Effects of Attention-Deficit/Hyperactivity Disorder on writing composition product and process in School Age Students

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Abstract

Objective: This study examined the relationship between ADHD and writing performance. Method: Students in Grades 3 to 7, 84 with ADHD and 135 age and gender-matched controls completed a writing task (including process logs), and measures of, working memory and attention. Results: Students with ADHD wrote texts of similar length but with poorer structure, coherence and ideation. 6.7% of the variance in writing quality was explained by whether or not the student had an ADHD diagnosis, after control for IQ and age-within-year, with students with ADHD producing text that was less coherent, well structured, and ideationally rich and to spend less time thinking about and reviewing their text. Half of the effect on text quality could be attributed to working memory and sustained attention effects. Conclusions: ADHD has some effect on writing performance which can, in part, be explained by working memory and attentional deficits.
Keywords: ADHD, written composition, attention, working memory.

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INTRODUCTION

The reported prevalence of attention deficit hyperactivity disorder (ADHD) ranges from between 3% to 17% of school-age children (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007; Vande Voort, He, Jameson, & Merikangas, 2014), and prevalence decreases with age, although there is some evidence of national variation (Faraone, Sergeant, Gillberg, & Biederman, 2003). A study with Spanish students, the population sampled in the present work, suggested rates of ADHD of 14% in 8-year-olds, decreasing to 3% in 15-year-olds (Das, Cherbuin, Easteal, & Anstey, 2014).

Current understanding of ADHD, as summarised in the DSM-5 (American Psychiatric and Association [APA], 2013), identifies two distinct sets of behaviours: Children may be hyperactive and act impulsively or they may be inattentive. Both hyperactivity/impulsivity and inattention may be present together and measures of these distinct components tend to correlate (Gambin & Małgorzata, 2009). ADHD is also typically associated with reduced scholastic achievement, relative to peers, and the more severe the diagnosis the more pronounced the effects (Martin, 2014). In a meta-analysis of 181 studies, Frazier and co-workers (2007) found moderate mean effects of ADHD on spelling, mathematics, and reading (with Cohen´s deltas of .55, .67, and .73, respectively). Their review also suggested that students with ADHD were more likely to be identified as having learning disabilities and to be grade-retained. Nevertheless, the effects of ADHD on standardized scholastic achievement tasks remain after controlling for general intellectual ability and co-morbid deficits in cognitive function (Alloway, 2009; Kent et al., 2011; Mayes & Calhoun, 2006). The effects of ADHD are also more pronounced for some areas of learning than for others. Specifically, individuals with ADHD experience greater difficulties with written composition than with mathematics (Mayes & Calhoun, 2006).

In a recent meta-analysis, Graham, Fishman, Reid, and Hebert (2016) reported that students with ADHD obtained lower scores than their normally achieving peers for writing quality, vocabulary, spelling, and handwriting. Further, neither study quality nor the population from which ADHD students were drawn (i.e., school/community vs. clinic/hospital) affected the results.

Handwriting, which is the focus of the present research, is by nature a complex process that comprises a number of sub-processes and associated skills (Alamargot & Chanquoy, 2001; García & Fidalgo, 2008; Marzban & Norouzi, 2012; Rodríguez, Grünke, González-Castro, García, & Álvarez-García, 2015). Writers must retrieve sufficient and relevant content, and must simultaneously monitor and maintain coherent expression of this content, in the absence of audience feedback, across sentences and paragraphs. At the sentence level, writers must retrieve appropriate words, spelling, and syntax, and engage in the necessary motor planning to create visible output on either the screen or page. To achieve this, writers must access content from their long-term memory and keep this information in mind while engaging in the necessary psycholinguistic processing to produce coherent text; this requires a high level of sustained attention (Olive, Favart, Beauvais, & Beauvais, 2009; Torrance & Galbraith, 2006). If a student experiences general difficulties in sustaining attention then this is likely to affect both writing processes and writing performance (García, Rodríguez, Pacheco, & Díez, 2009; Gregg, Coleman, Stennett, & Davis, 2002).

Children with ADHD produce less text than children without ADHD and they tend to score lower on writing quality, assessed as adequacy, structure, grammar, and lexicon (García et al., 2009; Re, Pedron, & Cornoldi, 2007). Re et al. (2007) suggest that children with ADHD may experience problems producing writing because they struggle to integrate ideas at the planning stage and may not consider a range of possibilities because of their attentional difficulties. Also, children with ADHD may experience difficulties with spelling because they may attempt to simultaneously reflect on their spelling and consider their ideas. Bruce, Thernlund, and Nettlbladt (2006) found that, according to parental reports, most ADHD children in their sample of 5- to 15-year-olds experienced writing difficulties. Compared to the control group, children with ADHD were more likely to have trouble with writing and spelling. Further, individuals with ADHD have trouble with writing production because of difficulties associated with handwriting (Shen, Lee, & Chen, 2012) which may contribute to the shorter text.

