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False Memory in Adults With ADHD: A Comparison Between Subtypes and Normal Controls

Abdrabo Moghazy Soliman[1,2] and Rania Mohamed Elfar[3]

Abstract

Objectives: To examine the performance on the Deese-Roediger-McDermott task of adults divided into ADHD subtypes and compares their performance to that of healthy controls to examine whether adults with ADHD are more susceptible to the production of false memories under experimental conditions. **Method:** A total of 128 adults with ADHD (50% females), classified into three *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV-TR*) subtypes, were compared with 48 controls. **Results:** The results indicated that the ADHD participants recalled and recognized fewer studied words than the controls, the ADHD groups produced more false memories than the control group, no differences in either the false positives or the false negatives. The ADHD–combined (ADHD-CT) group recognized significantly more critical words than the control, ADHD–predominantly inattentive (ADHD-IA), and ADHD–predominantly hyperactive-impulsive (ADHD-HI) groups. The ADHD groups recalled and recognized more false positives, were more confident in their false responses, and displayed more knowledge corruption than the controls. The ADHD-CT group recalled and recognized more false positives than the other ADHD groups. **Conclusion:** The adults with ADHD have more false memories than the controls and that false memory formation varied with the ADHD subtypes. *(J. of Att. Dis. XXXX; XX(X) XX-XX)*

Keywords

ADHD, cognition, false memory, recall, knowledge corruption

False memories are not simply memory errors; they refer to memories of an event that did not occur or to memories that differ from the actual circumstances (Gleaves, Smith, Butler, & Spiegel, 2004). Thus, false memories can take several forms, including changes to the context of an event (e.g., believing that one heard certain information from a televised news broadcast rather than from a friend) and changes in the memory content itself (e.g., believing that a criminal was holding a knife rather than a gun; Okado & Stark, 2005).

Several studies on clinical populations, including patients with frontal lobe disease (De Villiers, Zent, Eastman, & Swingler, 1996), Alzheimer's-type dementia (Sommers & Huff, 2003; Waldie & Kwong See, 2003), schizophrenia (Mammarella et al., 2010; Moritz, Woodward, Cuttler, Whitman, & Watson, 2004), Asperger's syndrome (Bowler, Gardiner, Grice, & Saavalainen, 2000), and post-traumatic stress disorder (Brennen, Dybdahl, & Kapidžić, 2007; Hauschildt, Peters, Jelinek, & Moritz, 2012; Khosropour, Ebrahiminejad, Baniasadi, & Faryabi, 2010), and on different age groups, including children (Brainerd & Reyna, 2002; Otgaar & Smeets, 2010; Otgaar, Verschuere, Meijer, & van Oorsouw, 2012; Riggs & Robinson, 1995; Thijssen, Otgaar, Howe, & de Ruiter, 2013), adolescents (Caza, Doré, Gingras, & Rouleau, 2011; Goodman et al., 2011; Zack, Sharpley, Dent, & Stacy, 2009), adults (McCabe & Smith, 2002; Otgaar, Peters, & Howe, 2012), and the elderly (Hamajima, Nakanishi, Fujiwara, Nakaaki, & Tatsumi, 2005; Kunimi & Matsukawa, 2011; Meade, Geraci, & Roediger, 2012; Plancher, Guyard, Nicolas, & Piolino, 2009), have shown increased false memory formation relative to controls. Such patterns are predicted by Fuzzy-Trace Theory (e.g., Reyna & Brainerd, 2011), which suggests that these clinical populations have difficulty processing the semantic gist of their experiences. However, false memory formation in developmental disorders such as ADHD remains unstudied.

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Adults with ADHD have several cognitive functioning deficiencies, including inefficient attention (Pazvantoğlu et al., 2012), executive functioning deficits (Antshel et al., 2010; Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005), deficits in working memory storage/rehearsal processes (Matt Alderson, Hudec, Patros, & Kasper, 2013) and response inhibition (Schecklmann et al., 2013), emotional face processing deficits (Ibáñez et al., 2011), sustained attention (Marchetta, Hurks, De Sonneville, Krabbendam, & Jolles, 2008), and verbal memory, processing speed, cognitive interference, and decision-making deficits (Tamm et al., 2013).

