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Individual differences in false memory from misinformation: Cognitive factors

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This research investigated the cognitive correlates of false memories that are induced by the misinformation paradigm. A large sample of Chinese college students ($N = 436$) participated in a misinformation procedure and also took a battery of cognitive tests. Results revealed sizable and systematic individual differences in false memory arising from exposure to misinformation. False memories were significantly and negatively correlated with measures of intelligence (measured with Raven's Advanced Progressive Matrices and Wechsler Adult Intelligence Scale), perception (Motor-Free Visual Perception Test, Change Blindness, and Tone Discrimination), memory (Wechsler Memory Scales and 2-back Working Memory tasks), and face judgement (Face Recognition and Facial Expression Recognition). These findings suggest that people with relatively low intelligence and poor perceptual abilities might be more susceptible to the misinformation effect.

Keywords: Misinformation; False memory; Individual differences; Cognitive factors.

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False memory refers to the memory distortion in which people sometimes develop vivid and detailed recollections of events that were never experienced; or people confuse events that happened before or after the target event with the event itself (Loftus, 2003; Roediger & Gallo, 2004; Schacter & Scarry, 2000). It is sometimes referred to as pseudo-memory or memory illusion. Unlike lying, people who have false memories genuinely believe that the non-experienced events have occurred to them.

Since the 1970s there has been an enormous interest in empirical studies of false memories (Roediger & McDaniel, 2007). Today, research in false memories has found applications in many areas, such as the accuracy and reliability of eyewitness memory in the legal settings; the authenticity of memory for childhood abuse; the attitude and behaviour changes caused by false memories; techniques of suggestion in advertising and marketing; and the discovery of pseudo-memories induced by hypnosis or dream interpretation in psychotherapy (see Loftus & Cahill, 2007, for a review). Many researchers have also proposed theories about the nature of false memories, such as the source-monitoring framework, the fluency-misattribution perspective, the activation-monitoring account, the fuzzy trace theory (FTT), and the constructive memory framework (see Brainerd & Reyna, 2005; Gallo, 2006; Steffens & Mecklenbräuker, 2007, for a description of these theories).

EXPERIMENTAL PARADIGMS USED TO INDUCE FALSE MEMORIES

False memories have been created in experimental settings using a variety of paradigms. Examples include the misinformation method (creating memory for details of past events that did not occur) (Loftus, 2003), the Deese-Roediger-McDermott (DRM) paradigm (creating false memories of words that were not presented) (Roediger & McDermott, 1995), and the rich false memory approach (planting entirely false memories for events that did not happen) (Loftus, 2005). Among them, the misinformation and DRM paradigms are used most widely. The misinformation effect refers to the phenomenon that a person's recollection of a witnessed event can be altered after exposure to misinformation about the event (Loftus & Hoffman, 1989). The classic misinformation paradigm involves three standard stages: experiencing an event, receiving misinformation about the event, and being tested for memory of the event (Loftus, 2005).

Although different paradigms can all induce false memories, there are controversies regarding the nature of such false memories (Pezdek & Lam, 2007; Wade et al., 2007) and whether the processes leading to false memories are similar in the various paradigms. Roediger (1996) introduced the label ‘‘memory illusions’’ to try to capture the potential diversity in false memories. Different types of false memories may or may not involve the same cognitive mechanisms. Past research, reviewed in the next section, has examined the cognitive correlates of false memories that arise in the DRM and some other paradigms, and these studies informed the present study, in which we focused on false memory induced by the misinformation paradigm. As will become evident, few studies have examined individual differences in misinformation false memory. The depth to which we have examined these in the current research represents one of the major contributions of this research.

INDIVIDUAL DIFFERENCES IN FALSE MEMORIES

Individuals are likely to vary in their experience of false memories and their susceptibility to misinformation. On the extreme, patients with schizophrenia frequently experience certain type of false memories (i.e., confabulation, but not DRM false memory) (Buckner & Schacter, 2004; Gallo, 2006). Among normal healthy young adults misinformation can lead many individuals (although not all) to believe things that never happened, sometimes with vivid details of the non-experienced events and with great confidence in their veracity (Loftus, 2004; Peters, 2007).

It is important to understand whether some people are more likely to experience false memories, and if so, why. Such research can help to clarify the nature of false memories and guide the many applications of false memory as mentioned above. Indeed, several researchers have pointed out the need to understand individual differences in false memories (Loftus, 2005; Reyna, Holliday, & Marche, 2002; Roediger & McDermott, 2000).

A number of studies have already reported various correlates of individual differences in false memories (see Gallo, 2006, for a review).