There is some evidence to support the idea that, independent of other learning deficits, children with ADHD tend to score lower on writing quality assessments and produce poorer quality text (Frazier, Youngstrom, Glutting, & Watkins, 2007; Re et al., 2007). The previous research that has explored the link between ADHD and writing quality is limited and argues that future research should explore the writing process of children with ADHD (Re & Cornoldi, 2010). For example, the written expression process was not usually considered in the previous research nor does it focus on comprehensive writing tasks, working memory, or attention measures (see Langmaid, Papadopoulos, Johnson, Phillips, & Rinehart, 2014). However, previous research has acknowledged that children with ADHD tend to experience problems with their written expression and to perform below their potential when their IQ scores are taken in to consideration (Mayers & Calhoun, 2006; Yoshimasu et al., 2011). In short, writing and its assessment as a process in children with ADHD has received limited empirical attention. Therefore, there is a need for research that examines the writing processes and the potential mediators in the relationship between ADHD and writing performance (Adi-Japha et al., 2007; Bruce et al., 2006; Rodríguez et al., 2009, 2015).

Working memory and writing process

Exploring the relationship between working memory and the writing processes is an emerging line of research. In general, the diverse models of writing (Hayes & Flower 1980; Kellog, 1996) and empirical research (e.g., Adams, Simmons, & Willis, 2015; Berninger, 2011; Kellogg, Olive, & Piolat, 2007) agree that writing is a cognitive task that requires the coordinated deployment of a relevant set of cognitive abilities that are used during the process of writing, including working memory. Kellogg (1996) argued that the three components of multicomponent working memory model of Baddeley (2000) (central executive, visuo-spatial, and phonological loop) are used to a greater or lesser extent, during the various processes of writing. In an attempt to explain the relationship between the activity of working memory and text production, Vanderberg and Swanson (2007) studied the different processes involved in written composition, finding that as the central executive component of working memory significantly predicted planning, editing and revising, as well as most of the microstructure measures of writing. Individual differences in young children's writing abilities can be attributed to differences in working memory capacity (Swanson & Berninger, 1996). Further, individuals with greater working memory capacity use different strategies to explore the visual source, make longer writing pauses, corrections are performed more efficiently, produce more detailed procedures, and achieve the communicative goal more efficiently by introducing more reader supports (Alamargot, Caporossi, Chesnet, & Ros, 2011, Piolat, Roussey, Olive, & Amada, 2004).

Related to working memory, children with ADHD have been found to score lower on backward digit spans and have different executive function control (Bruce et al., 2006; Holmes et al., 2010) compared to control groups. Together these results indicate difficulty in response inhibition and visual short-term memory respectively.

However, no differences were reported for performance on a visual working memory load task or second order visual tasks. Further, Bruce et al. (2006) attributed the link between ADHD and writing ability to working memory. More recently, Holmes et al. (2010) found that executive function tasks discriminated between children with and without ADHD, with measures of response inhibition and working memory the components that contributed the most to the discriminant function. Therefore, the present research will examine working memory as a potential mediator in the relationship between ADHD and writing ability.

Aims and hypothesis

The present work aimed to determine if there were differences between children with and without ADHD in a broad range of product and process writing measures. Therefore, based on previous research, the first objective of the study was to undertake a detailed examination of the differences in the writing performance between the control and ADHD group. Although there is a paucity of previous research, it is likely that the ADHD group's writing performance will be poorer than the control group's writing performance in terms of quality text and productivity. The potential differences in writing performance according to ADHD type will also be explored.

Second, it is assumed that students with ADHD will perform worse than the students in the control group in attention and working memory tasks. Therefore, the current study explored the relationship between working memory performance and writing performance.

Third, it is broadly recognized in the existing literature that execution is not the only aspect of the writing process. Planning and assessing during the writing process are core sub-processes that improve performance. Therefore, we expect that students with ADHD will perform lower than control group in these two phases.

In summary, the present work examined the potential mediators in the relationship between ADHD and writing performance. Specifically, attention, and working memory were tested as potential mediators across a range of outcome measures.

