant group effects in the animate-participle condition $\chi^2(3) = 13.31$, $p < .01$ and the inanimate-optional condition $\chi^2(3) = 13.36$, $p < .01$. In the animate-participle condition, both the remitted group and the ADHD-C group were significantly worse ($p < .05$) than control participants. In the inanimate-optional condition, the combined group was significantly worse than controls ($p < .05$) and the remitters were marginally worse than controls ($p = .055$). Thus, in terms of repair disfluencies, the remitted group patterned more similarly to the ADHD-C group, and both were worse than controls.

As a follow-up analysis, we again conducted a multiple regression in order to explore which variables in our dataset predict the proportion of repair disfluencies. We again included the variables from Tables 1 and 2, and used backwards elimination. For repairs in the animate-participle condition, results showed that two predictors were retained in the final model: Stroop performance $t(84) = -2.96$, $p < .01$, $\beta = -.31$ and years of education $t(84) = -1.82$, $p = .07$, $\beta = -.19$. The model with these two variables was significant $F(2,79) = 5.73$, $p < .01$, $R^2 = .13$. For repairs in the inanimate-optional condition, results showed a similar pattern. Both Stroop performance and years of education were retained in the final model $t(84) = -2.95$, $p < .01$, $\beta = -.31$ and $t(84) = -1.92$, $p = .058$, $\beta = -.20$, respectively. The model with these two variables was significant $F(2,82) = 5.87$, $p < .01$, $R^2 = .13$. These findings suggest that years of education has an effect on people's tendency to produce repair disfluencies. Perhaps more importantly, we observed that Stroop performance was also related to the number of repair disfluencies, which suggests a role for inhibitory control in the prevention of repair-type disfluencies.

[4]This interaction remains significant when both education and reading standard score are covaried.

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Voice Onset Times

We used a 2 × 2 × 4 (object order × verb type × group) mixed model ANOVA to analyze mean voice onset time (see Figure 4). Object order and verb type were within subject, and group was between subjects. The purpose of these analyses was to ensure that there were no speed-accuracy tradeoffs between the different diagnostic groups. Results showed a significant main effect of verb type $F1(1,84) = 50.98$, $p < .001$; $F2(1,84) = 45.68$, $p < .001$, in which participants were slower to begin speaking when the verb was a participle as compared to when it was optional. There was also a significant interaction between object order and group $F1(3,82) = 4.21$, $p < .01$; $F2(3,82) = 6.80$, $p < .01$ (see Figure 4, panel B).

To follow up this interaction, we conducted two one-way ANOVAs focusing on the group differences. Results showed only a marginal effect of group when the animate object was presented first $F1(3,82) = 2.19$, $p = .097$; $F2(3,82) = 3.23$, $p = .079$, and there was no group effect when the inanimate object was presented first ($p > .50$). As can be seen in Figure 4, the group differences seem to be in large part due to performance in the animate-participle condition. In this condition, the remitted group was significantly faster to begin speaking compared to the ADHD-C group $t(41) = 2.47$, $p < .05$. However, the correlations between voice onset time and the proportion of ungrammatical utterances were all positive and none were significant (animate-optional: $r = .123$, animate-participle: $r = .231$, inanimate-optional: $r = .108$, and inanimate-participle: $r = .213$). For the number of repair disfluencies, all of the correlations were again positive, and the animate-participle and inanimate-optional conditions were both significant $r = .271$, $p < .05$, and $r = .396$, $p < .01$, respectively. These results indicate that as the latency to begin speaking increases, participants are more likely to produce ungrammatical utterances and to make repair disfluencies. Therefore, we can rule out a speed-accuracy tradeoff between the timing of utterance onset and the tendency to produce grammatical and fluent utterances.

Discussion

The purpose of this study was to examine language production in a group of adults who had ADHD as children, but then as adults, no longer met diagnostic criteria (APA, 2000). These participants were tested on a sentence production task, as well as several measures of executive function. In the first set of analyses, we presented the data from the 21 “remitted” participants. Results showed that the verb type manipulation had a strong effect on participants’ ability to successfully manage task demands. Specifically, there were more ungrammatical and disfluent utterances when the verb was a participle compared to when it was optional, and the same pattern held for three types of disfluency (i.e. filled pauses, unfilled pauses, and repairs). Clearly, in cases in which speakers have less syntactic flexibility (i.e., with the participle verbs), they are more likely to have difficulty producing a grammatical and fluent utterance (V. Ferreira, 1996).