Researchers have examined factors such as intelligence (e.g., Salthouse & Siedlecki, 2007), personality (e.g., Gudjonsson, 2003; Liebman et al., 2002; Zhu et al., 2010), executive or frontal lobe functions (e.g., Peters, 2007; Roediger & Geraci, 2007), dissociative experiences (e.g., Merckelbach, Muris, Rassin, & Horselenberg, 2000), and affective traits such as depression and anxiety (e.g., Joormann, Teachman, & Gotlib, 2009; Roberts, 2002; Zoellner, Foa, Brigidi, & Przeworski, 2000). In the following sections we review the literature on cognitive factors related to individual differences in false memories, focusing on those most relevant to the current study (i.e., intelligence, perception, memory, and face judgement).

Intelligence

Several studies have reported a negative relation between intelligence (or related constructs) and false memories. Eisen, Goodman, Qin, and Davis (1997), cited in Eisen, Quas, & Goodman, 2002) found that false memories (measured as immediate acceptance of misinformation) of low-SES children were negatively related to verbal ability as measured with the Wechsler Scale. Gudjonsson (1983, 2003) also found that interrogative suggestibility (which is akin to the immediate misinformation paradigm and is assessed typically by the Gudjonsson Suggestibility Scale, GSS) was negatively related to intelligence scores on WAIS. In a separate study, Singh and Gudjonsson (1992) found that interrogative suggestibility was negatively related to WISC-R in adolescent boys. Furthermore, several researchers (e.g., Butler, McDaniel, Dornburg, Price, & Roediger, 2004; Meade & Roediger, 2006) found that frontal lobe functions (measured with tests that include the mental arithmetic subtest from WAIS-R) were negatively related to participants' false memory of words in the DRM paradigm, especially among the ageing population.

Other studies, however, have not found a significant association between intelligence (or similar measures) and false memory. Salthouse and Siedlecki (2007) did not find a significant relation between intelligence scores on the WAIS test and false recognition of words, faces, or dot patterns. Tata (1983), cited in Eisen et al., 2002) did not find an association between scores on a reading test and interrogative suggestibility. Powers, Andriks, and Loftus (1979) did not find a significant correlation between false memory from misinformation and scores on the Washington Pre-College Test (a SAT-like test).

Perception

Recently some researchers have speculated that perceptual discrimination ability might be a fundamental mechanism for false memory. For example, Davis, Loftus, Vanous, and Cucciare (2008) illustrated that ‘‘unconscious transference’’ (i.e., misidentifying an innocent bystander at a crime scene as the perpetrator) can be an instance of ‘‘change blindness’’. In support of the hypothesis that false memories have a perceptual basis, Intraub and Dickinson (2008) reported that, while viewing a picture, participants often falsely remember having seen the continuation of the view beyond its physical boundaries if the sensory input was disrupted for a fraction of a second. Intraub and Dickinson suggested that these very short-lived memories are not perfect, and change blindness is one example of such imperfections. These very short, imperfect memories can be consolidated into long-term false memories because of sustained attention on them. Finally, using functional brain-imaging data, Okado and Stark (2005) revealed that brain activities during visual encoding predicted whether subsequently reported memories would be true or false, suggesting that early encoding contributes to the formation of false memories. After reviewing these relevant studies, Laney and Loftus (2010) recently suggested that perceptual lapses (such as change blindness and inattentional blindness) have important implications for eyewitnesses.

Memory

Poor general memory may lead to increased susceptibility to source-monitoring errors, thus resulting in more false memories (e.g., Peters, Jelicic, Verbeek, & Merckelbach, 2007; Watson, Bunting, Poole, & Conway, 2005). Indeed, Jaschinski and Wentura (2002) found that working memory was negatively related to false memory from misinformation. Research has also found that false memory in the DRM paradigm was negatively related to working memory (Peters, 2007; Watson et al., 2005; also see Gallo, 2006, for a review) and veridical episodic memory (Lövdén, 2003).

Face judgement

Because face judgement plays a crucial role in eyewitness testimony, some researchers have explored the relationship between face recognition ability and false memory. Morgan et al. (2007) found a positive relation between performance on the Wechsler Face Test and eyewitness memory.

In sum, a number of cognitive factors have been examined in terms of their relations to false memories. The evidence is clearer for some factors (e.g., memory, face judgement) than for others (e.g., intelligence), but there were also few studies of the former. There are several limitations to these studies. First, as mentioned earlier, different studies used different paradigms to induce false memories that may or may not be of the same nature. Indeed, Bernstein and Loftus (2009) recently suggested that one of the reasons for the mixed findings of individual differences in false memory is that both individual differences and false memories are measured differently across studies. There are a sizable number of studies of individual differences in false memory induced by the DRM paradigm, interrogative suggestibility, and immediate acceptance of misinformation. Few studies of individual differences, however, have used the classic delayed misinformation paradigm. Second, different measures of the same cognitive construct have been used in different studies. It is not clear how these measures were related to one another and whether they had the same associations with false memory. Moreover, typically single measures were used. It is preferable to have multiple measures of related constructs that show converging evidence. Finally, the participants varied greatly, from children to older adults and from normal to special populations such as people with schizophrenia or intellectual disability.

