Spelling errors among children with ADHD symptoms: The role of working memory

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Spelling errors among children with ADHD symptoms: The role of working memory

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1. Introduction

Attention Deficit/Hyperactivity Disorder (ADHD) is a psychiatric diagnosis that identifies children who exhibit inappropriate levels of inattention and/or hyperactivity (American Psychiatric Association, 2013). The disorder is typically associated with poor scholastic outcomes (e.g., Fischer, Barkley, Edelbrock, & Smallish, 1990). Children with ADHD may also have a comorbidity with learning disabilities (Mayes, Calhoun, & Crowell, 2000; Re, Pedron, & Lucangeli, 2010); however, children with ADHD without any comorbidity may also encounter difficulties while performing school tasks, especially when their regulative deficits (i.e., attentional control, planning, organization, monitoring, etc.) are in conflict with the task requirements, such as in writing. Indeed, writing represents one of the most complex learning abilities for all children, particularly those with ADHD, because it involves several cognitive functions that include planning, working memory, organization, monitoring, attention, long-term memory, etc. Research has indicated that the influence of neurocognitive

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functions determines the difference between good and poor writers (Hooper, 2002). One such function is working memory (WM) (Berninger & Swanson, 1994; Swanson & Berninger, 1996). WM is crucial during the writing process because it allows one to maintain linguistic strings and retrieve words, ideas, and grammatical rules from long-term memory; further, it permits the online monitoring that is fundamental during writing (Kellog, 1996; McCutchen, 1996; Swanson & Berninger, 1996). A greater efficiency in the writing processes results in a better management of working memory resources, as well as in better writing performance (Olive, 2004).

Given the well-known deficit in executive functions, particularly working memory, within children with ADHD (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005), it is reasonable to expect that such individuals could encounter several difficulties in a writing task. Despite its importance and its crucial role in school learning (Hooper et al., 1993), the writing skills of children with ADHD have not received much attention thus far. Existing evidence suggests that children with ADHD have greater difficulties in writing (in different aspects of writing, such as written expression, spelling, and graphia) compared to other scholastic abilities (Kroese, Hynd, Knight, Hiemenz, & Hall, 2000; Mayes & Calhoun, 2007; Mayes et al., 2000). In a recent study, Re and Cornoldi (2013) also found that children with ADHD made more spelling errors than typically developing children—not only under dictation, but also in a copy task, particularly when they had to write accents and geminates.

In a series of studies on the expressive writing skills of children with ADHD and without comorbid learning disorders, Re and coauthors (Re, 2006; Re & Cornoldi, 2010; Re, Pedron, & Cornoldi, 2007) found that these children made more mistakes when invited to produce new texts, but these errors tended to disappear when the children were trained to adopt specific controlled procedures during text production (Re, Caeran, & Cornoldi, 2008). This finding suggests that the spelling errors were not due to orthographic weaknesses, but, rather to the self-regulatory problems of children with ADHD. Recently, Noda and colleagues (2013) studied writing performance in two clinical groups: ADHD and developmental coordination disorder. The authors considered several aspects of writing, such as spelling accuracy, tracing and copying accuracy, and handwriting. The results showed that inattention predicted spelling accuracy and handwriting fluency, while fine motor ability predicted tracing and copying accuracy.

In sum, there is initial converging evidence showing that children with ADHD have writing difficulties and make many spelling errors during the writing process. This spelling difficulty could be attributed to a series of factors associated with spelling, including working memory, that may be defective in children with ADHD (Martinussen et al., 2005), especially because of its phonological component that is critically associated with spelling (Baddeley, 1986). However, the specific role of working memory in the spelling accuracy of children with ADHD symptoms during a typical writing task, such as a dictation, has not yet been studied.