In the second set of analyses, we compared the remitted group to controls, ADHD-PI, and ADHD-C. Thus, the second set of analyses allowed us to investigate whether the remitted group patterned more similarly to ADHD participants or to controls. Results showed that the remitted group was more similar to the combined subtype in the number of ungrammatical utterances when the sentence contained a participle verb, and both the remitted group and ADHD-C participants were worse than controls. Also, the tendency to produce ungrammatical utterances in this condition seemed to be linked to reading ability and IQ, and the remitted group was similar to the ADHD-C subtype in reading. We should note, however, that the significant verb type × group interaction was actually driven by differences with the optional verbs. For the number of ungrammatical utterances with optional verbs, the remitted group performed significantly worse than all of the other three groups. Here there were no obvious explanations for the pattern that was observed. The

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highest correlation was with the perseveration errors: $r = -.10$. However, the correlation was not significant. At this point, the variance associated with ungrammatical utterances when the verb was optional remains unexplained. One possibility is that these differences may be related to state or motivational factors (e.g. Sergeant, Oosterlann, & van der Meere, 1999), and dual pathway models of ADHD specifically assume that state regulation and motivation are independent of inhibition and cognitive-control deficits (e.g. Sonuga-Barke, 2002). Another possibility is that, for this particular group of speakers, the flexibility associated with the optional verbs actually creates competition between potential responses, which in turn results in the production of ungrammatical sentences. Additional research is needed to distinguish these possibilities.

With regard to disfluencies, results showed significant group differences only in the number of repairs. Repairs refer to cases in which a person suspends articulation mid-utterance, and then restarts with a new word or phrase (e.g. *turn left ... right on Northumberland Street*). These disfluencies typically occur when a person says the wrong word, and then has to correct him- or herself. Thus, repairs are often viewed as an overt error in language production (Bortfeld, Leon, Bloom, Schober, & Brennan, 2001; Postma, 2000). In the current study however, most repairs (~60%) were cases in which the participant began with one noun phrase and then switched to the other one (e.g. *the girl ... the bicycle was ridden by the girl.*), which suggests that most of the production difficulty elicited by our task is due to syntactic planning difficulty rather than problems with lexical selection. However, these two processes are of course not independent of one another. Results showed that there were significant group differences in repairs in two of the within subjects conditions (i.e., animate-participle and inanimate-optional). The remitted participants patterned similarly to the ADHD-C group. In the other two (within subject) conditions, the remitted group tended to produce slightly more repairs compared to controls and ADHD participants (see Figure 3). However, there were no reliable group differences in either the inanimate-participle or the animate-optional conditions.

Our follow up regression analysis indicated that variance in the animate-participle and inanimate-optional conditions could partially be explained by the number of years of education and the Stroop task. In terms of education, the remitted participants fell in between controls and the two ADHD subtypes, and thus, were not significantly different from either controls or ADHD participants. Lower educational attainment however, is common in ADHD (Barkley et al., 2002; Faraone et al., 2000; Murphy & Barkley, 1996). Thus, the relationship between better language performance and more years of education could reflect the abilities of higher functioning individuals. The relationship between repairs and the Stroop task is more interesting because it implicates a role for inhibitory control in the ability to produce fluent speech. If so, then this has implications for both theoretical models of language production and theoretical models of ADHD. We discuss each of these in turn.

Theoretical Implications: Language Production

Models of language production assume the existence of a monitoring mechanism that is responsible for detecting problems in speech plans prior to articulation (for reviews see Blackmer & Mitton, 1991; Clark, 1994; Levelt, 1983; 1989; Postma, 1997; 2000). However, time constraints in the normal course of speaking are quite high. Postma (2000) estimated that the speech monitor has at most 100-150 ms to detect an error before phonetic plans are sent to the articulators. The results from the current study indicated that repair disfluencies are partially related to individual differences in inhibitory control. The role of inhibition in language production has been investigated across a number of paradigms and across a number of participant groups. For example, it has been shown that older participants have more difficulty with word retrieval compared to younger participants, and thus, have a

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greater tendency to produce disfluencies (Cooper, 1990; Hasher, Stoltzfus, Zacks, & Rypma, 1991; Hasher & Zacks, 1979; Le Dorze & Bedard, 1998; Mortensen, Meyer, & Humphreys, 2006; Schmitter-Edgecombe, Vesneski, & Jones, 2000). Shao, Roelofs, and Meyer (2012) reported data from a group of undergraduates, and they found that stop task performance correlated with object naming speed. Object naming is a sub-component of the sentence processing task used in the current study. It is generally assumed that when a picture is viewed, there is activation of conceptual-semantic representations, and that multiple response alternatives are activated in the mental lexicon (Dell, 1986; Levelt et al., 1999).