THE CURRENT STUDY

The present study examined the relations between individual variations in misinformation false memory and multiple measures of four sets of cognitive factors (intelligence, perception, general memory, and face judgement) among a large sample of normal adults. Results of this study should shed light on the nature of individual differences in misinformation false memory.

METHOD

Participants

As a part of a larger project, 557 undergraduates (sophomore) were recruited from Beijing Normal University in China (mean age = 19.72 years, *SD* = 0.94; 55% female). All participants were asked to complete all cognitive tests included in this study. Between 536 and 557 participants completed those tests. A random sample of 436 (78%) was asked to complete the misinformation test (while the remaining participants were given a different test for a separate study).

Misinformation false memory test

The misinformation test involved three standard stages (see Figure 1). First, participants saw picture slides depicting a story. Two stories were selected from the research of Okado and Stark (2005), each consisting of 50 digital colour slides. One story was about a man breaking into a car and stealing things from it, and the other was about a girl's wallet being stolen by a seemingly nice man. For each story 50 pictures were presented in sequence, with each picture shown for 3500 ms and an inter-slide interval of 500 ms. The presentation order of the two stories was randomised across participants. Of the 50 slides, 12 were critical slides that would be inaccurately described in the next stage (see below). To attain a balanced design, two different images of each critical slide (one for the first stage and the other for the second/misinformation stage) were generated. They were counterbalanced across participants. For example, one participant might see a man using his *left* hand to pick up the wallet and would be misinformed at the second stage

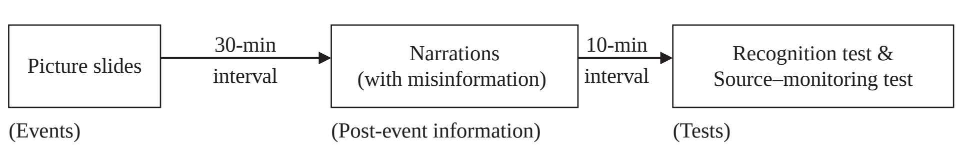

Figure 1. Misinformation procedure.

that he used his *right* hand, whereas another participant might see the man using his *right* hand to pick up the wallet but would be misinformed that he used his *left* hand.

Second, after 30 minutes of filler tasks, participants were asked to read narrations of the story that were presented visually in slides. The narratives consisted of one sentence for each slide image describing the scene depicted in the slide. For each story, 50 sentences were presented, including 12 inaccurate descriptions (misinformation) and 38 accurate descriptions (i.e., consistent with the picture slides). Each sentence was shown for 3500 ms, and the interval between sentences was 500 ms. The participants were told that they were to read narrations made by an eyewitness of those two events. Participants were not warned about potential discrepancies between the picture slides and the narrations.

Third, after 10 minutes of a filler task, participants took the recognition test and then the source-monitoring test. For the recognition test, 18 questions were asked about each story regarding what was presented ‘‘in the picture slides’’, 12 of which were critical questions (pertaining to critical slides) and 6 were control questions. Each question had three possible choices as answers. For the critical questions, choices included a detail presented in the picture (‘‘original item’’), a detail presented in the narrations with misinformation (‘‘misinformation item’’), and a new foil detail (‘‘foil item’’). For example, the participants might see in the slides a man hiding behind a door after stealing a girl's wallet and would then read the narration that he was hiding behind a tree. For the critical question ‘‘Where was the man hiding after stealing the girl's wallet?’’, the choices were ‘‘behind the tree’’ (misinformation item), ‘‘behind the door’’ (original item), and ‘‘behind the car’’ (foil). For control questions, choices included a detail presented both in the picture and the corresponding narration (‘‘correct control’’) and two new details (‘‘foil items’’). For the test of each story, the questions were presented in random order (i.e., not following the chronology of events depicted in the slides). When the participants were given the recognition test, they were told that ‘‘you saw the picture slides and read the narrations, please try your best to answer the following questions based on what you saw in the picture slides’’. We printed the words ‘‘picture slides’’ in red ink and highlighted them in the instructions of the recognition test. Again there was no explicit ‘‘warning’’ that narrations included misinformation.

It should be noted that most questions were based on the recognition test of Okado and Stark (2005). A few changes were made to accommodate language and cultural differences. For example, because we used Okado and Stark's slides, when a question was asked about certain English words in the slides, the question was modified (e.g., the question ‘‘What is the word written on the sign for the café?’’ was changed into ‘‘What is the colour of the word written on the sign for the café?’’).