To examine these issues, in the present study we compared the performance of a group of children with ADHD symptoms and a control group in two dictation texts, one under typical conditions and one under a pre-load condition that required the participants to remember a series of digits while writing. We hypothesized that the children with ADHD symptoms would be more prone to spelling errors and would have a lower performance in the working memory task than the children in the control group, as suggested by the previous literature; further, we expected that the concurrent working memory task would specifically affect the performance of children with ADHD symptoms. In particular, due to the phonological properties of the to-be-remembered material, we hypothesized that the spelling impairment in the dual task condition would mainly interest phonological errors and, to a lower extent, the other two error categories that are typically considered when assessing Italian spelling accuracy (Tressoldi, Cornoldi, & Re, 2012), such as non-phonological errors and errors within geminate accents.

2. Method

2.1. Participants

Nineteen children with symptoms of ADHD (mean age: 120 months, *SD* = 9, males = 16) and 19 typically developing children (mean age: 118 months, *SD* = 9, males = 16) participated in this study. All children were Italian and were recruited from local primary schools. The two groups were matched for age, gender, rated intellectual ability, and educational level.

Children were included in the ADHD group on the basis of teachers' interviews and the cut-offs available for the SDAI scale ('Scala per i Disturbi di Attenzione/Iperattività per Insegnanti,' ADHD scale for teachers; Marzocchi, Re, & Cornoldi, 2010); this scale includes 18 items, each depicting descriptions of one of the 18 symptoms of ADHD as indicated in the DSM-5 (APA, 2013). The scale includes two subscales, one for Inattention (9 items), and one for Hyperactivity/Impulsivity (9 items). Teachers are required to closely observe the child's behavior for about 2 weeks and report the frequency of the symptomatic behaviors that are described in each item. Scores range from 0 (problematic behavior never present) to 3 (very often present). We selected those children who scored above the cut off (14) in at least one of the two scales. The mean scores in the Inattention Subscale were respectively 14.84 (*SD* = 4.07) and 0.53 (*SD* = 1.43) for the ADHD and the control group, while the mean scores for the Hyperactivity Subscale were respectively 10.26 (*SD* = 7.53) and 0.37 (*SD* = .83).

Both children with ADHD symptoms and the children in the control group had an average cognitive level and did not present other serious psychological problems (i.e., oppositional and aggressive behaviors, anxiety, and depressive symptoms): These aspects were assessed through the specific items of the COM questionnaire (Marzocchi et al., 2010) that was completed by the teachers. Moreover, the teachers were interviewed in order to confirm the presence of ADHD symptoms, as well as to exclude children with other relevant difficulties. None of the children had a history of neurologic or psychiatric problems. Written consent from the children's parents was obtained before participating in the experiment.

2.2. Material and procedure

2.2.1. Dictation tasks

All children were tested in a quiet room at their school. They participated in two consecutively administered dictation tasks: a first text was taken from BVSCO (Batteria per la Valutazione della Scrittura e della Competenza Ortografica [Battery for the Assessment of Writing Skills of Children from 7 to 13 years of age], Tressoldi et al., 2012), and a second text was specifically designed for the purposes of the present study and had the same characteristics of the first text. The two texts were matched for their number of words (135), number of sentences (7), and orthographic difficulties. Within each text, the seven sentences varied in length, as well as in terms of linguistic and syntactic complexity, in order to represent the different typical sentences that a child can write. The presentation of one of the two texts was associated with a Phonological Working Memory task (PWM) which consisted of remembering 4-digit sequences that were read aloud by the experimenter before each sentence. The children were required to keep the digits in mind while writing the sentence dictated by the experimenter. Specifically, the experimenter first read the digits, then read one of the 7 sentences from the text (at the pace indicated in the test manual) and the child had to write down the sentence and the previously heard digits (see examples in Table 1). The order of the presentation of the two texts and the presence of the PWM task were counterbalanced between the participants according to the following scheme:

- Text A in standard condition; Text B in PWM condition.
- Text A in PWM condition; Text B in standard condition.
- Text B in standard condition; Text A in PWM condition.
- Text B in PWM condition; Text B in standard condition.

