Running Head: FALSE MEMORIES AND EYEWITNESS TESTIMONY

Consequences of False Memories in Eyewitness Testimony:

A Review and Implications for Chinese Legal Practice

Jianqin Wang1, Henry Otgaar1,2, Tom Smeets1, Mark L. Howe1,2, Harald Merckelbach1, and Chu Zhou3

1Maastricht University, The Netherlands

2City, University of London, UK

3Fudan University, China

Words: 5981

Correspondence to Wang, J ([jane.wang@maastrichtuniversity.nl](mailto:jane.wang@maastrichtuniversity.nl)), Clinical Psychological Science, Faculty of Psychology and Neuroscience, Maastricht University, PO Box 624, 6200 MD, Maastricht, the Netherlands

Or to Zhou, C ([zhouchu@fudan.edu.cn](mailto:zhouchu@fudan.edu.cn)), Department of Psychology, Fudan Unviersity, 220 Handan Rd., Shanghai, China

Abstract

False memories can have severe legal consequences, including the imprisonment of innocent people. False memory in eyewitnesses is the largest factor contributing to miscarriages of justice in the United States. To date, no study has focused on how false memories might play a role in the Chinese legal system. The purpose of this review is to summarize the latest findings on false memory and eyewitness testimony in the English literature, and to shed some light on how the Chinese legal system may incorporate these experiences into practice. Overall, false memories of eyewitnesses are generated either by external misleading information or by internal cognitive processes; false memories may guide police investigation in a wrong direction, or cause eyewitnesses to misidentify an innocent person as the perpetrator. We conclude that specially designed interview protocols such as the Cognitive Interview, warnings given to eyewitnesses, and blind lineup administration might prevent or lower the risk of false memory occurrence.

Keywords: false memory, eyewitness testimony, Chinese legal practice

**Consequences of False Memories in Eyewitness Testimony: A Review and Implications for Chinese Legal Practice**

Somewhere in December, 2003, Haisheng Zhang (张海生) was visiting his relatives in Lichuang County, Henan Province, China. Suddenly, he was detained by the police as a suspect for raping a 13-year old girl in the woods. He was eventually sentenced to 9 years of imprisonment by the Court of Lichuang County. The most important piece of evidence was the testimony by the victim stating that she was completely confident that Zhang was the culprit. Besides the testimony, three other teenage girls identified Zhang from a lineup as the person who talked to the victim and led the victim to the woods. Meanwhile, there was no physical evidence incriminating Zhang as the offender. More than a year after his conviction, another defendant, who was recently caught, confessed to a series of sex offending cases, including the one that Zhang was being charged with. When Zhang was released because of this confession, he had spent 480 days in prison.[[1]](#footnote-1)

This is not the only Chinese case in which an innocent person was falsely convicted and imprisoned because of erroneous memories. Another case occurred in 1990 and was recently revised as well. In this case, Jibin Xu (徐继彬) was wrongfully convicted of rape because he was identified by the victim as the assailant, even though the police should have found out that his blood type did not match the blood type of the real perpetrator. Only after 16 years, he was proven innocent by a blood test.[[2]](#footnote-2)

In these cases, innocent people were convicted because of the absolute reliance on eyewitness testimonies even when they included erroneous memories implying someone’s guilt. In the absence of physical evidence, these testimonies became crucial. Importantly, in the majority of criminal proceedings, eyewitness testimonies are the most important piece of evidence (e.g., Howe, Knott, & Conway, 2018). Objective evidence such as DNA evidence is frequently lacking (Howe & Knott, 2015; Perterson, Hickman, Strom, & Johnson, 2013). The result of this is that legal professionals often must rely on the memory of a victim and/or witness. However, memory is a flexible system that is not as reliable as people expect (Loftus, 2004; Schacter, 2012). Our memories are fallible. That is, they are not literally reproduced but reconstructed when they are retrieved (e.g., Howe et al., 2018). During such reconstruction, unintentional errors might slip in, which can lead to the occurrence of false memories. False memories refer to memories of events that did not happen, yet are experienced as real (Loftus, 2005). Although such false memories can occur in many different situations (e.g., misremembering that you placed your car keys on the table while in fact they were still in the car) and are oftentimes relatively innocuous, when they enter the legal arena, consequences can be quite dramatic especially when they involve false accusations of sexual abuse or faulty eyewitness identifications (Otgaar, Sauerland, & Petrila, 2013).