The recognition test was self-paced and administered on computer. Immediately after the recognition test, participants took the source-monitoring test. For the source-monitoring test, participants were asked from what presentation source they remembered the answers that they had chosen on the recognition test. Five options were given: ‘‘saw it in the picture only’’, ‘‘read it in the narrations only’’, ‘‘saw it in both and they were the same’’, ‘‘saw it in both and they conflicted with each other’’, and ‘‘guessed’’. Misinformation items that were further endorsed on the source memory test as ‘‘saw it in the picture only’’ or ‘‘saw it in both and they were the same’’ were considered ‘‘Robust False Memories’’ (RFM). Foil items that were further endorsed on the source memory test as ‘‘saw it in the picture only’’, ‘‘read it in the narrations only’’, and ‘‘saw it in both and they were the same’’ were considered ‘‘Robust Foil’’.

Cognitive tests

There were four sets of cognitive tests. The first set included intelligence tests: Raven's Advanced Progressive Matrices (Raven's APM) and Wechsler Adult Intelligence Scale (WAIS). The second set of cognitive tests aimed to assess perceptual discrimination abilities. We included Motor-Free Visual Perception Test (MVPT) and a test of change blindness to assess the visual discrimination abilities (which are relevant to the visual presentation of the original event). Moreover, to assess whether auditory perceptual abilities are associated with false memories induced by narrations, we included a simple tone discrimination test. The third set of cognitive tests included memory tests. We included both the classic Wechsler memory tests of pictures and words, and a working memory test (2-back task) using words as materials. The fourth set of cognitive tests included face judgement tests (i.e., face memory test and facial emotion expression recognition test), because they are relevant to person perception in the original event and to eyewitness identification in false memory research. The following sections provide brief descriptions of these tests.

Raven's Advanced Progressive Matrices. These were multiple-choice tests of abstract reasoning. Participants were given 30 minutes to complete as many items as possible. In each test item, participants were asked to select from several alternatives the missing segment that would complete a larger pattern. The whole test had 48 items, including 12 easy items and 36 difficult items. Each item was presented in black ink against a white background. Items were arranged in the order of difficulty from the easiest to the most difficult. This test is appropriate for adults and adolescents of above-average intelligence (Raven & Court, 1998). It has been used widely in China with good reliability and validity (the split-half reliability was .86) (Zhai, 1999). Cronbach alpha in this study was .75. The total score on this test was one measure of intelligence used in the current study.

Wechsler Adult Intelligence Scale–Revised (Chinese version). Six subtests (three verbal and three performance tests) of the Chinese adaptation of the Wechsler Adult Intelligence Scale-Revised (city version) (WAIS-RC) were used. This test was individually administered. Testing time was about 30 minutes. The verbal section included general knowledge (tapping general information acquired from one's culture), similarities (abstract verbal reasoning), and digit span (attention and concentration). The performance section included picture completion (ability to quickly perceive visual details), symbol digit coding (visual-motor coordination and motor and mental speed), and block design (spatial perception, visual abstract processing, and problem solving). This test had good reliability and validity in China (the test–retest reliability was .89). The split half reliabilities in specific tasks were between .58 and .89 for IQ verbal section; and between .67 and .75 for IQ performance section (Gong, 1992). The performance and verbal section scores were used as measures of intelligence in the current study.

Motor-Free Visual Perception Test (MVPT third edition). This test is commonly used to assess an individual's visual perceptual ability, with no motor involvement needed to make a response (Colarusso & Hammill, 2003). The participant was shown a line drawing and then asked to choose the matching drawing from a set of four presented on the following plate. Five categories of visual perception were measured: spatial relationship, visual closure, visual discrimination, visual memory, and figure ground. We used the standard score based on the score conversion table in Colarusso and Hammill (2003). The Cronbach alpha was .90 or above (Colarusso & Hammill, 2003).

Change blindness test. This test was adapted from Rensink, O'Regan, and Clark (1997). By using the "flicker" technique in which two images of a particular scene alternate repeatedly with a brief blank screen after each image, this test assessed the ability to detect changes in the details of pictures. Each image was presented for 300 ms and the inter-stimulus interval was 100 ms to create the flickering appearance. This test included 38 pairs of the same pictures and 38 pairs of different pictures. Of the pairs, 10 came from Rensink et al. (1997) and 66 were developed anew specifically for the current study. Participants had to identify whether two pictures were the same or different, and press a response key within 6 seconds. After 6 seconds without a response, a notice would be presented for 2 seconds asking for a response. Cronbach alpha in this study was .92. The discrimination score (d') on this test was used as the index of change blindness performance for the current study.