Previous research has indicated that adults with ADHD perform poorly on long-term memory tasks (e.g., semantic clustering, free recall, and recognition) measured by standardized memory scales such as the California Verbal Learning Test (CLVT; Delis, Kramer, Kaplan, & Ober, 1987) and the Logic Memory subscale of the Wechsler Adult Intelligence Test (WAIS; Wechsler, 1981, 1987). Furthermore, adults with ADHD fail to semantically organize information when performing free memory tasks (Ross, Harris, Olincy, & Radant, 2000). Cahn and Marcotte (1995) speculated that the memory problems observed in individuals with ADHD might result in the disrupted organization and immature encoding that underlie executive dysfunctions. Thus, individuals with ADHD symptoms are more susceptible to false memories when retaining or retrieving stored information.

According to the Activation-Monitoring Theory, false recall and recognition are byproducts of spreading activation. For example, when participants are shown a series of semantically related words during study phase (encoding) or memory testing (retrieval), the critical (non-presented) words are activated and become more accessible as activation spreads through the semantic network (Peters et al., 2008). This spread is a rule-governed monitoring process in which memories are attributed to a specific source (Johnson, Hashtroudi, & Lindsay, 1993). Several experimental studies (e.g., Dodd & MacLeod, 2004; Peters et al., 2008; Seamon et al., 2003) have reported that dividing participants' attention during the encoding phase of a Deese-Roediger-McDermott (DRM; Roediger & McDermott, 1995) paradigm results in an increase in false recall and recognition during the retrieval phase. A typical ADHD disorder is characterized by poor sustained attention and impulse control and, eventually, self-regulation impairments (Douglas, 1988). Hence, ADHD participants are thought to be more susceptible to false memory recall and recognition.

Several studies (e.g., Brainerd & Reyna, 2002; Brainerd, Reyna, Wright, & Mojardin, 2003; Odegard & Lampinen, 2005) have established that verbatim memory is used to suppress false memories ("No, I didn't read the word 'doctor.' I read the word 'physician' instead."). This suppression process is called recollection rejection. Recollection rejection theory proposes that if a clinical population has a verbatim memory deficit, it will show increased false memory creation. The empirical findings about memory limitations in individuals with ADHD—their attention deficits and failures to encode details—indicate that ADHD patients experience verbatim memory deficiencies and therefore an increased tendency to create false memories.

According to the DRM paradigm, the production of false memories is attributable to both surface feature processing (verbatim traces) and the associated semantic content (gist traces). Through this parallel processing, the recall of studied words becomes a key memory cue when reproducing the gist of the words, resulting in false recall of the critical items (Brainerd & Reyna, 1996, 1998, 2002). Therefore, given the attentional problems of individuals with ADHD, it is highly likely that adults with ADHD may produce more false recall of the critical words than normal controls. This prediction is also supported by the DRM paradigm's proposition that false memories are caused by failures of attentional control or of the monitoring systems that differentiate the activation of critical words in associative networks from the actual presentation of words during encoding (Balota et al., 1999). These failures result in individuals' inability to distinguish between highly activated but non-presented critical words and studied words (Roediger, Watson, McDermott, & Gallo, 2001; Watson, Balota, & Sergent-Marshall, 2001).

According to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV-TR*; American Psychiatric Association [APA], 2000), ADHD disorder is classified into three subtypes: combined (ADHD-CT, inattentive and hyperactive-impulsive symptoms), predominantly inattentive (ADHD-IA), and predominantly hyperactive-impulsive (ADHD-HI; Barkley, 1997; Goodyear & Hynd, 1992; Schweitzer, Hanford, & Deborah, 2006). Several researchers (e.g., Barkley, 1997) have argued that both ADHD-HI and ADHD-CT patients show behavioral inhibition deficits that impair cognitive functioning, including working memory and executive functions. Other researchers have speculated that the ADHD-CT and ADHD-IA subtypes share common dimensions due to a primary deficit in inhibitory control and that ADHD-CT and ADHD-IA populations should show deficits on tests requiring attention, processing speed, working memory, and vigilance. Both suppositions suggest that all three ADHD subtypes may show different patterns of impairment on cognitive tasks that require attention and information processing.