METHOD

Participants

Our sample comprised students drawn from Grades 3 to 6 (final four years in primary school) and Grade 7 (first year of secondary school). The ADHD sample was recruited across 38 schools and comprised 84 students. 36 of these were classified as the Inattentive presentation (8 female), 7 were classified as Hyperactive / Impulsive (3 female) and 41 were classified as the Combined presentation (5 female). These were compared with a control sample of students without ADHD, matched by age and sex (N = 135, 27 female) drawn from 4 of the same schools.

[Insert Table 1 near here]

Sample characteristics are detailed in Table 1. The mean age for the sample as a whole was 11 years 3 months (SD = 19.8) with the ADHD and non-ADHD groups differing in mean age by less than 1 month. The IQ scores were normally distributed and similarly dispersed in both groups, with slightly lower IQ in the ADHD group (100.6; SD = 15.1) compared to the control group (102.5; SD = 16.2) measured by Cattell g test (Cattell & Catell, 2001), although this difference was not statistically significant (p =.424).

The ADHD sample was identified by mental-health professionals (typically one or more psychiatrist-neurologist) on the basis of these criteria: (a) clinical diagnosis of Attention Deficit Disorder with Hyperactivity according to the Diagnostic and Statistical Manual of Mental Disorders-5 (APA, 2013); (b) symptom duration of more than 1 year; (c) the problem began before the age of 7 years; and, (d) the children had no associated disorders. Subjects who presented with a cognitive deficit, Asperger's syndrome, Guilles de LaTourette syndrome or extensive anxious depressive disorders were excluded from the study, (e) to confirm the diagnosis and rule out other associated disorders, all students underwent a semi-structured interview for parents Diagnostic Interview Schedule for Children DISC- IV (Shaffer et al., 2000), and (f) were administered a Spanish version of the Cattell g test of general intelligence (Cattell & Cattell, 1989) to evaluate the presence of specific (or other) cognitive deficits. As part of their diagnosis, students were identified as showing one of three ADHD presentations – inattention, hyperactivity / impulsiveness, or a combination of these. Diagnosis was confirmed as part of the present research using a Spanish version of Conners parents rating scale (Farre-Riba & Narbona, 1997). Nearly all of these students (94%) had been prescribed medication to control their ADHD symptoms. The socioeconomic level of the participants' families was between medium and low and the families' educational was mainly low (elementary studies).

The control sample was selected from a larger sample of 200 students. Students were included in the control group if they had no reported history of serious behavioral or emotional problems in school or at home. Participants with an IQ below 85 and over 130 in these scales were excluded. All of them underwent the same diagnostic assessment than ADHD sample to rule out other psychological disorders. To control for effects of sex (preliminary analysis of this non-ADHD sample, and previous research, suggests better writing performance in girls) we then randomly resampled the females to create a sub-sample of 135 students that which matched the male-female ratio of the ADHD group.

The schools attended by participants were in urban and semi-urban zones from the region in the north-west of Spain. All of the children with ADHD studied the same academic curriculum as their peers without ADHD.

For a sub-sample of students, we also obtained ratings of ADHD-related behavior from parents and teachers by via the Five to Fifteen questionnaire (Kadesjö et al., 2004). This sample comprised 45 students with ADHD (11 female) and 140 (73 female) non-ADHD with a mean age of 11 years 2 months and mean IQ of 104 (SD = 16.0).

Measures

Writing performance

Participants completed three short writing tasks. For Essay 1 students were free to choose their own topic. Essay 2 and Essay 3 both required texts with a compare-and-contrast structure. Students were asked to write about the similarities and differences between traditional games and video games (Essay 2) and similarities and differences between football and basketball (Essay 3). These topics were proposed as interesting by an earlier sample of similarly aged students and were chosen so as to draw on content knowledge that would be available to students across the ages represented in our sample. Tasks were not time-limited.

Reader-based evaluation Texts were evaluated holistically by trained readers for structure, coherence, and overall quality using methods described and evaluated by Spencer and Fitzgerald (1993) and used in a number of previous studies (e.g., Fidalgo, García, Torrance, & Robledo, 2009; Torrance, Fidalgo, & García, 2007). The three texts were evaluated against year-group expectations (i.e. required standard to get a particular score increased across grades). Scores were also centered with reference to grade-mean. Texts were rated by a trained rater with extensive experience of using such measures and who was blind to group membership (ADHD/nonADHD) of the writer. A subsample of 344 the texts was rated by a second, similarly-trained rater, blind to group and to first ratings. We found inter-rater correlations of .97, .94, and .93 for judgments of structure, coherence, and quality respectively.