In the legal arena, eyewitness misidentification has been shown to be the largest contributing factor leading to wrongful convictions, playing a role in more than 70% (*n* =243) of convictions which were later overturned through DNA testing in the United States (data achieved from the Innocent Project, http://www.innocenceproject.org/causes/eyewitness-misidentification/). Such comprehensive data are non-existent in China regarding the reasons for miscarriages of justice. The main purpose of this review is to assemble the most recent findings on false memories and eyewitness testimony. First, we will review whether the issue of eyewitness testimony has attracted the attention of scholars and legal professionals in China. Next, we will discuss classical research paradigms that demonstrate the malleability of memory. Following this, we will concentrate on the latest findings in the field of eyewitness false memory, which have mainly been published in English journals. Finally, conclusions and implications for legal practice in China are discussed.

**Eyewitness Testimony in Chinese Cases**

The judicial system in China adheres to the civil law system or the continental legal system similar to most of the European countries. Judges are the trier of facts and they make judgements based on evidence and the law. Eyewitness testimony is listed as one of the main categories of evidence (Article 42, The Criminal Procedure Law of China). In many historical cases like the ones we introduced in the beginning, eyewitness testimony was assigned particular weight among all kinds of evidence, even when it was contradicted by forensic evidence. Moreover, eyewitness testimony could be the sole evidence leading to convictions, which leaves possibilities for wrongful convictions when eyewitness’ statements are not reliable.

Chen (2007) reviewed 20 nationally-known wrongly convicted cases that were exposed by the media and concluded that torture, improper evidence collection, and ignoring the use of scientific techniques were the most frequently mentioned risk factors in these cases. One limitation of this review is that the cases described by Chen were “famous” cases exposed by journalists, who were particularly interested in uncovering cases involving torture. There was no focus on whether any erroneous memories might have been present in such cases.

To our knowledge, very few studies have ever focused on the important role that erroneous eyewitness testimonies and hence, false memories, might have played in legal proceedings in China. To examine this issue more closely, we selected the China National Knowledge Infrastructure (CNKI) Database, which covers 10,267 Chinese academic journals (almost all academic journals in China), and the CNKI Masters’ Theses Database and Doctoral Dissertations Database to search for literature on false memories and eyewitness testimony at the time of this writing. The following keywords were selected to search for the literature: Eyewitness, eyewitness testimony, eyewitness memory, false memory, eyewitness events, children witnesses, or memory distortions. This literature search resulted in 18 papers and six theses/dissertations concerning eyewitness memory, seven papers on eyewitness identification, and nine papers on child witnesses, dated from 1991 to 2016. After reviewing these papers, we found that not one paper specifically looked at the relationship between legal cases and false memories. This suggests that in the Chinese psychological literature, the topic of false memories in the courtroom has not attracted much attention, although we know from many cases in other countries that false memories is an important source of wrongful convictions (Garrett, 2011; Loftus, 2013). Based on this observation and the Chinese cases reviewed earlier, it is likely that false memories might have affected testimonies in Chinese cases as well.

**The Fallibility of Memory**

The idea that memory can be easily distorted has been examined by relying on false memory paradigms in which false memories are produced suggestively or spontaneously. Loftus (1975) first demonstrated how leading questions could impact eyewitness reports by using the *misinformation paradigm*. Basically, the misinformation paradigm consists of three stages. First, in the encoding phase, participants generally view a video depicting an event such as a crime or an accident. Then participants are exposed to misleading information (e.g., in the form of statements or leading questions). Finally, in the memory retrieval phase, participants are asked to recall details from the witnessed event. In a pioneering experiment, Loftus (1975) tested 40 college students who watched a 3-min videotape depicting eight demonstrators who disrupted a class and then left the classroom. After the videotape, half of the participants received subtle misinformation by asking them a misleading question: “was the leader of four demonstrators a male?”. The other half was asked: “was the leader of the twelve demonstrators a male?”. One week later, all participants were interviewed about the number of demonstrators in the videotape. The first group falsely recalled on average two more demonstrators than the second group (average 8.85 compared with 6.4).

