Children with ADHD symptoms are less susceptible to gap-filling errors than typically developing children

Published version:

DOI:10.1016/j.lindif.2012.05.008

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1. Introduction

In recent years, the examination of developmental trends in spontaneous memory distortions (i.e., distortions that are not induced by provision of misleading information or social pressure) has motivated a large number of studies (for reviews: Brainerd, Reyna, & Zember, 2011; Brainerd, Reyna, & Ceci, 2008; Gallo, 2006). It has been shown that false memories increase with age when paradigms which involve the semantic processing of information are employed (e.g., Deese-Roediger-McDermott paradigm: Roediger & McDermott, 1995), revealing an important role of conceptual knowledge on the susceptibility to these memory errors. The result suggests that children with learning difficulties and poor semantic processing abilities could produce fewer false memories than typically developing children, with important implications for judging their eyewitness reliability in legal cases in which children with disabilities are required to testify; indeed, these cases are increasing in frequency. However, special populations of children with disabilities have only been studied in a handful of studies. For example, Brainerd and colleagues (Brainerd, Forrest, Karibian, & Reyna, 2006) found that children with learning disabilities compared to a control group were less prone to evince false memories induced with the Deese–Roediger–McDermott (DRM) task, which requires to memorize lists of semantically related words and results in high levels of false recognition for distracters that represent the theme of each of the studied lists. This result is likely due to their less efficient semantic processing abilities. Furthermore, Weekes, Hamilton, Oakhill, and Holliday (2008) showed that this false-memory effect was reduced in children with a specific reading comprehension disability.

While these studies provide convincing evidence that semantic processing may result in fewer false memories for children with learning disabilities, it is not clear whether other paradigms, involving different processes at the basis of illusory memories, may also differentiate typically developing children from children with certain disabilities. We thus decided to focus on two types of memory errors which have been found to influence recognition performance in a memory task which involves the presentation of materials organized in scripts, both in adults (Hannigan & Reinitz, 2001) and children (Lyons, Ghetti, & Cornoldi, 2010).

Early research on the organization of general event knowledge suggested that children as young as 3 years are able to temporally organize sequences of recurring events and report on them (Nelson & Gruendel, 1981). Children's event knowledge improves with age, and children's reports – in the form of scripts – about their familiar experiences become richer and with a greater amount of component actions as they grow older (e.g., Hudson & Shapiro, 1991). Although script knowledge facilitates recall and story comprehension (e.g., Brewer & Treyens, 1981), it also induces memory distortions when a person ought to make memory decisions about events that were not previously experienced but are consistent with a known script. In particular, if an individual is presented with images which are consistent with the script initially studied but that were nonetheless absent, s/he may incur in a *gap-filling error*, i.e., thinking that the image was part of the script when indeed it was not (Hannigan & Reinitz, 2001; Lyons et al., 2010). If the person is presented with an image that represents an effect of a possible, but not typical, action embedded in a script, then s/he may mistakenly recognize the inferred, but not presented, corresponding cause (*backward causal inference error*) (Hannigan & Reinitz, 2001; Lyons et al., 2010). In Hannigan and Reinitz' study (Experiment 2, 2001), gap-filling errors were reported by adults to be associated, at the subjective level, to a sense of familiarity with the encountered event, whereas the backward causal inference errors were associated to a vivid recollection. This is also supported by developmental evidence which suggests that the production of causal errors increases with increasing age, likely resulting from the influence of recollection, which is known to develop during childhood, whereas the production of gap-filling errors remains invariant, likely resulting from the process of familiarity, which is known to be stable from about age 7 (Ghetti & Angelini, 2008; Lyons et al., 2010).

The present study examines these phenomena in a special population of children, namely children with Attention Deficit/Hyperactivity Disorder (ADHD). This population is of particular interest, because an impaired semantic memory elaboration has been sometimes observed in this group (Cornoldi, Barbieri, Gaiani, & Zocchi, 1999; Shallice et al., 2002). Based on this research, we predict lower rates of gap-filling errors in children with ADHD compared to typically developing children.