In this and previous research (Torrance et al., 2007) we found strong positive correlations among these reader-based measures, suggesting poor discriminant validity. To explore this we tested two structural equation models. The first model assumed good discriminant validity, with structure scores from each of the three writing tasks loading onto a single "structure" latent variable, coherence scores loading onto a "coherence" latent variable and overall quality scores loading onto an "overall-quality" latent variable. In a second model we assumed that all three measures for Essay 1 (structure, coherence, and quality) loaded onto a single "Essay 1 quality" latent variable, all three measures for Essay 2 loaded onto "Essay 2 quality", and similarly for Essay 3. This second model showed reasonable fit to the data, χ^2 (24) = 79.4, RMSEA = .102, CFI = .98, with loadings of above .9 for coherence and quality and slightly lower for structure (> .75 in all three cases) for all three essays. Correlations between the three latent quality variables were also high (all > .75). The first model, by contrast, showed substantially poorer fit, χ^2(24) = 446, RMSEA = .236, CFI = .84. Therefore, on the basis of this analysis we combined reader-based scores to give a single measure representing the quality of students' writing averaged across all three texts (unless otherwise noted).

Writing processes measures For one of the writing tasks (Essay 3) the students were asked to complete a writing process log (Torrance, Thomas, & Robinson, 1999; Torrance et al., 2007; Fidalgo et al., 2009). During writing students heard a one second tone played at random intervals of between 30 and 90 seconds. On hearing the tone students were trained to complete a section in a "writing log" identifying their current writing process from one of seven different activities: Reading reference materials, thinking about content, outlining, writing text, reading text, changing text, and not task-related. Students were initially taught, with examples, how to relate these categories to their own writing. After the initial training students completed writing logs while watching a video in which a writer thought aloud while planning and composing text. Comparison of their categorizations with those of an expert judge were showed agreement (Cohen's kappa) averaging .90 and varying from .75 for reading text to .94 for thinking about content for the ADHD group. The non-ADHD group showed slightly higher agreement.

Working memory and attention

Attention. Ability to focus and sustain attention was assessed with Brickenkamp's (2002) D2 measure. This involved presenting students with letters (p's and d's), some with varying patterns of small dashes above or below them. Students were required to mark just those characters that matched a particular pattern (e.g., d's with two strokes) as quickly and as accurately as possible within a limited period of time. Scores take into account both speed and accuracy.

Forward digit span. Students were presented with lists of digits, spoken at an even pace by a researcher, and were asked to recall them in the order in which they presented. Lists were presented in two blocks of seven lists, with lists in each block increasing in length from 1 to 7 digits. Responses were scored on basis of the number of items in the longest list to be successfully recalled in both the first and second block. Forward span is typically seen as a measure of short-term memory (e.g., Swanson & Berninger, 1996; Alloway, Gathercole, & Pickering, 2006).

Backward digit span. This followed the same procedure as the test for forward digit span, with the exception that students were required to recall digits in reverse order. Therefore, the task introduced additional processing component typically assumed to be associated with central executive functions (Alloway, Gathercole, Kirkwood, & Elliot, 2009).

Reading span. Reading span is a working memory measure that evaluates the ability to retain information in memory while engaging in the processing necessary to comprehend text. Students performed a Spanish version of the Daneman and Carpenter (1980) reading span task (Elosua, Gutierrez, Madruga, Luque, & Garate, 1996). This involved reading sets of sentences and rating each as true or false (to ensure comprehension). After a set had been read students then recalled the final word of each sentence. This was marked as corrected if the words were remembered in the same order that were presented with participants receiving the highest score when they obtained least 2 right series correct of 3.

Listening span. The listening span task was taken from a Spanish version of the Pickering and Gathercole working memory test battery (Pickering, Baques, & Gathercole, 1999). It followed a similar procedure to reading span. Students listened to set of sentences. After that had heard a set they were asked to recall the final words of each sentence, in the order in which they had been presented. This was scored using the same procedure as reading span. Listening span provided a measure of working memory that assessed the students' ability to retain information while comprehending language, but that was independent of their reading skills.

Procedure

Letters explaining the aims of the study were sent to the parents who had an ADHD diagnosis, who were asked to provide informed consent for their son/daughter to participate in the research. After that, sample of students not ADHD belongs to schools in the same area as the ADHD group. All participants in the study and their parents gave written informed consent after receiving a comprehensive description of the study protocol. Participants had volunteered to be involved in this study and they were not given any incentive to take part in it. To that end, once parental consent to evaluate the children was provided, the corresponding Conners parents rating scale (Farre-Riba & Narbona, 1997) were conducted to verify the diagnosis and to participate in this research.