The two dictation tasks were administered consecutively in a unique session that lasted about 30 min.

2.2.2. Scoring

The procedure recommended in the test manual (Tressoldi et al., 2012) was used to score the children's productions. We computed the total number of spelling errors and then categorized three different kinds of errors according to the classification in the manual:

- *Phonological errors* (*PhE*): Reading the written word would produce a different phonological result from the real word (e.g., "il bane" rather than "il pane");
- *Non-phonological errors* (*NphE*): Reading the written word would produce the same sound as the real word (e.g., "ilpane" instead of "il pane"). Examples of possible non-phonological errors include splitting a word in two, combining two words into one, and errors in the use of "h" (in Italian, "anno" [year] and "hanno" [they have] are pronounced in the same way) or "q" (in Italian the initial sound for "quota" and "cuore" is identical).
- *Refinement errors due to accents or geminates*: The right sequence of letters is written, but there are errors that relate to double letters or accents on the last vowel (e.g., "girafa" for "giraffa," or "citta" for "città").

Given that a few dictated words were sometimes missing and, therefore, the amount of written material could differ from one participant to another, we computed the overall percentage of errors for each child, and the percentages of the three types of error in relation to the total number of words written by each child.

For the scoring of the phonological working memory task, we considered the total number of digits correctly recalled (and in the correct order) by the children.

2.2.3. Data analysis

First of all, we conducted a mixed ANOVA on the total percentage of errors in order to examine the differences between groups and between conditions (i.e., with or without PWM). We then analyzed the specific types of errors with a mixed ANOVA. Finally, we compared the two groups on the PWM task with *t*-tests.

Table 1
Example of procedure for the dictation with concurrent PWM.

Experimenter	7. 2. 9.5 (PWM)
Experimenter	In the endless American plains, before the arrival of the White men, Indian tribes lived for longtime in their lands, in harmony with nature (*Nelle sterminate pianure americane, prima dell'arrivo dell'uomo bianco, le tribù indiane vivevano da secoli nelle loro terre, in armonioso equilibrio con la natura*). (dictation)
Children	7. 2. 9. 5. (written)
Experimenter	6. 1. 3. 8. (PWM)
Experimenter	Dictation...

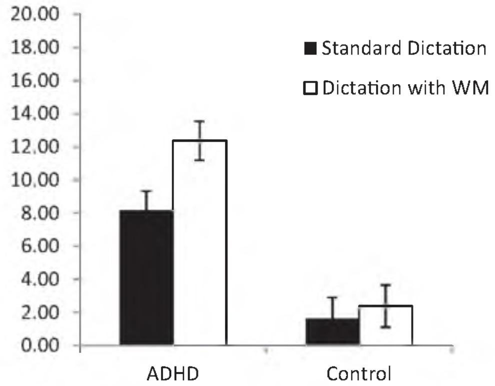

Fig. 1. Percentage of total errors in the two groups of participants (bars represent standard errors).

Table 2
Mean percentages of errors in the standard dictation and in the dictation with PWM in both groups of participants (standard deviations are reported in parentheses).

	Standard dictation			Dictation with PWM		
	Phonological	Non-phonological	Other	Phonological	Non-phonological	Other
ADHD	7.74 (7.28)	1.63 (1.73)	3.63 (3.30)	14 (8.78)	2.42 (2.85)	3.84 (3.35)
Control	1.53 (1.43)	.37 (.83)	.79 (1.51)	1.89 (1.91)	.68 (.94)	1.32 (1.83)