Of interest, some studies indicate that episodic memory and autobiographical memory are particularly well-functioning in children with ADHD, given their levels of functioning in other cognitive domains (e.g., Skowronek, Leichtmann, & Pillemer, 2008). If this is the case, in this population, we should expect higher production of backward causal inference compared to gap-filling errors, given that the former errors are thought to largely depend on episodic recollection processes (Lyons et al., 2010). There is an additional reason why these errors should be more frequent in children with ADHD. The recollective nature of these errors makes their experience vivid and subjectively compelling (Lyons et al., 2010). Thus, they should be particularly difficult to inhibit. The main deficits of ADHD revolve around executive dysfunction (Pennington & Ozonoff, 1996; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), including impulsivity and lack of attentional control, which can be assumed to influence the performance in a false memory paradigm. Executive dysfunction has been associated with the generation of memory errors (Barkley, 1996), and previous research showed that children with ADHD exhibited higher memory errors due to intrusions of irrelevant information (Cornoldi et al., 1999; Marzocchi, Lucangeli, De Meo, Fini, & Cornoldi, 2002). Thus, children with ADHD may encounter great difficulty at inhibiting backward causal inference errors.

However, we should consider one alternative hypothesis. Given the evidence of inhibitory difficulties in ADHD (e.g., Marzocchi et al., 2002), one could predict that children with ADHD will generate more errors overall thereby obscuring other errors such as gap-filling errors and backward causal inferences. Furthermore, if children with ADHD encounter particular difficulty at controlling and monitoring their cognitive processes, then they should be expected to manifest higher confidence in their errors, compared to control children, likely resulting from their impulsivity.

Thus, the general goal of this study was to investigate episodic false memories in children with ADHD symptoms. Due to study constraints and the lack of agreement in Italy for the diagnosis of ADHD, we adopted the same selection procedure adopted in previous studies (e.g. Cornoldi et al., 2001) based on teachers' ratings. To examine memory we used a recognition memory paradigm for material organized in scripts (adapted from Lyons et al., 2010). We decided to employ this type of material because of its ecological validity and its interesting appearance for children, especially for those who have problems keeping their attention on a particular task. The current paradigm, previously used with adults (Hannigan & Reinitz, 2001) and then adapted for typically developing children (Lyons et al., 2010) was further adapted. As in its original version, it allows for the investigation of memory accuracy and memory errors that may occur when a person sees pictorial images that represent the typical actions that compose a script, for example eating at a restaurant, and then remembers elements not presented, although consistent with the presented material. In the present study we administered four scripts: eating at a restaurant, going grocery shopping, getting up in the morning and attending a lesson in school. Embedded in the scripts were images of the effects of peculiar scenes whose causes were not presented. In the recognition phase some target photographs were presented with distracter images which could be either consistent with the script or causes whose effects had been previously presented. Participants had to perform a *yes/no* recognition test and tell their degree of confidence relative to their responses.