For example, if a picture of a dog is viewed, there will be activation of super- and sub-ordinate category labels (e.g. animal, collie, puppy) and also semantically associated words (e.g. cat, bone, bark). Following the spread of activation, the second process is to select one of the activated alternatives (Kempen, 1978). It is easy to conceive that inhibition of semantically-related items would facilitate naming and cut down on the chances of the wrong word being selected. Computational models of word production often include lateral inhibition as a basic mechanism in their processing architectures (Berg & Schade, 1992; Dell, 1986; Dell & O'Seghdha, 1992; Dell, Burger, & Svec, 1997). At this point, the role of inhibitory processes in syntactic processing is less well understood compared to word production (cf. Dell, Chang, & Griffin, 1999; Vosse & Kempen, 2000).

Another view on why speakers sometimes make errors focuses on the role of selective attention and general cognitive resources in the speech monitoring process. Evidence for this view comes from word errors, and the time it takes people to correct themselves after making an error. Levelt (1983), for example, showed that the error-to-correction time is shorter depending on where the error occurs within a phrase. If the error occurs early in phrase, the correction takes longer compared to when the error occurs later in the phrase (Levelt et al., 1991). At the start of a phrase, conceptual planning and articulation run in parallel, which places heavy demand on resources. In contrast, toward the end of a phrase, conceptual planning has ended and the speaker then has more cognitive resources available, which allows for faster correction of an error. This view emphasizes the role of cognitive resources, such as selective attention, in the ability to monitor speech effectively. In evaluating these alternative explanations, one runs into the dilemma of how inhibition and attention are related to one another. Many of the theories of ADHD assume that the primary (or causal) impairment is deficient inhibitory control. Deficits in inhibition then lead to the secondary consequence of inattentive symptoms in ADHD (e.g. Barkley, 1997; Nigg, 2001). However, evidence for deficits of selective attention in ADHD, for example from the attentional blink task, have produced mixed results (Armstrong & Munoz, 2003; Hollingsworth, McAuliffe, & Knowlton, 2001; Li et al., 2004; Nigg et al., 2007). This pattern is consistent with imaging data that shows similar activation, size, and blood flow between control and ADHD children in parietal regions when the task requires selective attention (Booth et al., 2005; Indefrey & Levelt, 2000; Nigg & Casey, 2005).

With respect to the current findings, the relationships with inhibition tasks were mixed. Stroop performance predicted some findings but not others. Stop signal reaction time, which is typically one of the best cognitive markers of ADHD status (Nigg et al., 2007), was not a significant predictor of either grammaticality or disfluency. However, as Friedman and Miyake (2004) argued, with most inhibition tasks, the proportion of variance attributable to the latent construct (i.e. inhibition) is relatively small compared to variance attributable to idiosyncratic task demands and/or error variance. Thus, task impurity is a problem. As for the role of selective attention, as an alternative (or complimentary) explanation for the findings we observed, we cannot conclusively say how much of the group differences may be due to attentional deficits. It is certainly possible, especially given Levelt's error-to-

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correction time data, that some language production problems originate from demands on attention resources in the monitoring process.

Theoretical Implications: Models of ADHD

Turning now to theories of ADHD, Halperin et al. (2008) argued that symptom remission in ADHD is driven primarily by improvements in effortful control. Halperin and colleagues based their "effortful-control" argument on a prefrontal recovery hypothesis (Halperin & Schulz, 2006; Shaw et al., 2010). They showed that working memory performance for remitted individuals was no different from controls, but there were differences between ADHD and controls (see also, Engelhardt, Nigg, Carr, & Ferreira, 2008; Martinussen & Tannock, 2006). However, Halperin et al. did find performance differences between control and remitted participants on a continuous performance task (i.e. a sustained attention task). Based on these data, they concluded that improvements in effortful control are what lead to symptom remission in ADHD over the course of development.