Previously to writing assessment sessions, IQ, Working memory and attention tasks were then administered by one of the authors in two different sessions with order of span tasks counterbalanced across children. Children were tested individually in a quiet room.

After cognitive assessment, the children completed the writing measures in as whole classes, in two different sessions with each lasting 45-50 minutes. In the first session the children completed the first writing task (free topic essay) and second task (comparative-contrast essay). In the second session the children completed the second comparative-contrast essay with time-sampled self-report. The same task was presented in two different sessions was measure productivity without the distortion provoked by self-report.

The study was conducted in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki), which reflects the ethical principles for research involving humans (Williams, 2008).

RESULTS

Writing competence (quality and productivity)

Students diagnosed with ADHD produced reliably poorer quality text than students in the non-ADHD group. This was true for all three reader-based ratings, averaged across the three tasks: Structure, ADHD M = 1.6, SD = .52; non-ADHD M = 2.1, SD = .65; $t(219) = 5.35$, $p < .001$, d = .83, Coherence, ADHD, M = 1.7, SD = .47; non-ADHD M = 2.1, SD = .67; $t(219) = 5.16$, $p < .001$, d = .67, and overall quality, ADHD, M = 1.9, SD = .53; non-ADHD M = 2.2, SD = .74; $t(219) = 3.92$, $p < .001$, d = .45. Therefore, there appears to be reason to believe that ADHD results contribute to underperformance on writing tasks.

The analyses that follow aimed to explore the size of this effect more thoroughly, controlling for factors likely to be associated with ADHD but are independent of the ADHD diagnosis, and explore the possible reasons for ADHD students' underperformance. Our approach was as follows. Using hierarchical multiple regression we first controlled for effects of age-within-grade and general ability (Model 1). We then performed two separate analyses: (1) We added a dummy variable representing ADHD diagnosis to the model (Model 2a). (2) We added working memory and attention variables (Model 2b), and then added ADHD diagnosis to the model (Model 3). The comparison of Model 1 and Model 2a gives an indication of the variance in performance explained by ADHD diagnosis whereas the comparison of additional variance accounted for by Model 2a and by Model 3 gives an indication of the extent to which effects of ADHD diagnosis are independent of the effects captured by working memory and sustained attention measures.

Because quality scores were rated relative to grade-peers, and subsequently also centered relative to grade-mean, we centered all predictor variables in a similar way. All measures therefore control for grade. Age-within-grade (students' chronological age centered by mean age for the student's grade) provides a measure of whether the child was older or younger than was typical for students in their classes. This is particularly relevant in the Spanish educational system in which progression through grades is partly dependent on performance, giving an age range of more than one year within each grade. For reasons discussed in the methods section, we used a single aggregate measure of reader-assessed writing quality.

Taken together, age-within-grade and IQ predicted 15.2% of variance in writing quality, Model 1: R^2 = .154, $F(2,218)$ = 19.4, p < .001. IQ was positively related to writing competence, β = .36, p < .001. There was no effect of age-within-grade. ADHD diagnosis explained an additional 6.7% of variance in writing performance, Model 2a: R^2 = .218; R^2 change = .067, $F(1,217)$ = 18.6, p < .001. Adding memory and attention variables to Model 1 explained an additional 19.1% of variance in writing competence, Model 2: adjusted R^2 = .320; R^2 change = .191, $F(5, 213)$ = 12.3, p < .001. This model suggested positive effects for sustained attention, D2; β = .12, p = .046, forward digit span, β = .14, p = .036, backward digit span, β = .25, p = .001, and reading span, β = .16, p = .044, but no statistically reliable effect of listened span. Finally, a dummy variable identifying group membership (ADHD vs. not-ADHD) explained a further 3.6% of variance in writing competence, Model 3: R^2 = .354; R^2 change = .036, $F(1,212)$ = 12.1, p < .001. Comparison of Model 2a and Model 3 suggests that approximately half of the effect of ADHD on writing quality was explained by measures of working memory and sustained attention.