2. Method

2.1. Participants

Twenty-six children (23 males and 3 females) referred by teachers for ADHD symptoms (from now described as ADHD group) and 28 control children (13 males and15 females) participated in this study. The two groups were matched for age and educational level. Mean age was 9.5 years ($SD = .83$) for the ADHD group and 9.8 years ($SD = .75$) for the control group (age ranges were respectively 8–11 years and 8.5–11.2 years). Children in the control group were recruited from local schools. Nineteen children with ADHD symptoms were recruited from the same schools based on teachers' reports. Teachers' reports on ADHD symptoms were further supported by other convergent information collected on children on their behavior in out-of-school and family contexts. Seven children were recruited at the Unit for ADHD of San Donà di Piave, Italy on the basis of a diagnosis made by a clinical psychologist expert in ADHD. Children of the ADHD group did not receive any medication for ADHD symptoms. Both children with ADHD and control children were within the average for what concerns the cognitive level and did not present other serious psychological or social problems: these aspects were assessed through the specific items of the COM questionnaire (Marzocchi, Re, & Cornoldi, 2010) filled by the teachers and the clinicians (the Scale has been shown to have values of reliability and interjudge agreement between .49 and 1) or through a standardised intelligence test. Thus, all children had good intellectual abilities and those with low intellectual abilities were excluded from the study. The 19 children with ADHD symptoms were recruited from the schools on the basis of the cut-offs for ADHD validated for the *SDAI* scale (Marzocchi & Cornoldi, 2001): children had a mean score per item either above 1.5 in the attention subscale or above 1.3 in the Hyperactivity Subscale (or in both) of the *SDAI* ('Scala per i Disturbi di Attenzione/Iperattività per Insegnanti', *ADHD scale for teachers*; Marzocchi et al., 2010) (the group resulted to include 2 children of the Inattention subtype, 8 children of the Hyperactivity subtype and 9 children of the Combined subtype). The SDAI includes 18 items, each giving precise descriptions of one of the 18 symptoms of ADHD as indicated in the DSM-IV TR (APA, 2000). The scale has been validated and standardized for the Italian population (Marzocchi & Cornoldi, 2001) and has shown good reliability ($r = .81$) and inter-rater agreement ($r = .78$; Marzocchi & Cornoldi, 2001). The scale includes two subscales, one for Inattention (9 items), and one for Hyperactivity/Impulsivity (9 items). Teachers are required to observe closely the child's behavior for about 2 weeks, and report the frequency of symptomatic behaviors described in each item. Scores range from 0 (problematic behavior never present), to 1 (sometimes present), 2 (often present), and 3 (very often present). With the exception of the 7 children diagnosed at the ADHD Unit, both ADHD and control children were rated by the same teachers. The mean scores in the Inattention SDAI subscale were respectively 13 ($SD = 9.9$) and .26 ($SD = .73$) for the ADHD and the control group, while the mean scores for Hyperactivity Subscale were respectively 17 ($SD = 7.4$) and .47 ($SD = .77$).

2.2. Materials

2.2.1. Pictorial stimuli

A series of color photographs depicting one of four scripts was used. The scripts were: eating at a restaurant, attending a lesson at school, going grocery shopping and getting up in the morning. For each script, 24 photographs were created: 20 photographs depicted the typical sequence of actions in the script (16 were used in the presentation, the remaining 4 photographs were used as distracters in the recognition phase), 4 photographs depicted two sets of cause–effect scenes, in particular 2 negative sequences (e.g., effect: wiping the table at the restaurant; cause presented only at test: knocking over a glass of coke) and 2 positive sequences (e.g., wearing new shoes before going to school; cause: mum giving new shoes in a wrapped box). Pilot testing with younger children confirmed that the material was understandable even at the age of 5 years. Further, the study stimuli also included 10 photographs that were inconsistent with any of the script. They represented other children doing different actions such as playing in the yard, playing at the beach etc.

2.2.2. Recognition phase

A unique randomized sequence of 72 photographs was used for all participants. The test included, for each script: (a) 6 old script-consistent photographs, (b) 4 new script-consistent photographs, (c) 2 cause photographs whose effects had been presented during the encoding phase, (d) 2 control cause photographs (e.g., photographs of effects whose causes had not been seen at the encoding phase), (e) 2 old script-inconsistent photographs and (f) 2 new script-inconsistent photographs.

2.2.3. Confidence rating board (CRB; Ghetti, Qin, & Goodman, 2002)

Two photographs depicting respectively a child with a confident expression and the same child with a doubtful expression were positioned on the opposite sides of the board. Three dots were drawn between these photographs which represent the three degrees of confidence (very sure, somewhat sure, not sure at all). Children were instructed to point to the dot near the picture of the child with a confident facial expression when they were very sure (that they saw or that they did not see the photograph), the middle dot, when they were somewhat sure, and the dot near the doubtful facial expression when they were not at all sure.