The current results are in line with previous studies in that (adult) ADHD and remitted participants showed certain language output problems. Moreover, some of these production problems were related to executive function (i.e., the Stroop task). There has been some research to suggest that executive function weakness in ADHD is linked more with the inattention symptom domain, rather than the hyperactive-impulsive symptom domain (e.g. Sonuga-Barke, 2002). However, the DSM-IV symptoms of impulsivity are implicated in inappropriate language outputs (e.g. talks excessively, blurts out answers in class, intrudes in conversations, etc.). In our study, we assessed the grammaticality and fluency of utterance production, whereas the symptoms of ADHD that are specific to language output deal more with social-pragmatic issues. Thirteen of the 21 participants in the remitted group were classified as ADHD-PI as children, eight were classified as ADHD-C, and five were classified as ADHD-PH. Thus, the vast majority of the remitted group showed problems with inattention, and indeed, the Conner's (1) score, shown in Table 2, was slightly above average and at approximately the 75th percentile. This suggests that the remitted participants had greater inattention problems than the majority of people in this age range.

In summary, there have been only a handful of studies that have investigated language production in adults with ADHD, and there are even fewer studies that have investigated whether particular cognitive deficits persist or remit in ADHD (e.g. Carr et al., 2006; Halperin et al., 2008). With respect to language production in remitted ADHD, the pattern that seems to be emerging is that there is some persistence of problems in the quality and continuity of language output. Based on our data, we would make a tentative link between repair disfluencies and inhibitory control. Therefore, we think the language production problems in ADHD likely stem from weakness in certain executive functions, and remain apparent in remitted ADHD (Chhabildas, Pennington, & Willcutt, 2001; Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Murphy, Barkley, & Bush, 2001; Martel, Nikolas, & Nigg, 2007; Nigg, Blaskey, Huang-Pollack, & Rappley, 2002; Nigg et al., 2007). However, as mentioned above, we do not currently have selective attention data, and so we are not in a position to comment on how individual differences in attentional control impact on language production.

Limitations

The study had a few limitations. The first is that the sample was somewhat limited (i.e., there were approximately 20 participants in each group). We, of course, recommend that these issues be looked at in another study, and possibly larger sample of participants with remitted ADHD. Second, as a reviewer pointed out, a longitudinal study would be a more definitive way of testing how language production changes over the course of development

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in ADHD. The current study compared a sample of remitted participants to participants with ADHD and to controls in order to determine whether the remitters' performance was more similar to controls or to ADHD. However, conclusively testing whether language production problems persist or remit would require repeated testing over the developmental period from adolescence into young adulthood (Biederman et al., 2010). The findings we report here set the stage for a longitudinal study, allowing future researchers to develop precise predictions concerning the patterns of data that should be observed. Finally, our study was conducted in a laboratory setting in which the speaker did not interact with an interlocutor. Therefore, the results may not reflect more spontaneous (or naturalistic) language production. The restricted nature of the laboratory ensures that external distractions were reduced. Also, because the task did not involve interpersonal interaction, there was no turn taking required and no alternating between comprehension and production. For these reasons, we think our task is likely less demanding than naturalistic conversation, but at this point, it remains an open issue as to whether the group differences would be larger or smaller in more naturalistic language production situations.

Conclusions

The ability to consistently produce grammatical and fluent utterances was impaired even in participants who had recovered symptomatically from ADHD. Our findings furthermore suggest that the tendency to produce ungrammatical sentences is linked to reading ability, and the tendency to make repair disfluencies is partially linked to inhibition. These findings have implications, not only for clinical groups, but also for typically-developing individuals as well. If we were to explicitly incorporate inhibition into theories of language production, then individuals who vary in inhibitory control should systematically vary in their ability to produce grammatical and fluent language output (Underwood, 1975). Including these types of individual difference variables into theories of language production will make the questions about intervening processes and mechanisms clearer, which should then lead to investigations of how inhibition and/or selective attention mediate the relationship between task manipulations and language output. We believe that the results from the remitted group are largely consistent with the pattern of impairments that have been observed in remitted participants in previous studies (e.g. Biederman & Faraone, 2000; Carr et al., 2006; Halperin et al., 2008). Thus, the current study contributes to the on-going discussions concerning language production problems in adults with ADHD and remitted ADHD.

Appendix

Appendix

Stimulus materials used in the sentence production task.