Although ADHD is a neurobiological disorder that reportedly affects both genders, it has been found to affect males more than females, and most investigations only study males (Hinshaw, Owens, Sami, & Fargeon, 2006). Moreover, several studies (e.g., Biederman et al., 2002) have indicated that females diagnosed with ADHD are more

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likely to have ADHD-IA; other studies (e.g., Biederman et al., 2005; Robison et al., 2008) have documented that females diagnosed with ADHD are equally or more impaired than males. For example, Biederman et al. (1999) compared a large group of girls with and without ADHD recruited from pediatric and psychiatric facilities and found that girls with ADHD showed more comorbid psychopathology, social dysfunction, and cognitive impairments. Such findings indicate that false memory production may be related to gender. In addition, gender differences according to ADHD subtype have been found in comorbidity (Levy, Hay, Bennett, & McStephen, 2005), motor performance (Meyer & Sagvolden, 2006), and neuropsychological functioning (Nigg, Blaskey, Huang-Pollock, & Rappley, 2002).

Numerous experimental paradigms have been used to create false memories, including incorrect memories of past events (e.g., Loftus, 2003), fabricated memories of words that were not presented in word lists (Roediger & McDermott, 1995), and the implantation of false memories of events that never occurred (Rich False Memory Approach; Loftus & Bernstein, 2005; Loftus & Cahill, 2007). One of the most widely used experimental techniques for creating false memories is the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995). In a typical DRM paradigm, participants are presented with lists of semantically related words and are later asked to recall these lists. Each word list is linked to a critical lure (a word that is semantically associated with the list but is not presented in the list). For example, the word "king" could be a lure or critical word for the following word list: queen, princess, crown, prince, palace, and royal. After studying the lists, participants are asked to recall the words and are then given a recognition test. In a previous study by Roediger and McDermott (1995), participants recalled approximately 40% of the lures (absent words) and 14% of other absent words. In addition, in the recognition test, participants believed that they had studied the unseen words in the lists that they were shown. Furthermore, even after the participants learned about the false recognition phenomenon, the false alarm rate for unseen words was consistently higher than the false alarm rate for new dissimilar words (McDermott & Roediger, 1998).

It is important to investigate the cognition of individuals with ADHD because although they lead normal lives, with families and jobs, they experience a wide range of problems in nearly all aspects of life due to the disorder. This suggestion is based on the findings that adults with ADHD exhibit more psychological, neurocognitive, educational, and occupational functioning problems and psychiatric morbidity than healthy individuals (Biederman, 2005). The early diagnosis and assessment of ADHD in adults offer insight into diagnoses that do not consider other conditions that may be comorbid with memory problems. Moreover, it is important to examine the vulnerability of adults with ADHD to false memory that is crucial for autobiographical memory. This vulnerability affects patients' reports, and its assessment is therefore important for developing therapeutic techniques and management strategies for individuals with ADHD (Schilling, Wingenfeld, Spitzer, Nagel, & Moritz, 2013).

The Present Study

This study examines the performance on the DRM task of adults divided into ADHD subtypes based on self-reported symptoms and compares their performance with that of healthy controls to examine whether adults with ADHD are more susceptible to the production of false memories under experimental conditions than those without ADHD and to determine whether ADHD patients exhibit more knowledge corruption than their normal counterparts. Adults with ADHD are expected to produce more false memories and false recognitions than controls and to show more knowledge corruption than controls. The ADHD-CT subtype is expected to produce more false memories and recognitions and more knowledge corruption than the other ADHD subtypes.

Method

Participants

A sample of 132 adults with ADHD and a control group of 50 adults who were carefully matched to the ADHD sample with respect to age, estimated IQ, and handedness participated in this study. The ADHD participants were recruited from outpatient clinics at the Psychiatric Hospital associated with the Egyptian Ministry of Health in Tanta and the Abu-Alazaiem Psychiatric Hospital in Nasser City in Cairo, Egypt. The ADHD participants met the diagnostic criteria of the *DSM-IV-TR* (APA, 2000). The criteria were assessed by performing a detailed interview, as recommended and implemented by Matthies, Philipsen, and Svaldi (2012). The interviews were conducted by expert psychologists working in the psychiatric units. The ADHD screening included completion of the ADHD Rating Scale-IV–Home Version (DuPaul, 1991).