2.3. Procedure

2.3.1. Encoding phase

All participants were tested individually in quiet rooms in their schools (with the exception of the 7 children who were tested at the clinical service for ADHD). They were told that they would view a series of photographs in logical order representing other children performing everyday actions. They were also told to pay close attention to every picture and to try to understand what the situation represented depicted. For each of the 4 scripts, participants studied 18 photographs in a logical sequence. Embedded in these photographs, there were 2 effect photographs (e.g., oranges on the floor of a grocery store) whose corresponding causes (e.g., a child removing an orange from the bottom of a stack) were not viewed. Each photograph was shown on the computer screen for 2 s followed by a 3-second interval during which a black slide was presented. Scripts were presented sequentially without interruptions among them. Script order was counterbalanced. Five script-inconsistent photographs were presented at the beginning and at the end of the encoding phase to reduce primacy and recency effects. Overall, the encoding phase lasted approximately 7 min.

2.3.2. Recognition phase

After a 15-minute filler task (during which participants performed a series of search tasks) participants were administered a self-paced *old/new* recognition task. The test included a sequence of 72 photographs (see the Materials section) presented in a randomized sequence. For each photograph, participants had to tell "yes" if they recognized the picture as seen during the encoding phase, and "no" if they thought the picture had not been seen in the encoding phase. Further, for each recognition answer, participants gave confidence ratings using the CRB. The overall duration of the task (including encoding, interval, and recognition test) was approximately 30 min.

3. Results

Given that – due to the typical characteristics of ADHD population – the group of children with ADHD symptoms included a higher number of males than did the control group, a preliminary analysis within the control group examined whether gender could affect the pattern of results. Such a comparison did not show any gender effect ($p>.6$) and therefore the subsequent analyses were conducted collapsing across genders.

To assess memory accuracy and memory errors, we measured the following dependent variables consistent with previous research (Lyons et al., 2010): (1) rate of "yes" responses to target photographs consistent with the script (i.e., hit consistent), (2) rate of "yes" responses to target photographs inconsistent with the script (i.e., hit inconsistent); (3) rate of "yes" responses to script-consistent distracters *minus* rate of "yes" responses to script inconsistent distracters (i.e., gap-filling errors); and (4) rate of "yes" responses to distracters representing the unseen cause of a seen effect *minus* rate of "yes" responses to distracters representing the unseen cause of an unseen effect (i.e., backward causal inference errors).

We conducted a 2 (group: ADHD vs. control)×2 (item type: script consistent vs. inconsistent) mixed ANOVA with rates of "yes" responses to target images as the dependent measure. We found a main effect of item type, $F(1,52)=24.8$, $p<.001$, $\eta_p^2=.32$, such that in both groups of children, more target images inconsistent with the script were correctly recognized ($M=.93$, $SD=.20$) than were target images consistent with the script ($M=.77$, $SD=.16$). However, no significant main effect of group or interaction effect between group and item was found ($ps\geq.49$). In contrast, group differences emerged when we examined memory errors (see Table 1a). As evident in Table 1a, participants overall showed low levels of false alarms for script inconsistent and control cause distracters; and these levels were nearly identical in the two participant groups. We then conducted a 2 (group: ADHD vs. control) × 2 (error type: gap-filling vs. backward causal inference), and found that, in general, there was a difference in error type: $F(1,52)=16.27$, $p<.001$, $\eta_p^2=.24$, such that all participants produced a higher rate of gap-filling errors compared to backward causal inference errors. As the control group tended to produce more gap-filling errors than the ADHD group and the opposite was true for backward inference errors (see Table 1a), we computed a relative error score, computing the proportion of gap-filling errors with respect to the overall proportion of errors (backward + gap filling) and we found that the score was respectively .63 ($SD=.48$) for the ADHD group and .89 ($SD=.40$) for the controls, a difference which was significant, $t(48)=2.06$, $p<.05$. Thus, children with ADHD symptoms exhibited a decreased propensity for gap-filling errors.