Trial	Picture1	Picture2	Verb	Condition
1	chicken	corn	found	animate-optional
2	man	piano	played	animate-optional
3	goat	motorcycle	avoided	animate-optional
4	girl	boat	described	animate-optional
5	baby	ball	caught	animate-optional
6	woman	car	rented	animate-optional
7	baby	drum	recognized	animate-optional
8	horse	wagon	pulled	animate-optional
9	man	umbrella	closed	animate-optional
10	dog	bone	hidden	animate-participle

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Trial	Picture1	Picture2	Verb	Condition
11	girl	bike	ridden	animate-participle
12	doctor	book	written	animate-participle
13	batter	ball	thrown	animate-participle
14	woman	bucket	taken	animate-participle
15	magician	hat	worn	animate-participle
16	astronaut	moon	seen	animate-participle
17	man	cup	chosen	animate-participle
18	woman	clock	woken	animate-participle
19	baby		cried	intransitive
20	magician		Joked	intransitive
21	glass		cracked	intransitive
22	woman		kneeled	intransitive
23	man		sighed	intransitive
24	mail		disappeared	intransitive
25	jeep		stalled	intransitive
26	boat		sank	intransitive
27	glass		shattered	intransitive
28	plane		crashed	intransitive
29	jaguar		dozed	intransitive
30	boy		shouted	intransitive
31	man		fainted	intransitive
32	man		apologized	intransitive
33	phone		rang	intransitive
34	boy		whined	intransitive
35	ice cream		melted	intransitive
36	flower		grew	intransitive
37	house	biker	passed	inanimate-optional
38	pipe	man	smoked	inanimate-optional
39	comb	girl	used	inanimate-optional
40	tree	deer	approached	inanimate-optional
41	sock	baby	wanted	inanimate-optional
42	newspaper	man	burned	inanimate-optional
43	chair	man	moved	inanimate-optional
44	bed	cat	liked	inanimate-optional
45	shell	seal	touched	inanimate-optional
46	jacket	man	torn	inanimate-participle
47	doll	girl	given	inanimate-participle
48	bottle	man	shaken	inanimate-participle
49	jeep	man	driven	inanimate-participle
50	chain	bear	broken	inanimate-participle
51	suitcase	woman	stolen	inanimate-participle
52	mop	man	forgotten	inanimate-participle

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Trial	Picture1	Picture2	Verb	Condition
53	cake	woman	eaten	inanimate-participle
54	kite	man	flown	inanimate-participle

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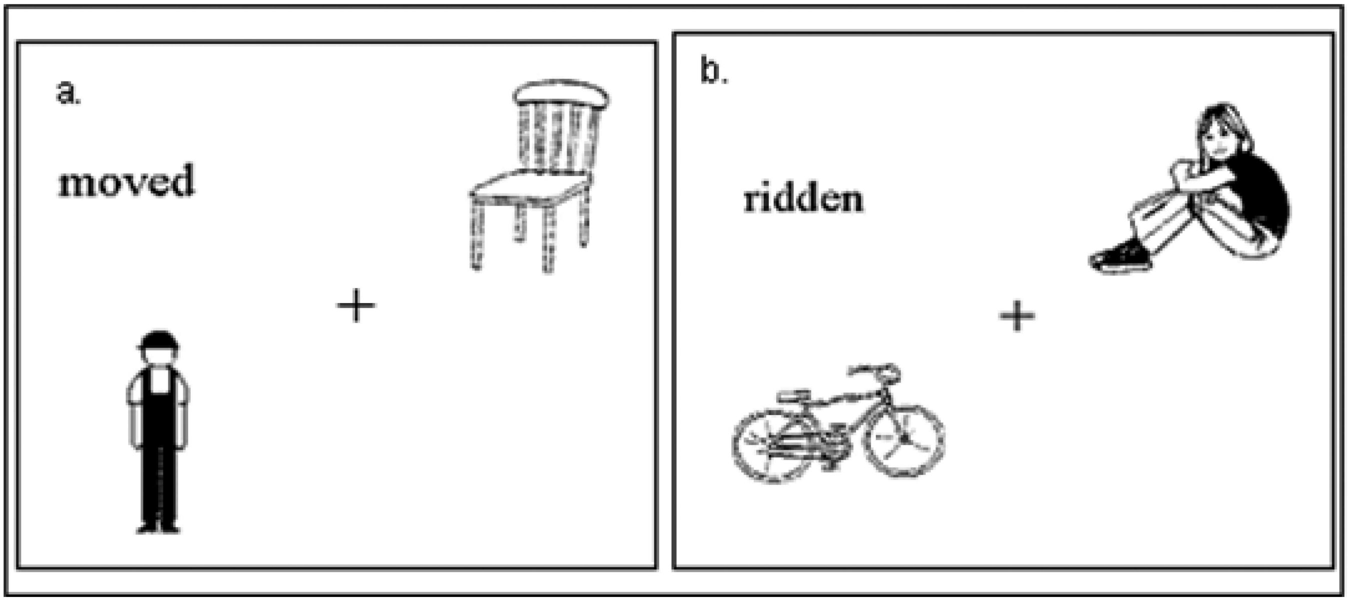