Tone discrimination test. This task was adapted from the absolute pitch test of Zatorre (2003) to measure tone discrimination among general college students. Participants listened to a tone twice and were asked to choose the name of the tone. Seven piano tones were used, each presented three times in a random order. Before the formal test, participants were asked to practise three times with feedback. Cronbach alpha in this study was .85. The number of correct responses in the formal test was used for analysis.

Wechsler Memory Scale-Recall (WMS-Recall). This is a subtest of the Wechsler Memory Scale–Chinese Version (WMS-C) (Gong, 1989). Participants were presented with 20 items to study for

90 seconds. These items were pictures of common objects, such as a boat or a cap. Afterwards, participants were asked to say out loud the items they just saw. The test–retest reliability for the total WMS scale was .82 (Gong, 1989).

Wechsler Memory Scale-Recognition (WMS-Recognition). This was another subtest of the Wechsler Memory Scale–Chinese Version (WMS-C) (Gong, 1989). Participants were presented with eight items simultaneously for 30 seconds. Items included pictures of common objects and Chinese characters. Then participants were asked to pick out the 8 studied items from 28 items (including 8 studied and 20 unstudied similar items). The test–retest reliability for the total WMS scale was .82 (Gong, 1989).

Working memory test. Working memory was tested with the typical 2-back paradigm (Owen, McMillan, Laird, & Bullmore, 2005; Xue, Dong, Jin, & Chen, 2004). Participants were presented with three series of characters (two series of Chinese characters and one series of Tibetan letters) sequentially and were asked to continuously judge whether the current character was related to the character presented two characters earlier (hence the name "2-back"). There were three judgement tasks: semantic judgement (whether the characters were from the same semantic category, such as cabbage and radish) and phonological judgement (whether the characters rhymed) for the two series of Chinese characters, and morphemic judgement (whether two characters were the same) for Tibetan letters, which were unfamiliar and meaningless to participants in our study. Each judgement task consisted of four blocks and 10 trials in each block. Before the judgement tasks participants had a practice block (judging small circles and squares), in which they had to pass 70% of trials before they could take the formal tests. Cronbach alpha in this sample was .82. The average score (accuracy) of three tasks was used as the index of working memory in the current study.

Cambridge Face Memory Test. This test was used to assess the memory of faces (Duchaine & Nakayama, 2006). It had three blocks. First, participants saw a target face from the front, the left, and the right, and were then asked to identify the target face from three different faces. For the second block, participants saw six different faces, all presented at the same time for 20 seconds, and were then asked to identify one of these faces from three alternative choices (including one target face and two other foil faces each time). The third block was the same as the second block except that noise was added to the faces. For the first block, there were 6 target faces and 18 trials in total; for the second and the third block there were 6 target faces and 54 trials in total. The averaged accuracy rate for three blocks was used in this study. Cronbach alpha in this study was .85.

Facial expression recognition test. This test was adapted from the Chinese facial expression of emotion test (Wang & Markham, 1999) and a facial expression of emotion test developed by Matsumoto and Ekman (1988). It assessed the ability of Chinese participants to judge facial expressions represented on Asian and Caucasian faces. Six basic emotions were included: happiness, surprise, anger, sadness, fear, and disgust. For each emotion there were six pictures from Wang and Markham (1999) and six pictures from Matsumoto and Ekman (1988). Participants selected from the six basic emotions to match it to each face. The total number of correct responses was used in this study. Cronbach alpha in this study was .83.

Procedure

Participants were tested over three sessions spread across a period of 8 months. Most tests (including the misinformation test) were administered in the first session; the WAIS IQ tests, WMS-Recall, and Tone Discrimination tests were administered in the second session (1 month after the first session); and the MVPT was administered in the third session (7 months after the first session). Except for the individually administered paper version of Raven's APM and WAIS IQ tests, all other tests were administered on the computer.[1]

RESULTS

Misinformation test

The mean endorsement rate for misinformation items (overall false memory) was .32 ($SD = .18$)

[1] As part of a larger research project, the participants in the current study also completed many other tests. Due to the current focus of this paper (i.e., false memory from misinformation), we do not report these tests here, but they can be found in the dissertation of Zhu (2010).