We repeated the same analysis with students' productivity as the outcome variable, measured as the number of words written when completing the writing tasks, centered by grade-mean, and averaged across the three writing task. We found positive effects for IQ and a weak negative effect for age-within-grade – older children within a grade tended to write shorter texts, Model 1: R^2 = .118, $F(2,218)$ = 14.6, p = .001; IQ, β = .28, p < .001, age-within-grade, β = -.14, p = .036. Memory and attention variables explained an additional 10.7% of variance in productivity, Model 2: adjusted R^2 = .215; R^2 change = .122, $F(5,213) = 6.82$, $p < .001$, with effects for just sustained attention, D2; $\beta = .19$, $p = .004$, and backward digit span, $\beta = .25$, $p = .013$. There was no evidence that ADHD diagnosis explained variance in text length, either with or without control for working memory and sustained attention measures, R^2 change test $p > .05$ for both Model 2a and Model 3. There was a fairly strong positive relationship between text quality and length, $r = .65$, $p < .001$.

The analyses presented so far do not make a distinction between different presentations of ADHD. It is possible that inattention or hyperactivity / impulsiveness, or a combination of these uniquely contribute to the poor writing performance of students with ADHD. We approached this first by looking for evidence of a difference in performance between students diagnosed with the inattentive ADHD presentation compared with the combined presentation (there were too few students in the sample diagnosed as just hyperactive / impulsive to make analysis in terms of this group possible). There was no statistically significant difference between the performance of the inattentive and hyperactive / impulsive groups either in terms of text quality, $F(1,73) = 1.53$, or text length, $F(1,73) = 1.32$ when IQ and age-within-grade were controlled. Second, rather than representing ADHD as a dichotomous variable, we explored the effects of parent and teacher ratings of students' tendency towards hyperactivity / impulsiveness and inattention. This has the additional advantage of evaluating whether the context in which these behaviors occurred made a difference to their relationship with writing performance. We therefore conducted hierarchical regressions with writing quality and text length as outcome variables. This analysis used data from a subsample of students (N = 185), as detailed above. We first controlled for IQ, age-within-year, and sex (Model 1) and then added teacher and parent hyperactivity / impulsiveness and inattentiveness ratings (four variables; Model 2). Variables in Model 1 explained 22.5% of the variance in writing quality, $R^2 = .225$, $F(3,181) = 17.5$, $p < .001$. Parent and teacher ratings made a small, but reliable contribution to variance in writing quality, Model 2: adjusted $R^2 = .272$, R^2 change = .075 $F(4,177) = 4.75$, $p = .001$. This effect appeared to be exclusively associated with teachers' ratings of inattentiveness, $\beta = -.31$, $p = .011$. We found no statistically significant effects for teacher ratings of hyperactivity / impulsiveness, parent ratings of hyperactivity / impulsiveness, or parent ratings of inattentiveness. We repeated this analysis with productivity (number of words written) as the outcome variable. Results followed an identical pattern to the previous analysis, with the exception that we also found a reliable, negative effect of age-within-grade, Model 1: $R^2 = .246$, $F(3,181) = 17.5$, $p < .001$; Model 2: adjusted $R^2 = .289$, R^2 change = .070, $F(4,177) = 4.53$, $p = .002$; Teacher inattentiveness rating, $\beta = -.30$, $p = .012$. We also conducted analyses including working memory and attention variables as predictors: Model 1, sex, age-within-grade, IQ; Model 2, D2, forward and backwards span, reading span, sentence span; Model 3, teacher and parent ratings of inattentiveness and hyperactivity / impulsiveness. With writing quality as the outcome variable, these analyses followed the same pattern as the previous analysis, but with slightly reduced effects of parent and teacher ratings, Model 3: adjusted $R^2 = .370$, R^2 change = .043, $F(4,172) = 3.17$, $p = .015$; Teacher inattentiveness rating, $\beta = -.25$, $p = .028$. We did not find evidence that parent and teacher ratings contributed variance to productivity, over-and-above that explained by working memory variables, Model 3: R^2 change = .008, $F < 1$.

Working memory

These findings suggest that both working memory measures and, independently, ADHD diagnosis, predict the quality of students' texts. It is therefore important to explore relationships between ADHD and measures of working memory in our sample. Relationships between ADHD and working memory indicate that ADHD not only has direct effects on writing performance, but also mediated effects via working memory. We used hierarchical binomial logistic regression to predict ADHD-group membership from scores on working memory measures. We first controlled for age-within-grade (Model 1). We then explored effects of working memory (Model 2). Analyses reported here are again based on grade-centred scores.