The exclusion criteria for ADHD participants were as follows: age below 20 or above 50 years; estimated IQ ≤ 90; psychotic disorders; any history of substance or alcohol abuse/dependence, as defined by the Structured Clinical Interview for *DSM-IV-TR* Axis I; psychotropic medications; clinically noteworthy medical conditions; mental retardation; clinically unbalanced psychiatric conditions (psychosis, criminality, suicidal behaviors); obsessive-compulsive disorder; current major depressive episode; bipolar disorder; and drug or alcohol abuse or dependence within 1 year prior to the study.

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The inclusion criteria for the control group (healthy adults) were the absence of ADHD symptoms and an age between 20 and 50 years. Symptoms were assessed using both the ADHD Rating Scale-IV–Home Version and the Mini-International Neuropsychiatric Interview (M.I.N.I., Sheehan et al., 1998). In the ADHD groups, two participants were excluded due to substance abuse, and four were excluded because they were taking medication. In the control group, two participants were excluded because they were taking psychoactive drugs. The final ADHD sample consisted of 128 participants (50% males and 50% females) with a mean age of 34.99 years ($SD = 8.50$, range = 29). This sample consisted of three ADHD subgroups. The ADHD-CT group consisted of 44 participants (45.5% males and 44.5% females) with a mean age of 34.08 years ($SD = 8.35$, range = 28). The ADHD-IA group consisted of 43 participants (51.2% males and 48.8% females) with a mean age of 36.52 years ($SD = 8.42$, range = 28). The ADHD-HI group consisted of 41 participants (48.8% males and 51.2% females) with a mean age of 33.66 years ($SD = 8.50$, range = 29). The control group consisted of 48 participants (54.2% males and 45.8% females) with a mean age of 32.47 years ($SD = 8.56$, range = 29). The four groups (Control, ADHD-CT, ADHD-IA, and ADHD-HI) were examined for homogeneity in age. An analysis of variance (ANOVA) revealed that the four groups were similar in age, $F(3, 168) = 1.69$, $p = .10$, and no gender differences in age, $F(1, 176) = 0.02$, $p = .88$, or differences in age as a function of gender were found across the four groups, $F(3, 168) = 1.06$, $p = .30$. All of the participants gave informed consent. The healthy controls were tested in convenient locations, for example, university offices. The participants were first asked to provide demographic data, for example, socioeconomic status, education, history of drug use, and medication use. The ADHD participants were screened according to the *DSM-IV-TR* criteria. The participants who met the *DSM-IV-TR* criteria were then administered the DRM task. All of the participants volunteered to participate in this study.

Apparatus/Materials

DRM. Eight successive lists, each composed of 15 semantically related words, were presented to the participants. These lists were adapted from Roediger and McDermott (1995) and previously used by Bhatt, Laws, and McKenna (2010). Participants were allowed 1 min of recall time after each list. After all 8 lists had been presented, a recognition task was performed in which 23 words were presented to the participants one at a time. The participants were asked to determine whether these words were new or old (recognition) and to report how confident they were that they had seen the word in the previous lists.

The participants were shown eight consecutive word lists. The 15 words in each list were semantically related, for example, school, book, and class. For each 15-word list, there was a critical lure (a word that was semantically related to the words in the list but not presented with them). For example, the critical lure "bread" was associated with the following word list: butter, food, eat, sandwich, rye, jam, milk, flour, jelly, dough, crust, slice, juice, loaf, and toast. For the complete word lists, please see Bhatt et al. (2010). The 15 studied words for the 15-word lists were calm, emotion, enrage, fear, fight, fury, happy, hate, hatred, ire, mad, mean, rage, temper, and wrath. The 8-word lists were successively presented to the participants. For each list, the 15 words were presented individually in the center of a 15-inch screen at a rate of 1 word every 2,500 ms, with a 1,500-ms interval between words. Following the last word in each list, the participants were instructed to immediately recall and write as many of the words as they could remember in any order.