3. Results

All of the children paid attention to both tasks and were included in the data analyses. In order to investigate whether or not differences between the two groups would emerge in the number of errors and if these findings depended on the type of dictation, we first examined the case of the total number of errors, as this measure was the most robust. Therefore, we conducted a mixed ANOVA 2 (Group: ADHD vs. control) × 2 (Type of dictation: standard vs. with PWM), with Group as the between-participant factor and Type of dictation as the within-participant factor on the percentages of total errors as the dependent measure. We found a main effect of Group, $F(1,36) = 25.14$, $p < .001$, $\eta_p^2 = .41$, such that the ADHD group produced more overall errors than the control group of children; further, we found a main effect of Type of dictation, $F(1,36) = 21.03$, $p < .001$, $\eta_p^2 = .37$, which was qualified by an interaction with Group, $F(1,36) = 10.17$, $p < .01$, $\eta_p^2 = .22$; post hoc tests showed that, only in the group of children with ADHD, a significantly higher percentage of errors was produced in the dictation with the WM load ($M = 12.36$, $SD = 7.48$) compared to the standard dictation text ($M = 8.14$, $SD = 7.08$) (see Fig. 1).

Further, we examined whether differences would also emerge in terms of the specific types of errors. To this end, we conducted a mixed ANOVA 2 (Group) × 2 (Type of dictation) × 3 (Type of error) on the percentages of errors. As predicted, the three-way interaction was significant, $F(2,72) = 12.50$, $p < .001$, $\eta_p^2 = .26$. Post hoc comparisons showed that the preload condition produced a significant increase in comparison to the standard condition in the percentage of errors of children with ADHD, only in the case of phonological errors (see Table 2), a pattern of results that was not observed in the control-group children. This ANOVA also revealed the effects found in the previous analysis and for this reason they will be not discussed here.

Further, we examined whether groups indeed differed in the working memory performance. Thus, we performed a *t*-test on the total number of correctly recalled digits. A digit was considered correctly recalled if it was recalled and appeared in the correct order. We found a difference between groups, $t(36) = 6.81$, $p < .001$, with the typically developing children having a higher WM performance ($M = 26.42$, $SD = 1.61$) than children with ADHD symptoms ($M = 18.05$, $SD = 5.1$). More generally, a higher WM performance was related to better spelling performance. Indeed, in the total sample of children, the WM score was negatively highly correlated with the total percentage of errors in both the standard dictation task ($r = -.65$, $p < .001$) and in the dictation with PWM ($r = -.77$, $p < .001$).

4. Discussion

One of the main difficulties that children with ADHD encounter in their lives is related to academic failure. However, literature has not brought sufficient attention to the nature of these academic difficulties, especially in the case in which ADHD is not comorbid with a learning disability. The present study examines the case of spelling and offers further evidence on the difficulties of children with ADHD symptoms in this field (Re & Cornoldi, 2013). The results show that these difficulties hold true, even when children do not present a comorbid diagnosis of learning disabilities.

The present study offers information on mechanisms that relate to writing and that highlight the role of phonological working memory in the writing process.

Indeed, in the present study we compared children with ADHD symptoms and a group of typically developing children on two dictation texts: one under typical conditions and one under a pre-load condition that required them to remember a series of digits while writing the sentence dictated by the experimenter. The results showed an increase in spelling errors, especially in the PWM load condition, and this increase was particularly evident in the group of children with ADHD symptoms. This result is consistent with the notion that the phonological loop is responsible for the maintenance and processing of both series of digits and words (Baddeley, 1986) and an impaired phonological loop affects spelling performance (Re, Tressoldi, Cornoldi, & Lucangeli, 2011). We know from the principal writing models that WM is crucial during the writing process for two main reasons: first, because it allows one to maintain all of the conceptual information to produce a sentence (such as linguistic strings, ideas, and grammatical rules from long-term memory); second, because it permits the online monitoring that is fundamental during writing (Cornoldi, Del Prete, Gallani, Sella, & Re, 2010; Kellog, 1996; McCutchen, 1996; Swanson & Berninger, 1996). A good efficiency of WM permits a good management of all of the requested information during the writing process. In the specific case of this research, an efficient WM permits the maintenance of the digits and the retrieval of the correct spelling of the dictated words.