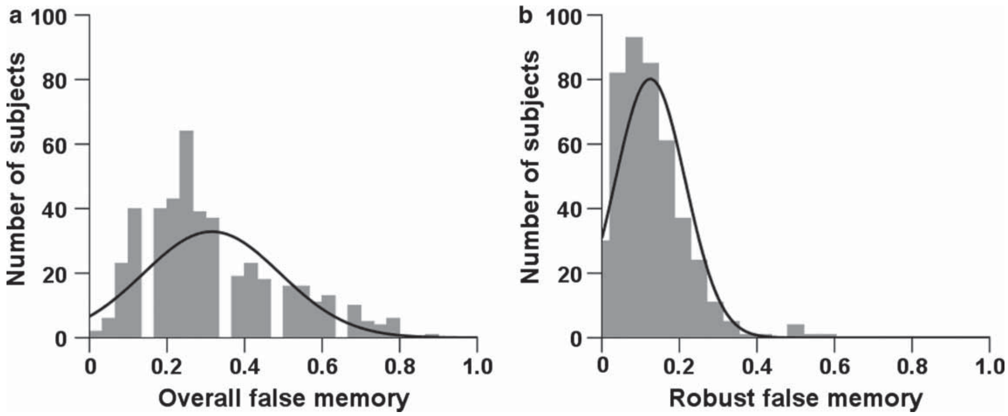

Figure 2. Distribution of misinformation false memory: (a) overall false memory; (b) robust false memory.

and that for foil items (overall foil) was .08 ($SD =$ .05). The mean rate of endorsement of the original items was .60 ($SD = .17$). As Figure 2a shows, there was a very sizable range of false memory across individuals, ranging from 0 to .88. Overall, those with a high level of false memory (1 *SD* above the mean) endorsed about half or more of the misinformation items, whereas those with a low level of false memories (1 *SD* below the mean) endorsed about 10% or fewer of such items. It is further worth noting that the correlation between the overall false memory rates of the two stories was relatively high, $r(435) = .58$, $p < .001$, indicating a good level of internal consistency of this two-story test (equivalent Cronbach alpha was .76).

Based on the source-monitoring data, overall false memory can be further refined to yield robust false memory (participants claimed that they saw the misinformation item in the picture or they did not see a conflict between the picture and the narration). Similarly, overall endorsement of the foil items can be refined as robust foil, when participants claimed that they saw the foils in the picture or narration, or they did not see a conflict between the picture and the narration. The mean rates of robust false memory and robust foil were .12 ($SD = .09$) and .04 ($SD = .04$) respectively. Figure 2b shows the distribution of robust false memory, which again indicates a sizable range.

The rate for overall false memory was significantly higher than that for the overall foil items, $t(435) = 25.29$, $p < .001$; and the rate for robust false memory was significantly higher than that for robust foil, $t(435) = 19.38$, $p < .001$, suggesting that the misinformation used in this paradigm reliably created false memory.

Cognitive correlates of false memory from misinformation

Before we identify the cognitive correlates of misinformation false memory, we first examined the intercorrelations among the various measures of cognitive abilities. Table 1 shows the descriptive statistics and correlations among the cognitive tests. In general, various measures of cognitive abilities were positively correlated with one another. Stronger correlations appeared between measures of intelligence and perceptual abilities, and between perceptual abilities and face judgement. Nevertheless, it is worth noting that most correlation coefficients were modest to moderate, suggesting that they measure different constructs. Even within each general category of test (especially among the various measures of memory), inter-measure correlations were quite small, suggesting that they measure different components or aspects of the construct. It is thus important to examine the associations between each of these measures and misinformation false memory.

Table 2 shows bivariate correlations between scores on these cognitive tests and false memory induced by the misinformation paradigm. As evidenced by the data, these cognitive tests had significant negative correlations with misinformation false memory. These correlations ranged from modest to moderate. In the following sections we describe the details of these results (including some relevant information on subscales that are not shown in the table).

Intelligence. Generally, false memory in the misinformation paradigm was significantly negatively related to intelligence. Among all the cognitive tests, the Raven's APM test had the highest negative correlation coefficient with

TABLE 1
Descriptive statistics and correlations among variables in the cognitive tests

	M	*(SD)*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
(1) Raven's APM	36.81	(4.41)										
(2) WAIS-V	124.10	(8.75)	.23***									
(3) WAIS-P	123.29	(9.78)	.42***	.26***								
(4) MVPT	101.11	(16.63)	.39***	.25***	.38***							
(5) Change Blind	.75	(.59)	.28***	.10*	.30***	.26***						
(6) Tone Discrim	7.51	(5.07)	.17***	.23***	.24***	.26***	.17***					
(7) WMS Recall	17.34	(2.26)	.19***	.20***	.17***	.22***	.08	.10*				
(8) WMS Recog	14.70	(1.40)	.08*	.05	.08	.07	.05	.00	.02			
(9) Working Mem	.87	(.07)	.27***	.18***	.22***	.29***	.18***	.14**	.21***	.09*		
(10) Face Recog	.60	(.10)	.17***	.12**	.24***	.25***	.20***	.22***	.15***	.03	.19***	
(11) Facial Expr	58.35	(5.19)	.21***	.17***	.16***	.24***	.14**	.19***	.08	.04	.13**	.29***

(1) Raven's APM = Raven's Advanced Progressive Matrices; (2) WAIS-V = WAIS IQ verbal; (3) WAIS-P = WAIS IQ performance; (4) MVPT = motor-free visual perception; (5) Change Blind = change blindness; (6) Tone Discrim = tone discrimination; (7) WMS Recall = WMS recall; (8) WMS Recog = WMS recognition; (9) Working Mem = working memory; (10) Face Recog = face recognition; (11) Facial Expr = facial expression recognition. *$p < .05$. **$p < .01$. ***$p < .001$.