There were three scores in the recall section: (a) number of correct recalls (the total number of correctly remembered words of the 120 studied words in the eight lists presented), (b) number of critical words (the total number of eight possible critical words not presented in the lists but semantically related to the words in the lists), and (c) number of unrelated words (the number of words that the participants recalled that were neither from the word lists nor one of the eight studied words).

The recognition test was then followed by a 23-word recognition test (8 words from the set of studied words, 8 critical words and 7 unrelated words [words that were neither studied nor one of the critical words]). The participants were asked to indicate whether they had seen these words. Following the procedures used in Bhatt et al. (2010), the participants rated their confidence on a 4-point Likert-type scale (1 = *definitely old*, 2 = *probably old*, 3 = *probably new*, and 4 = *definitely new*). The ratings ranged from certainty that a word was previously seen (false positives) to certainty that a word was new and had never been seen before (false negatives). Following the procedures explained by Moritz et al. (2004) and used by Bhatt et al. (2010) in a similar context, the Knowledge Corruption Index (KCI) was estimated by computing the ratio of high-confidence errors to overall errors. Moritz and colleagues reported that the KCI reveals knowledge corruption even in normal participants. Therefore, the KCI was assessed in the recognition test. Following the procedures that were outlined by Moritz et al. (2004), it was possible to separately calculate how knowledge corruption was associated with false-negative and false-positive errors. The following three recognition test scores were obtained: correct recognition, false negatives, and false positives.

The task was programmed using Super Lab software, Version 4. The word lists were presented in Arabic, and some words that are not accepted in the cultural context were altered using other contextual words, for example,

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Table 1. Means and Standard Deviations of the Scores on Recall, Recognition, and Confidence for the Control and Three ADHD Subtype Groups.

	Control	ADHD-CT	ADHD-IA	ADHD-HI
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Recall				
Correct words	87.65 (5.636)	81.40 (6.53)	84.28 (6.97)	83.86 (7.79)
Target words	3.52 (0.656)	5.44 (0.34)	4.70 (0.45)	4.66 (0.46)
Other words	4.34 (0.629)	4.50 (0.66)	4.41 (0.59)	4.27 (0.71)
Recognition				
Correct words	19.49 (1.71)	16.84 (1.70)	20.30 (1.68)	19.73 (1.75)
Critical words	2.94 (0.66)	4.14 (0.69)	2.78 (0.56)	2.74 (0.58)
Unrelated words	2.36 (0.33)	2.37 (0.39)	2.40 (0.36)	2.31 (0.41)
Confidence				
Recall	74.98 (6.05)	68.09 (5.51)	70.45 (5.26)	69.86 (6.17)
Recognition	83.69 (4.53)	76.57 (4.42)	80.74 (4.60)	79.28 (4.65)
Total KCI (%)	29.39 (9.25)	41.70 (9.10)	43.65 (8.43)	44.32 (8.34)
False-positive KCI	46.29 (12.82)	56.66 (12.50)	55.58 (13.15)	56.34 (10.29)
False-negative KCI	6.87 (2.31)	20.59 (2.77)	19.53 (2.75)	19.66 (2.83)

Note. ADHD-CT = Combined Inattentive and Hyperactive-Impulsive Symptoms; ADHD-IA = Predominantly Inattentive; ADHD-HI = Predominantly Hyperactive-Impulsive; KCI = Knowledge Corruption Index.

"wine and juice." The participants were tested individually in suitable locations in each hospital.

Results

Descriptive Statistics

The following descriptive statistics were calculated for the four groups (Control, ADHD-CT, ADHD-IA, and ADHD-HI): correct word recall, critical word recall, recall of unrelated words, correct word recognition, false positives, false negatives, recall confidence, recognition confidence, total KCI (%), false-positive KCI (%), and false-negative KCI (%). The descriptive statistics are presented in Table 1.