3.1. Confidence ratings

We first compared the two groups on their confidence judgments relative to the hit rates (both consistent and inconsistent) by performing a 2 (group: ADHD vs. control)×2 (item type: script consistent vs. inconsistent) mixed ANOVA with confidence judgments associated with the hit consistent and inconsistent rates. We found a main effect of item type, $F(1,52)=9.6$, $p<.01$, $\eta_p^2=.16$, such that both groups of children reported higher confidence when they correctly endorsed script inconsistent photographs ($M=1.89$, $SD=.19$)

Table 1
a. Mean proportions (and standard deviations) of the raw scores of false-alarm rates: "yes" responses to script-consistent distracters (i.e., False alarms Consistent), "yes" responses to script-inconsistent distracters (i.e., False alarms Inconsistent), "yes" responses to causal distracters (i.e., False alarms Causal) and "yes" responses to control causal distracters (i.e., False alarms Control causal), and corrected indices of gap-filling errors and backward causal inference errors in the group of children with ADHD symptoms and in the control group of children. *b*. Means of the raw scores of confidence ratings relative to both gap-filling errors and backward causal inference errors (scores went from 0 = unsure to 2 = very sure).

	ADHD group		Control group	
	M	*SD*	*M*	*SD*
a				
False alarms Consistent	.20	.16	.26	.23
False alarms Inconsistent	.00	.00	.009	.04
Gap-filling errors	.20	.16	.25	.24
False alarms Causal	.18	.26	.12	.15
False alarms Control causal	.05	.09	.05	.10
Backward causal inference errors	.13	.21	.07	.13
b				
Confidence relative to gap-filling errors	1.57	.39	1.15	.66
Confidence relative to backward causal inference errors	1.94	.16	1.63	.50

than the script consistent ones ($M = 1.82$, $SD = .23$). Further, we found a main effect of group, $F(1,52) = 6.4$, $p < .05$, $\eta_p^2 = .11$, which was qualified by an interaction with item type, $F(1,52) = 6.5$, $p < .05$, $\eta_p^2 = .11$: post-hoc comparisons showed that the group of children with ADHD associated higher confidence with the hit consistent rate ($M = 1.92$, $SD = .12$) compared to the control group ($M = 1.73$, $SD = .26$). This difference was not found for the hit inconsistent items.

As for memory errors (shown in Table 1b), confidence ratings associated with backward causal inference errors and gap-filling errors were entered in a 2 (group: ADHD vs. control) × 2 (error type: script consistent distracter vs. causal distracter) mixed ANOVA. A significant main effect of type of error was found, $F(1,18) = 6.9$, $p < .05$, $\eta_p^2 = .28$: all participants gave higher confidence ratings associated with backward causal inference errors than gap-filling errors (Table 1b). We also found a main effect of group, $F(1,18) = 6.3$, $p < .05$, $\eta_p^2 = .26$, with ADHD children reporting higher confidence ($M = 1.76$, $SD = .10$) than the control group ($M = 1.39$, $SD = .10$) when committing memory errors, regardless of the type of error.

4. Discussion

The main goal of this study was to examine memory for script-based material in children with ADHD symptoms, focusing on their tendency to form false memories. To our knowledge, performance in false-memory paradigms has never been examined in children with ADHD; yet given the high frequency of ADHD in the population and the frequency with which children with developmental disabilities provide allegations in forensic contexts (Bruck & Ceci, 1999), it is important to establish the extent to which their behavior matches normative developmental trends.