In particular, the dual task especially increased phonological errors, which further supports the specific effect due to the phonological WM load. In fact, the phonological representation in memory of a word is crucial (and potentially sufficient) for avoiding phonological errors. The phonological loop is not sufficient for avoiding the other types of errors where the access to the long-term memory orthographic lexicon is necessary (Kellog, 1996). Furthermore, children with ADHD symptoms who performed poorly on the writing tasks had also a poor performance in the working memory task. Thus, it was not the case that they devoted much higher attention to the working memory task to the detriment of the dictation task. In general, the overall poor performance of children with ADHD in the WM load condition may be due to their impaired WM (Barkley, 1997); the association of the two concomitant tasks in the current study—dictation and memory for digits—likely overwhelmed these children's abilities, while it was within the capacity limits of typically developing children. We note that evidence of a disrupted WM in children with ADHD mainly refers to visuo-spatial working memory (VSWM) tasks (Martinussen et al., 2005), and active WM tasks (Cornoldi, Giofrè, Calgaro, & Stupiggia, 2013) whereas phonological memory may be intact (Cornoldi et al., 2001). In the current study, children with ADHD symptoms had a worse performance, even in a phonological WM task. This is likely due to the fact that the dual task proposed here required high cognitive and attentional resources, even if the digit span was a passive (and simple) working memory task that children with ADHD symptoms usually perform well (Martinussen et al., 2005). This result is consistent with the assumption that, when there is a dual request, a passive simple span also becomes an active task, thus creating a particular difficulty for children with ADHD (Cornoldi & Vecchi, 2003).

We cannot exclude the assertion that the present findings were influenced by the minor orthographic weakness of children with ADHD: If retrieval of a correct orthographic representation is less automatic in these children, it is therefore likely that a secondary task which limits the cognitive resources would damage the final performance (McCutchen, 1996). For this reason, future research is warranted in order to examine this specific aspect, including, for example, a secondary task which does not involve phonological working memory. It would also be important to replicate the study with clinical samples of children with ADHD and other severe disorders (we must note that in Italy there is a general caution for the diagnosis of ADHD and typically the diagnosis is made only in the most severe cases that usually present several comorbidities). Further, a wider body of larger written materials should be considered in future research. Indeed, it is possible that the fact that part of our results did not replicate previous findings (i.e., the higher frequency of accents and geminates; Re & Cornoldi, 2013) could be due to the specific material proposed in this study that included a small number of words that could elicit this type of error.

With these limitations in mind, the present study nonetheless shed light on the important role of working memory in sustaining the writing process, which represents one of the most important learning abilities. The results of the present study support the importance of the role of working memory during the writing process. The outcome of this research adds an important piece to the puzzle of the specific role of working memory in the spelling accuracy of children with ADHD symptoms during a typical writing task such as a dictation. Indeed, our children with ADHD symptoms made more errors in the condition with PWM load and significantly more phonological errors. This result offers further confirmation of the hypothesis that the spelling difficulties of children with ADHD are related to the more general problem in executive functions of these children, in particular on WM, than to general spelling weakness; this research shows how WM difficulties can worsen a performance in a scholastic task such as a dictation. In a precedent-setting study on the expressive writing of children with ADHD symptoms, the authors found that a simple facilitation such as a guide-scheme (that support the planning phase of the expressive writing process) could improve significantly the performance of these children, even significantly reducing spelling errors (Re et al., 2008). The results of the present study once again confirm those results, underlining the fact that errors may be worse if children are put into non-optimal conditions, particularly if their executive dysfunctions are not taken into account.

Consequently, from an educational perspective, from this study we can deduce important considerations. We notice that children are typically required to write under conditions that affect their phonological WM capacity, as it happens when they are disturbed by concurrent auditory noise, or when they must write while remembering other verbal information, instructions, etc. These conditions may foster the likelihood of incurring spelling errors, even in the absence of a dysorthography. By reducing this concurrent load, it should be possible to attenuate the difficulties of children with ADHD symptoms and develop the autoimmunization of orthographic competencies.

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