TABLE 2
Correlations between cognitive tasks and false memories from misinformation

	False memory	
	OFM	*RFM*
Intelligence		
Raven's APM	−.35***	−.23***
WAIS IQ verbal	−.13**	−.10
WAIS IQ performance	−.29***	−.18**
Perception		
Motor-free visual perception	−.29***	−.14**
Change Blindness d'	−.23***	−.06
Tone Discrimination	−.23***	−.20***
Memory		
WMS Recall	−.18***	−.05
WMS Recognition	−.12*	−.08
Working memory	−.17***	−.13**
Face judgement		
Face recognition	−.16**	−.15**
Facial expression recognition	−.19**	−.15**

OFM = overall false memory (endorsement rate of misinformation item); RFM = robust false memory. *$p < .05$. **$p < .01$. ***$p < .001$.

overall false memory ($r = -.35$). For the WAIS IQ test, the performance scores had a much higher negative correlation with overall false memory ($r = -.29$) than verbal scores ($r = -.13$). Within the WAIS IQ performance tests, the overall false memory was significantly negatively correlated with the scores of Picture Completion ($r = -.25$) and Block Design ($r = -.26$), but not with Symbol Digit Coding. Within the WAIS IQ verbal tests, there was a small significant negative correlation between overall false memory and General Knowledge subtest ($r = -.10$), but not with the other subtests (Digit Span and Similarities).

Perception. Overall false memory was significantly correlated with MVPT ($r = -.29$), discrimination rate in change blindness ($r = -.23$), and tone discrimination ($r = -.23$). Robust false memory had a similar pattern, but the correlation coefficients were smaller and in the case of change blindness, not significant ($r = -.06$).

Memory. All general memory tasks had significant negative correlations with overall false memory. Among them, working memory tasks and WMS recall had the highest negative correlations with overall false memory. The correlations between robust false memory and scores of general memory tasks were also negative, but some of them (WMS recall and WMS recognition) were not significant.

Face judgement. Face recognition and facial expression recognition abilities had significant negative correlations with overall false memory (rs = −.16 and −.19), and robust false memory (rs = −.15).

Because a large number of analyses were involved, a correction for multiple comparisons was needed to show the robustness of the results.[2] Correcting for multiple comparisons rendered 1 of the 18 significant correlations for false memory non-significant (the correlation between overall false memory and WMS recognition).

Finally, a stepwise regression procedure was conducted to investigate the combined and unique effects of cognitive correlates of false memories in the misinformation paradigm. For the first analysis, the overall false memory score was used as the dependent variable. Of all the cognitive tests, four predictors (scores of Raven's APM, MVPT, tone discrimination, and change blindness) entered the regression in that order. The total predicted variance was $R^2 = .15$ (adjusted $R^2 = .14$), $F(4, 389) = 17.48$, $p < .001$. The associated increment in the squared multiple correlation was $\triangle R^2 = .09$ for Raven's APM, $\triangle R^2 = .04$ for MVPT, $\triangle R^2 = .02$ for tone discrimination, and finally $\triangle R^2 = .01$ for change blindness. When the dependent variable was the robust false memories, three predictors (scores of Raven's APM, tone discrimination, face recognition) entered the regression. The total predicted variance was $R^2 = .06$ (adjusted $R^2 = .06$), $F(3, 390) = 8.79$, $p < .001$. The associated increment in the squared multiple correlation was $\triangle R^2 = .03$ for Raven's APM, $\triangle R^2 = .02$ for tone discrimination, and finally $\triangle R^2 = .01$ for face recognition.

DISCUSSION

The current study found that individual differences in misinformation false memory were significantly related to measures of intelligence, perception, memory, and face judgement. We next discuss the role of each cognitive correlates of misinformation false memory.

Intelligence and misinformation false memory

Our results showed that intelligence was significantly related to misinformation false memory. This was shown using two quite different tests of intelligence: WAIS and Raven's APM. People with higher intelligence scores were less likely to incorporate post-event misinformation into their memory of the original event. It should be further noted that the associations between intelligence and false memories are most likely to be underestimated in our study due to the restricted range of intelligence scores of our participants (all of whom were college students in one of the top universities in China, with mean IQ scores of about 120 and standard deviations less than 10). Our speculation would be further supported if Gudjonsson (2003) is correct in arguing that it is more likely to find a significant relation between intelligence and false memory when the sample includes persons with below-average intelligence scores.