Age-within-grade did not reliably predict ADHD, Model 1: $\chi^2(2) = 1.61$, $p > .05$. Adding in working memory and attention variables provided a better, although still weak, prediction of group membership, Model 2: $\chi^2(5) = 16.1$, $p = .006$; Nagelkerke pseudo $R^2 = .148$). Coefficients for individual predictors in Model 2 suggested an association between being diagnosed with ADHD and having low backward digit span, Wald $\chi^2(1) = 4.19$, $p = .040$, but no statistically significant effects for any of the other variables, $p > .10$ in all cases.

We also performed linear multiple regression analyses with teacher and parent ratings as outcome variables, based on the subsample of students for which these data were available, Model 1, age-within-grade, sex; Model 2, adding working memory and attention variables. There was some evidence that teacher ratings of inattentiveness were predicted by working memory measures, independently of sex and age-within-grade, Model 1: $R^2 = .074$, $F(2,182) = 12.4$, $p < .001$; Model 2: adjusted $R^2 = .176$, R^2 change $= .102$, $F(5,177) = 5.95$, $p < .001$. There were, however, no clear effects of any specific working memory variable, Sustained attention, $\beta = -.15$, $p = .049$; other working memory variables, $p > .05$. Parent inattentiveness ratings showed a similar pattern. Model 1: $p > .05$; Model 2: adjusted $R^2 = .101$, R^2 change $= .111$, $F(5,177) = 4.53$, $p = .001$. There was a statistically significant unique contribution from backward digit span, $\beta = -.222$, $p = .010$, but not from the other four working memory variables. We found no evidence that either parent or teacher ratings of hyperactivity / impulsivity were predicted by working memory measures

Writing process

Writing process data were collected during just the third task. Data were heavily positively skewed for several activities, with writing logs from large numbers of students failing to indicate any instance of the activity. Table 2 reports both the percentage of students indicating a specific activity at any time during the writing task, and, for these students, estimated mean time in activity. Note that the time sampling method used to collect process data may generate some false negatives – by chance logs may sometimes fail to register an activity-type when it has in fact occurred – although this bias will be independent of other variables. For example, all students did, in fact, write some text, contrary to the estimates given in Table 2. We found differences between ADHD and non-ADHD groups in three areas: Students with an ADHD diagnosis were less likely to indicate that they spent time thinking about the content of their text, Mann Whitney $U = 7096$, $Z = 2.58$, $p = .010$, reading the text that they had written, U = 6911, Z = 3.38, p = .001, or changing the text that they had written, $U = 7225$, $Z = 2.65$, $p = .008$. There were no statistically-reliable differences in estimated time spent in the other four activities.

[Insert Table 2 near here]

We estimated total time-on-task from writing logs by summing across all on-task activities. The resulting values were roughly normally distributed. Estimated total writing time Time-on-task was less for students with ADHD, ADHD $M = 9.9$, $SD = 3.9$; not-ADHD $M = 11.0$, $SD = 5.0$, but this difference was not statistically significant, $F(1,216) = 2.90$, $p > .05$, when grade, age-in-grade, and IQ were controlled for.

DISCUSSION AND CONCLUSIONS

Consistent with the findings of previous research (Re et al., 2007), we found that the influence of ADHD on writing performance was in part independent of working memory and sustained attention effects. It also appeared to be independent of text length. Although there was a relatively strong correlation between text quality and length, there was no evidence that length was predicted by group. Participants with ADHD therefore wrote texts that were not significantly shorter, but were rated as less well structured, less coherent, and less idea-rich than those written by their non-ADHD peers.

Gregg et al. (2002) found evidence that it was particularly the impulsivity aspect of ADHD that resulted in poorer writing performance. This was not replicated in our findings. There were no overall differences in performance across ADHD presentations. There was, however, some evidence that in the subsample of students for which teacher and parent ratings were available, teacher ratings of students' inattentiveness alone predicted text quality. These results are consistent with other studies concluded that handwriting impaired in ADHD children depends on the symptoms severity (Langmaid et al., 2014). This effect remained after control for scores on the working memory and sustained attention tasks. We found no effect of students' impulsiveness, as rated by either teachers or parents.

The poorer quality of the ADHD students' texts is likely to be explained, in part, by differences in their writing processes. ADHD students did not write for a significantly shorter period of time than controls. However, they appeared to use this time rather differently. ADHD students were slightly less likely to report thinking about the content of their text. Perhaps more importantly, they were much less likely to report either reading through or editing what they had written. DSM-5 (APA, 2013) lists failure to think of future consequences of behavior as diagnostic criteria. Failure to review and edit text could be interpreted as an example of this. While ADHD students performed similarly during the initial act of producing text, they were less likely to be concerned with how this text would then be perceived by others. Lack of association between teacher ratings on impulsivity and the students writing performance is, perhaps, inconsistent with this argument. Failure to revise and edit, occurring as it does towards the end of performing the writing task is however, also consistent with an inability to sustain attention.