Figure 1.
Example stimuli. The left panel contains an optional verb, and the right panel contains a participle verb.

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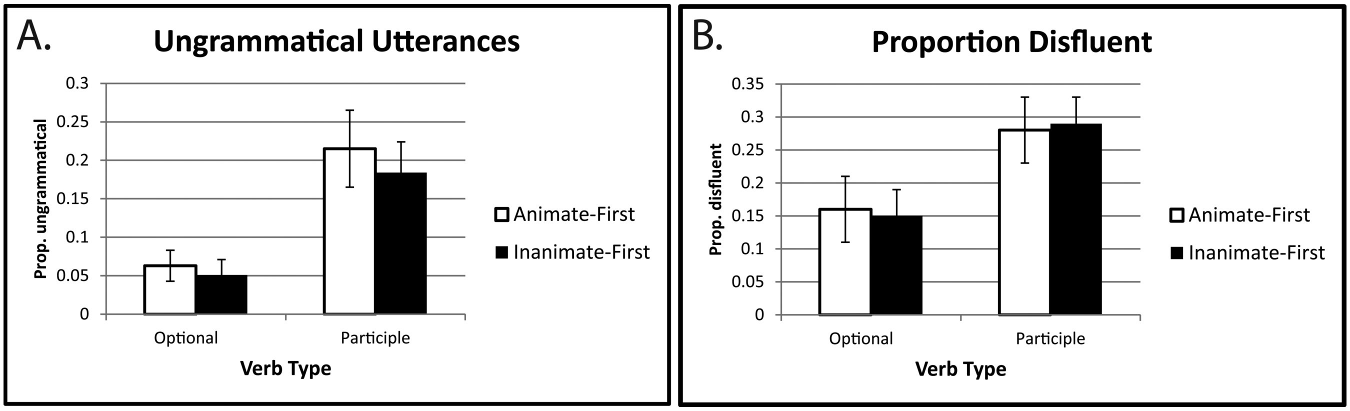

Figure 2.
Results from the remitted group. Panel A shows the proportion of ungrammatical utterances produced in each of the four conditions. Panel B shows the proportion of trials with a disfluency in each of the four conditions. Error bars show the standard error of the mean.

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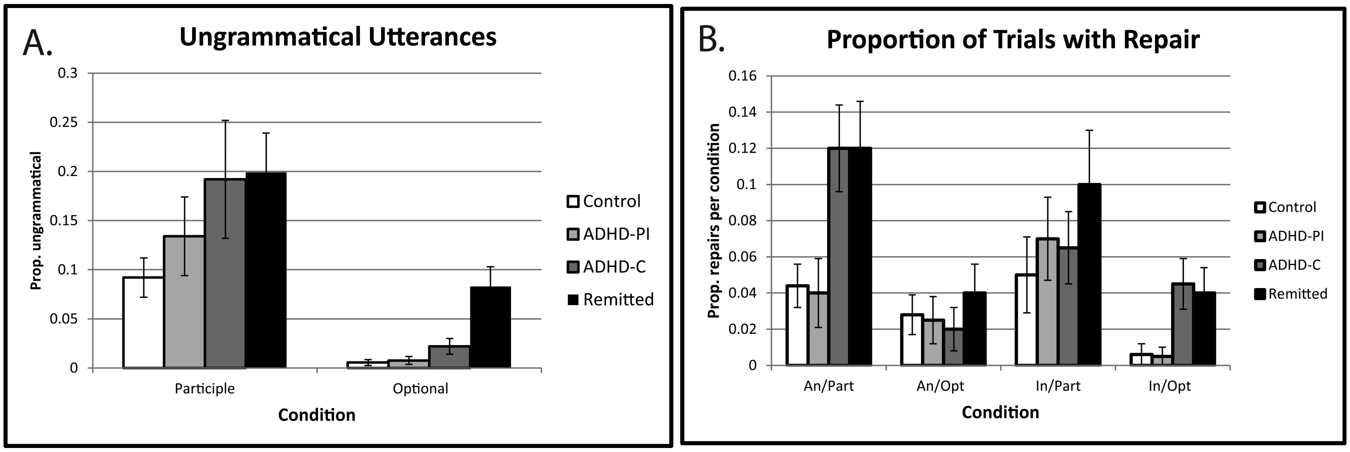