Among the measures of intelligence, Raven's APM and WAIS performance scores showed stronger and more consistent associations with false memories in the misinformation paradigm than did WAIS verbal scores (as well as all other cognitive tests). As shown by the regression analysis, only Raven's APM was found to make a unique contribution to the prediction of misinformation false memory. There are debates about the constructs tapped by intelligence tests. Some subtests of the intelligence tests have been used (in combination with other tests) to measure executive functions or frontal lobe functions. For example, Roediger and Geraci (2007) used the mental arithmetic subtest from the WAIS-R, mental control and backward digit span from the WMS-III, verbal fluency, and the Wisconsin Card Sorting test to create a composite Z score to index frontal lobe functioning. They found that among an ageing population low frontal lobe functioning was associated with susceptibility to the misinformation effect. Taken together the results of this study and those of Roediger and Geraci (2007), Eisen et al. (1997), Gudjosson (1983, 2003), and Singh and Gudjosson (1992), as reviewed in introduction, it

[2] It should be noted that by correcting for multiple comparisons, our results were statistically conservative because the same correlations can also be corrected for attenuation due to less-than-perfect reliability of the measures (Jensen, 1998). If both corrections (multiple comparisons and adjustment for reliability attenuation) were used, the corrected results would be virtually the same as the original results.

appears that intelligence measures have moderate associations with misinformation false memory. Two previous studies that did not find an association between intelligence-like measures and misinformation false memory (Powers et al., 1979; Tata, 1983) may have been due to their use of achievement tests, rather than standard intelligence tests.

Perception and misinformation false memory

Our results showed that false memory in the misinformation test was negatively related to perception, whose unique contributions were further confirmed by the regression analysis. Most of the false memories tested in these experimental settings as well as in real life (such as eyewitness testimony) involve fine discriminations about perceptual details. As Laney and Loftus (2010) pointed out, perceptual abilities or inabilities (such as change blindness and inattentional blindness) are highly relevant to accuracy in eyewitnesses' memories. Our results provided the first clear evidence for such a claim. It is especially worth noting that perceptual discrimination abilities in both visual and auditory modalities are important. It seems that abilities in both fine visual and auditory discrimination are needed to perform well in the misinformation test because it involves both pictures and narratives.

General memory ability and misinformation false memory

Memory (including WMS and working memory tasks) was significantly related to false memories in the misinformation paradigm. Working memory and other memories based on WMS were important in false memory perhaps because the misinformation test is fundamentally a complicated task that involves a large number of memory capacities. To process the original events and false information accurately, participants need to memorise them and manipulate them in their working memory. Our results are consistent with Jaschiski and Wentura (2002), who found a significant correlation between working memory (measured as operation word span) and misinformation false memory. These results extended previous studies that found significant correlations between memory and false memory in the DRM paradigm (e.g., Lövdén, 2003; Peters, 2007; Watson et al., 2005). Interestingly, however, general memory scores did not make unique contributions to the prediction of false memory from misinformation, when intelligence scores and other cognitive scores were included in the regression. These results suggest that false memory is more than merely poor memory.

Face judgement ability and misinformation false memory

False memory in the misinformation paradigm was negatively correlated with accuracy of face judgement, including face recognition and facial expression recognition. This result is in line with Morgan et al.'s (2007) finding of significant correlations between face recognition ability and accuracy on an eyewitness task. Given that the misinformation paradigm used pictures with humans in them, it is likely that face judgement abilities would be important in efficiently processing the slides and memorising them.

CONCLUSIONS AND IMPLICATIONS

In summary, our study found that misinformation false memory was robust and its individual differences are sizable and systematic. Intelligence and perception made unique contributions to the prediction of false memories from misinformation. It is especially worth noting that perceptual discrimination abilities in both visual and auditory modalities were important. Overall, participants with relatively low intelligence and perceptual lapses appear to be more susceptible to the misinformation effect. We note that these results also have practical implications. For example, given the systematic relations between cognitive factors and misinformation false memory, eyewitness evidence should be considered in light of the witnesses' cognitive abilities.

Our results also point to several directions of future research. First, we explored a few factors but future research should examine other individual factors in misinformation false memory, such as personality, social and even genetic factors. These factors may also interact with one another in producing different amounts of misinformation false memory (e.g., Zhu et al., 2010). Second, our study focused on false memory induced by the classic misinformation paradigm. The cognitive correlates we identified for the misinformation paradigm (e.g., face judgement, perceptual abilities) may or may not be relevant to other types of false memory (e.g., the DRM, rich false memory). Future research needs to directly compare the cognitive factors involved in different types of false memories. Third, future research should link individual differences in lab-based false memories to real-life false memories. Individual differences in false memories should be extended to the examinations of real-life eyewitnesses.

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