A series of individual ANOVAs was performed with group (Control, ADHD-CT, ADHD-IA, and ADHD-HI) as a between-participants variable and 11 dependent variables, including correct word recall, critical word recall, recall of unrelated words, correct word recognition, false negatives, false positives, recall confidence, recognition confidence, total KCI, false-positive KCI, and false-negative KCI. A post hoc analysis was performed using the Scheffé test to compare the control group and the three ADHD subgroups. The effect sizes recommended by Cohen (1988) were adopted in this study: 0.01 = small effect size, 0.06 = medium effect size, and 0.14 = large effect size.

Recall

The ANOVA revealed a significant group effect on total correct word recall, $F(3, 172) = 6.73$, $p < .01$; $\eta^2 = 0.105$, and critical word recall, $F(3, 172) = 118.66$, $p < .001$; $\eta^2 = 0.674$. However, there were no significant effects on unrelated word recall, $F(3, 172) = 0.927$, $p = .429$. A more focused comparison among all possible contrast groups was performed using the Scheffé test. It showed that both the ADHD-CT and the ADHD-HI groups recalled significantly fewer correct words than the control group. The three ADHD groups remembered significantly more critical words than the control group, and the ADHD-CT group remembered the fewest critical words among the three ADHD groups. However, the four groups recalled a similar number of unrelated words. There was no significant main effect of group on unrelated word recall, and there were no significant interactions between group and gender for any of the recall or recognition variables. The pairwise comparisons are displayed in Table 2.

Recognition

The ANOVA revealed a significant group effect on correct word recognition, $F(3, 172) = 35.47$, $p < .001$, $\eta^2 = 0.39$, and critical word recognition, $F(3, 172) = 45.49$, $p < .001$, $\eta^2 = 0.47$, but there were no significant differences for unrelated word recognition, $F(2, 172) = 0.429$, $p = .732$. The multi-group pairwise analysis performed with the Scheffé test revealed that the control group recognized more correct words than the ADHD-C group, which recognized significantly fewer correct words than the ADHD-IA and ADHD-HI groups.

The ADHD-CT group recognized significantly more critical words than the control, ADHD-IA, and ADHD-HI

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groups, but there were no significant differences between the control, ADHD-IA, and ADHD-HI groups. The pairwise comparisons between the four groups are presented in Table 2.

Memory Confidence

The ANOVA indicated that there was a group effect on confidence in correct word recall, $F(3, 172) = 12.03$, $p < .001$, $\eta^2 = 0.173$; confidence in critical word recognition, $F(3, 172) = 19.52$, $p < .001$, $\eta^2 = 0.254$; total KCI, $F(3, 172) = 29.26$, $p < .001$, $\eta^2 = 0.338$; false-positive KCI, $F(3, 172) = 7.64$, $p < .001$, $\eta^2 = 0.118$; and false-negative KCI, $F(3, 172) = 282.06$, $p < .001$, $\eta^2 = 0.831$.

The pairwise analysis revealed that the control group was more confident in both recall and recognition of correct words than the ADHD-IA and ADHD-HI groups. The three ADHD groups displayed significantly more knowledge corruption in the total KCI and false-positive KCI, but not in the false-negative KCI. Among the ADHD groups, the ADHD-IA group displayed greater recognition confidence than the ADHD-CT group, but there were no other significant differences in the recognition variables between the ADHD groups.

Discussion

The present study used the DRM task to examine whether adults with ADHD are more susceptible to the production of false memories under experimental conditions than those without ADHD. The results supported the hypothesis that adults with ADHD have impaired verbal recall and recognition (Douglas, 1988). As predicted, the ADHD participants recalled and recognized fewer studied words than the controls. These results are in agreement with previous studies indicating that ADHD patients show impaired semantic clustering, free recall, and recognition when measured by standardized memory scales such as the CLVT (Delis et al., 1987). This verbal impairment may be due to deficits in semantic verbal fluency in ADHD individuals (Lovejoy et al., 1999; Walker, Shores, Trollor, Lee, & Sachdev, 2000). Verbal fluency is an individual's ability to use controlled strategies to create spontaneous verbal production and organization while retrieving verbal information under time constraints (Marchetta, Hurks, Krabbendam, & Jolles, 2008). A pairwise comparison showed that the ADHD-CT group recalled and recognized fewer studied words than the ADHD-IA and the ADHD-HI groups. This result is consistent with previous studies in which the ADHD-CT participants showed impairment on tests requiring attention, processing speed, working memory, and vigilance (Barkley, 1997). The recall and recognition accuracy percentages are displayed in Figure 1.