The first main result of the present study is that ADHD children do not produce a higher overall number of false memories than the control group. This result stands in apparent contradiction with the assumption that executive dysfunctions may promote memory errors and the observation that ADHD children may exhibit increased intrusion errors in memory tasks compared to matched controls (Cornoldi et al., 1999; West, Houghton, Douglas, & Whiting, 2002). However, in these studies, errors concerned intrusions of irrelevant, semantically unrelated, material. In contrast, in the present study false memories concerned plausible, semantically associated, materials. In our study we found that children with ADHD symptoms and control children do differ in regard to their performance in the production of false memories based upon the peculiar type of error: children with ADHD produce fewer gap-filling errors than their peers, but more backward causal inference errors. Gap-filling errors have been shown to be supported by the familiarity that the item at test shares with the target scripted material and thus reflect ease of access to script knowledge (Lyons et al., 2010). Our results show that children with ADHD may somewhat be protected from this false-memory effect because of a slower or less adept access to script knowledge. A poorer organization of script knowledge in semantic memory may also underlie this reduced propensity to gap-filling errors.

In contrast, backward causal inference errors likely emerge from a recollective state: When the individual is tested on the unseen cause of a seen effect they likely recollect inferring the cause, and misattribute this inference to direct experience of the photograph. If children with ADHD exhibit particularly good episodic recollection, they should have greater difficulty at differentiating such inferential mental state from a true memory, because both would be vividly recollected. Our results are consistent with this view. Of interest, these results also indicate that while script knowledge seems to be less readily accessible in children with ADHD, this difficulty does not extend to causal inferences: thus, to the extent that studied material depicts relatively unique or distinctive events, children with ADHD draw causal inferences readily and later recollect them. It may also be that backward causal inference errors have more direct implications in applied forensic contexts, given that erroneously inferring the cause of an experienced effect could have severe consequences on the reconstruction of the event itself.

The second main result of the present study concerns the differences in metacognitive judgments between the children with ADHD and controls. Despite the differences in type of false memories produced in the two groups, children with ADHD exhibited higher levels of confidence than controls across types of false memories (and, in part, in true memories as well). One of the hypotheses we set out to test was that children with ADHD compared to control participants would exhibit increased memory errors and confidence in these errors due to the documented impulsivity and reduced inhibition and control capacity in ADHD (Cornoldi et al., 1999; Marzocchi et al., 2002). While we found no evidence of such a tendency in memory performance, confidence judgments appeared to be generally inflated compared to control participants. This tendency cannot be interpreted as reflecting generally faulty metacognitive mechanisms; the high levels of memory performance observed suggest that monitoring and controlling mechanisms operated well enough not to interfere with memory performance. In addition, in some cases, high levels of confidence may be well justified given the high levels of memory discrimination. Nevertheless, it is possible that this over-confidence may be a reflection of a response style. Furthermore, we found that both groups of children attributed higher confidence to backward causal inference errors compared to gap-filling errors, thus, even children with ADHD maintain a certain ability to introspect on their memory states and discriminate between them.

Before concluding we acknowledge some limitations of the present study which should be overcome in future research. Specifically, ADHD is notoriously heterogeneous (Barkley, 1990); thus, future research should further differentiate children with ADHD into the specified subgroups of ADHD of clinical relevance to evaluate whether these findings would differ as a function of types and severity of ADHD symptoms (prevalence of inattention vs. hyperactivity). Furthermore, research should better understand the level of elaboration of scripts at which differences between ADHD children and controls emerged.

Nevertheless, the present study offers important theoretical and practical information on the nature of memory function in children with ADHD, with an emphasis on circumstances that can generate false-memory formation. The present results provide initial evidence that the nature of false-memory formation may differ in children with ADHD compared to control participants. While children with

ADHD appear to produce false memories based on associative encoding errors linking effects to their causes resulting in false recollection, in control children false memories seem to emerge from prompt access to script knowledge and processing of semantic gist of the situation.

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