Figure 3.

Results from the between groups comparison. Panel A shows the proportion of ungrammatical utterances broken down by verb type. Panel B shows the results for the proportion of trials with a repair disfluency. Error bars show the standard error of the mean.

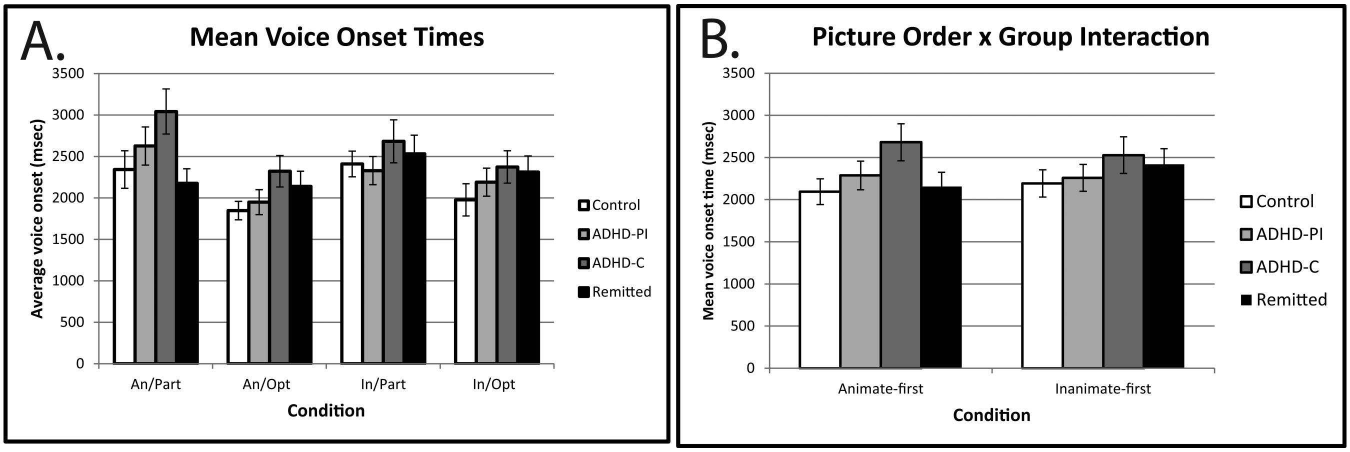

Figure 4.
Mean voice onset times for each of the four diagnostic groups. Panel A shows all conditions, and panel B shows the object order by group interaction. Error bars show the standard error of the mean.

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Table 1

Example responses coded for both grammaticality and disfluency type

	Gram.	**Disfluency**
1. Girl ridden the bike.	No	-
2. The astronaut seen the moon	No	-
3. The man forgotten to mop.	No	-
4. Uh, Chicken found some corn.	No	filled pause
5. Jeep is – was driven by the man.	No	repair
6. The woman (pause) described the sailboat.	Yes	unfilled
7. The baby recognized (pause) the drum.	Yes	unfilled
8. The lug – the luggage was stolen by this woman.	Yes	repetition
9. The man, er, the hat was worn by the man.	Yes	filled + repair
10. Uh, the (pause) chicken found the corn.	Yes	filled + pause
11. Um, the umb – the man closed the umbrella.	Yes	filled + repair

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Table 2

Sample characteristics for the remitted participants and the three comparison groups