More generally, explicit, self-regulatory writing behaviors, and particularly tendency to make use of deliberate planning and revising strategies, has been associated with good writing performance (Graham, Harris, & McKeown, 2013; Torrance et al., 2007). ADHD is associated with a lack of self-regulation (Rodriguez, González-Castro, García, Núñez, & Álvarez, 2014; Shiels & Hawk, 2010). Also, there is a general tendency for students not to revise and edit their texts, particularly in the context of low-commitment class tasks, and effective revision strategies appear to be relatively resistant to instruction (Piolat et al., 2004; Rodríguez et al., 2009, 2015). Inattention in writing classes may explain both failure to adopt effective writing processes, and other deficits in ADHD students' performance.

The effect of ADHD on writing performance was relatively weak, with under 6.7% of the variance in writing quality explained by whether or not the student had an ADHD diagnosis. Half of this effect could be attributed to the working memory and sustained attention, with a remainder independent of working memory effects (as captured by the particular measures used in this study). We did, however, find that, across both groups, working memory and attention measures explained a relatively high proportion of variance in writing performance, with significant positive relationships with all measures apart from listening span. Taken together, these findings suggest that individual differences in writing performance are predicted by individual differences in working memory and attention, but that membership of the ADHD groups was largely independent of working memory and attention measures.

It is important to note the effect that teachers' ratings of inattentiveness symptoms have on predicting writing quality; an effect that remains significant even controlling from working memory and sustained attention (established both by means of performance measures). This result suggests the relevance of observation measures as complementary of those based on performance, as well as the important role that teachers´ observation may play on the detection of ADHD symptoms at school.

The relationship found between attentiveness, but not hyperactivity/impulsivity- symptoms, and writing performance is also worth noting. This is consistent with some previous research that suggests that that the inattentive dimension of ADHD is more strongly related to school performance, not only in writing but also in reading and mathematics. Greven Kovas, Willcutt, Petrill and Plomin (2014) argue that even when a significant association between hyperactivity-impulsivity and academic performance is found, this association may be related to shared genetic influences between the hyperactive-impulsive and inattentive dimensions.

Some limitations of the present study should be considered in future investigations. First, working memory and some other components that are crucial for mastering this competency (see, e.g., McCuthchen, 2011) were assessed in particular way in this study, related with writing task. Finally, we used a very heterogeneous sample with regard to age. This may be considered problematic, because students perform writing tasks differently at different developmental stages. However sample sizes would be small to analyze writing performance separately at different ages.

Finally and to highlight, there are also theories and some empirical findings that consider the relationship between writing and ADHD. This could lead to the creation of a specific model which accounts for both aspects, as a first step in future research

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Table 1 Participants' demographic characteristic across group

	not ADHD (n = 135)	ADHD (n = 84)
N female	27 (20.0%)	17 (20.0%)
Grade level		
Third	22 (16.3%)	9 (10.7%)
Fourth	27 (20.0%)	20 (23.8%)
Fifth	24 (17.8%)	16 (19.0%)
Sixth	24 (17.8%)	22 (26.2%)
Seventh	38 (28.1%)	17 (20.2%)
Ethnicity		
White Spanish	123 (91,1%)	77 (91.7%)
Roma	7 (5,2%)	5 (5.9%)
Other	5 (3,7%)	2 (2.4%)
Age (months)		
M	134.4	135.0
SD	20	18.7
Minimum	101	99

Table 2 Percentage of students reporting engaging in specific writing activities and, for those students, estimated time spend in the activity (standard deviation in parenthesis). Data taken from writing logs completed by students during the third writing task.

	not ADHD	ADHD
reading the assignment	18%, 1.6 (1.08)	10%, 2.2 (1.1)
thinking about content*	78%, 2.7 (1.7)	63%, 2.7 (1.3)
writing an outline	16%, 1.5 (1.1)	12%, 1.8 (.9)
writing text	96%, 6.5 (4.0)	97%, 6.4 (4.0)
reading own text**	46%, 1.7 (.8)	23%, 1.9 (.8)
changing text*	40%, 1.9 (1.1)	26%, 2.2 (1.3)
off task	34%, 2.0 (1.3)	30%, 2.1 (1.4)

Note: * $p \leq .05$, ** $p < .01$ from comparison of all students in each group (Mann Whitney)