The results also showed that the ADHD groups produced more critical words or false memories than the control group. This result was expected because of the memory problems previously observed in adults with ADHD (e.g., Tamm et al., 2013). It has been suggested that memory impairment results in greater vulnerability to source monitoring errors, which lead to false memory formation (Peters, Jelicic, Verbeek, & Merckelbach, 2007; Watson, Poole, Bunting, & Conway, 2005). It has been further suggested that adults with ADHD have difficulty retaining information from early childhood, which may make them highly susceptible to memory inaccuracy or distortion (Hardt & Rutter, 2004). An alternative theoretical interpretation of this result based on Roediger et al. (2001) proposes that such memory deficiencies in individuals with ADHD may result in problems with information encoding (Barnett, Maruff, & Vance, 2005).

The Fuzzy-Trace Theory (e.g., Brainerd & Reyna, 2005) assumes that individuals encode information using a two-track process: gist (general theme of an event) and verbatim (event-specific details). According to this account, DRM false recall and/or recognition are byproducts of over dependence on gist-based processing. Because ADHD patients have verbatim memory deficits, they are expected to produce more false memories. Furthermore, facility in learning and retrieving new information depends upon a learner's ability to produce associative semantic networks and to integrate new information into such networks (Mandler, 2002). Both experimental and empirical investigations have shown that this type of memory organization is dramatically affected in individuals with ADHD (Krauel et al., 2009; Lorch et al., 2000; Lorch et al., 2004; O'Neill & Douglas, 1996).

Moreover, Fuzzy-Trace Theory suggests that there is a reciprocal relationship between true and false memories. For example, false memory formation is expected to increase if true memory is poor and vice versa (Lee, Iao, & Lin, 2007). In this study, poor memory performance could be responsible for false memory production because all of the ADHD groups displayed similar memory impairment when compared with the normal controls, but there were differences among the three ADHD subtypes in correct word recall and recognition.

These results, especially the lack of significant differences in correct word and critical word recall between the ADHD groups, emphasize the effects of ADHD symptoms on correct and false memory recall and support the claim that ADHD symptoms result in memory deficits that lead to false memory generation. Moreover, because the control group and the ADHD groups were carefully matched for age and IQ, the memory impairment found in ADHD patients cannot be traced to age or intellectual functioning (Bhatt et al., 2010; Huron & Danion, 2002).

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Table 2. Multiple Comparison Test (Scheffé Test) for Recall and Recognition Scores.

	C vs. ADHD-CT	C vs. ADHD-IA	C vs. ADHD-HI	ADHD-CT vs. ADHD-IA	ADHD-CT vs. ADHD-HI	ADHD-IA vs. ADHD-HI
Recall						
Correct words	**C > ADHD-CT	—	*C > ADHD-HI	—	—	—
Target words	**ADHD-CT > C	**ADHD-IA > C	**ADHD-HI > C	**ADHD-CT > ADHD-IA	**ADHD-CT > ADHD-HI	—
Other words	—	—		—	—	—
Recognition						
Correct words	**C > ADHD-CT	—	—	**ADHD-IA > ADHD-CT	**ADHD-HI > ADHD-IA	—
False positives	**ADHD-CT > C	—		**ADHD-CT > ADHD-IA	**ADHD-CT > ADHD-IA	—
False negatives	—	—	—	—	—	—
Confidence						
Recall	**C > ADHD-CT	**C > ADHD-IA	**C > ADHD-HI	—	—	—
Recognition	**C > ADHD-CT	C > ADHD-IA	**C > ADHD-HI	**ADHD-IA > ADHD-CT	—	—
Total KCI	**ADHD-CT > C	*ADHD-IA > C	**ADHD-HI > C	—	—	—
False-positive KCI	**ADHD-CT > C	**ADHD-IA > C	**ADHD-HI > C	—	—	—
False-negative KCI	**ADHD-CT > C	**ADHD-IA > C	**ADHD-HI > C	—	—	—

Note. The letter indicates the direction of significance. C = Control; ADHD-CT = Combined Inattentive and Hyperactive-Impulsive Symptoms; ADHD-IA = Predominantly Inattentive; ADHD-HI = Predominantly Hyperactive-Impulsive; KCI = Knowledge Corruption Index.
*Significant at the .05 level. **Significant at the .01 level.