	Controls (20)	ADHD-PI (22)	ADHD-C (22)	Remitted (21)	*p1*	*p2*	*p3*	*p4*	*p5*	*p6*	*p7*
Variable	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**							
Age (years)	23.60 (4.99)	22.50 (3.91)	22.91 (3.82)	24.14 (4.94)	.63	.43	.62	.73	.73	.23	.36
% Male	65.0	72.7	77.3	61.9	.70	.60	.39	.84	.74	.46	.28
Education	15.00 (1.95)	13.71 (1.68)	13.09 (1.48)	14.00 (1.07)	.01	.03	.00	.09	.20	.59	.07
Full scale IQ	115.65 (10.24)	113.43 (15.55)	107.27 (13.30)	110.76 (7.54)	.14	.59	.03	.09	.17	.48	.30
Reading SS	105.85 (7.85)	106.43 (10.28)	97.95 (10.30)	99.71 (9.85)	.01	.84	.01	.03	.01	.04	.57
Conners' (1)	48.65 (9.33)	67.29 (7.98)	69.71 (6.43)	58.55 (8.09)	.00	.00	.00	.00	.28	.00	.00
Conners' (2)	43.65 (6.39)	57.29 (9.32)	67.86 (5.46)	54.41 (7.35)	.00	.00	.00	.00	.00	.27	.00

Note. Conners' scores are t-scores: (1) is "cognitive problems" which is closely related to DSM-IV inattentive symptoms; and (2) is hyperactive-impulsive symptoms. Values represent average of informant and self-report. P1 is one-way ANOVA with four groups. P2 compares controls to ADHD-PI. P3 compares control to ADHD-C. P4 compares control to remitted. P5 compares ADHD-PI to ADHD-C. P6 compares ADHD-PI to remitted. P7 compares ADHD-C to remitted.

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Table 3

Means of executive function measures for the remitted group and the three comparison groups

	Controls (20)	ADHD-PI (22)	ADHD-C (22)	Remitted (21)	*p1*	*p2*	*p3*	*p4*	*p5*	*p6*	*p7*
Variable	**Mean(SD)**	**Mean(SD)**	**Mean(SD)**	**Mean(SD)**							
Inhibition measures:											
Stroop	9.85(8.85)	8.97(6.81)	5.56(6.69)	8.46(10.78)	.40	.72	.09	.66	.11	.86	.30
SSRT	225.78(33.25)	237.94(52.21)	263.10(70.08)	245.51(61.88)	.20	.38	.04	.21	.19	.67	.39
Set shifting measures:											
Trails (B – A)	24.73(14.56)	29.39(10.96)	32.54(11.89)	32.55(18.07)	.25	.25	.07	.14	.38	.50	.99
Perseveration	7.56(5.14)	6.30(3.23)	7.27(3.03)	6.54(2.64)	.64	.35	.82	.42	.32	.80	.41

Note. SSRT = stop signal reaction time, Perseveration errors = number of errors on the Wisconsin Card Sorting task. P1 is one-way ANOVA with four groups. P2 compares controls to ADHD-PI. P3 compares controls to ADHD-C. P4 compares controls to remitted. P5 compares ADHD-PI to ADHD-C. P6 compares ADHD-PI to remitted. P7 compares ADHD-C to remitted.

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Table 4

Correlations between demographic variables, executive function measures, and dependent variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	-	.61**	.06	-.19	-.11	-.05	-.09	-.22*	.00	.05	.06	-.06	.02	.01
2. Education		-	.33**	.22*	-.30**	-.28*	-.29**	-.06	-.11	.00	-.13	-.04	-.15	-.12
3. IQ			-	.51**	-.11	-.18	-.20	.23*	-.38**	-.49**	-.28**	-.03	-.13	-.17
4. Reading SS				-	-.08	-.29**	-.27*	.17	-.37**	-.32**	-.38**	-.08	-.18	-.12
5. Conners (1)					-	.67**	.22*	-.15	.07	-.05	-.03	-.06	.07	.15
6. Conners (2)						-	.28*	-.28*	.13	.08	.12	.03	.16	.14
7. stop-signal reaction time							-	-.25*	.06	.09	-.02	.02	.13	-.01
8. Stroop								-	-.17	-.17	-.03	-.04	-.30**	-.30**
9. trails (B – A)									-	.39**	.15	.08	.10	.11
10. Perseveration errors										-	.05	-.10	.17	.06
11. Ungram: participle											-	.41**	.13	.24*
12. Ungram: optional												-	.12	.10
13. Repairs: animate/participle													-	.49**
14. Repairs: inanimate/optional														-

Note. N = 85

*$p < .05$

**$p < .01$.