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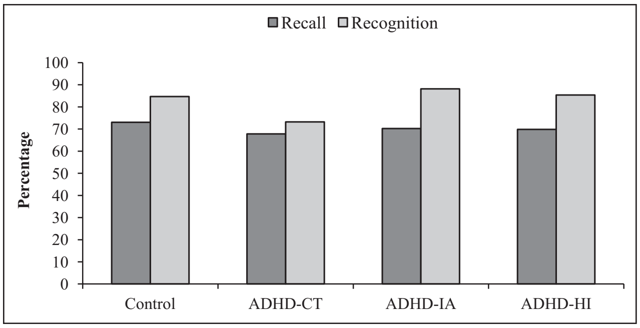

Figure 1. Recall and recognition accuracy percentages.

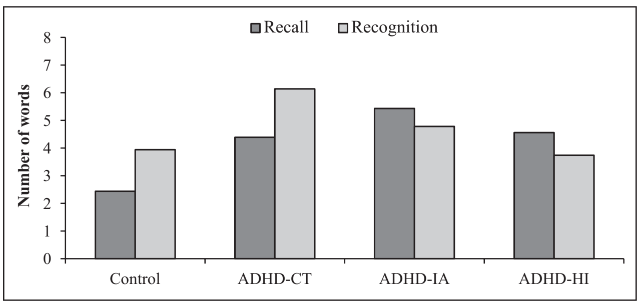

Figure 2. False-positive recall and recognition.

The results of the recognition task indicated no differences in either the false positives or the false negatives. Although no previous study has examined false recognition in ADHD patients, this result is in line with similar findings reported in clinical populations (e.g., schizophrenic patients; Bhatt et al., 2010; Moritz et al., 2004; Moritz, Woodward, & Rodriguez-Raecke, 2006). A confounding effect of presenting the recognition task after the recall task is expected in this framework. Indeed, all of the participants across all groups performed similarly in both the recall and recognition tasks. Although the requirements of memory research determine the order of these tasks, presenting the recognition task alone may lead to different result patterns for both normal and ADHD participants.

The ADHD groups' KCIs increased as they reported greater confidence in their incorrect responses than normal participants. The positive recall and recognition scores are shown in Figure 2.

The ADHD groups showed greater proportions of knowledge corruption and false positives. Although no previous studies have addressed knowledge corruption in ADHD populations, false-positive and false-negative responses seem to be associated with different aspects of poor memory functioning in ADHD patients (e.g., formation and maintenance; Bhatt et al., 2010).

In conclusion, these findings suggest that the memory problems in ADHD adults, such as disrupted organization and immature encoding and semantic organization during the encoding phase, resulted in the production of more false recall and false recognition of memory items. This finding is supported by the DRM paradigm's suggestion that false memories are byproducts of failures of attentional control or of the monitoring systems that differentiate the activation of critical words in associative networks from the actual presentation of words during encoding (Balota et al., 1999). Furthermore, due to the complex comorbidities in the ADHD-CT subtype, individuals in that category produce more false memories, more false recognitions, and more knowledge corruption than do the other ADHD subtypes.

Limitations and Future Research

The results from the present study are limited to the clinical ADHD adult population, those with an IQ ≥ 90, and those who can be classified into one of the ADHD subtypes using the *DSM-IV-TR*. In addition, the sample size was relatively small. Future research should investigate the cognition of adults with ADHD and ADHD subtypes, specifically their memory processes, using larger sample sizes and should examine their formation of false memories using verbal and visual paradigms. Future research should also compare the performance of adults with ADHD using verbal and visuospatial paradigms. Finally, the ecological validity of the DRM paradigm should be investigated.

Declaration of Conflicting Interests

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