In the misinformation paradigm, false memories are caused by external misleading information and we term them *exogenous false memories*. These false memories have been found in all age populations (from infants to older people) through more than 40 years of investigation (Frenda, Nichols, & Loftus, 2011; Loftus, 2005). The misinformation paradigm focuses on false memories for details of an event. Yet, rich false memories of a wholly novel event can also be created using suggestive pressure. For instance, in the false memory implantation paradigm, participants have been presented with some fake evidence depicting a false event (e.g., a photo shopped old family picture) and then they are interviewed to elaborate on the false event. Otgaar, Candel, Merckelbach, and Wade (2009) presented children with a fake newspaper article about people being abducted by an UFO in their hometown when they were aged 4. The child participant was then told that his mother confirmed that he had been abducted by the UFO as well. Later, the participant was interviewed twice over seven days and asked to recall the UFO abduction. Many children (over 70%) vividly and falsely remembered that they were abducted by aliens (e.g., one child remembered seeing flashes, blue/green puppets and other abducted children in the UFO).

**Exogenous False Memories**

**Misinformation during Interview and Interrogation**

External misleading information can be both verbal and nonverbal. During police interviews and interrogations, the phrasing of the questions as well as gestures made by the interviewers might undermine the accuracy of witnesses’ memories. In one research line examining possible impacts from different types of questions (Kebbell, Evans, & Johnson, 2010; Kebbell & Johnson, 2000; Kebbell & Giles, 2000), participants first watched a short video of a crime such as a woman being attacked by a man; one week later, they answered “yes” or “no” to questions about the crime. Researchers found that negative questions (e.g., “Did the woman not have black hair?”), double negative questions (e.g., “Is it not true that the woman did not have black hair?”) as well as leading questions in which the expected answer was given (e.g., “It is true to say that the attack happened in a park, isn’t it?”) resulted in less accurate eyewitness memories compared with more simple questions (e.g., “Did the attack happen in a park?”).

Sharman and Powell (2012) compared witnesses’ susceptibility to misinformation across various phrasing structures of the interview questions. Participants went through the typical three-stage misinformation procedure (i.e., witnessing an event, receiving misinformation, and answering memory questions). Specifically, they were misinformed that there was an AJ’s logo on the perpetrator’s van when in fact there was an RJ’s logo in the film. They constructed different types of questions containing misleading information. Of relevance here are the closed specific questions that require a “yes” or “no” response and contain specific misleading details at the same time (e.g., “Did Eric have an AJ’s logo in large black letters on his van?”) and open presumptive questions that suggest certain (misleading) information is true (e.g., “Tell me more about the AJ’s logo on Eric’s van”). They found that these two types of questions resulted in the highest false memory rates (38%) for the misinformation as well as the least accurate memories for correct details.

Nonverbal misinformation such as gestures during interviews can also lead to eyewitness memory distortions, which has recently been termed the *gestural misinformation effect* (Gurney, Pine, & Wiseman, 2013). In Gurney et al.’s (2013) study, participants watched footage of a crime scene and were later investigated by an experimenter who acted as a police interviewer. During the interview, no verbal misinformation was given but when asked “Did you notice any jewellery?”, the interviewer made either a gesture of a ring by pointing to a finger of the opposing hand or a gesture of a watch by grasping his wrist. The researchers found that more participants (30%) erroneously reported seeing a watch when a watch gesture was made than when a ring gesture was made (5%). Also, most participants (95%) reported seeing a ring when a ring gesture was made. In a similar research line, it was found that participants who saw a head nod of the interviewer reported higher confidence in their eyewitness reports than those who saw a head shake of the interviewer (Gurney, Vekaria, & Howlett, 2014).

More recently, Gurney, Ellis, and Vardon-Hynard (2016) examined whether subjective estimates of the nature and severity of the crime could be altered by misleading nonverbal information. Participants saw a video of a man punching another man in an alleyway and were then interviewed as eyewitnesses. The authors showed that a ‘punching’ gesture led participants to recall the crime more accurately, but a ‘stabbing’ gesture led more participants (61%) to recall that the victim was stabbed and severely injured compared with the punching condition (5.6%). The authors also noted that gestural misinformation had the same and sometimes even a larger memory contaminating effect than verbal misinformation.

**Misinformation concerning Eyewitness Identification**

Misinformation can directly lead eyewitnesses to misidentify innocent people in a lineup. For example, Searcy, Bartlett, and Memon (2000) had participants look at a recording of an actual crime, the murder of an attendant at a dry cleaner’s. Fifteen minutes later, participants had to listen to several narratives in which the witnessed crime was described. One narrative included misleading information that the perpetrator had a chipped tooth while in fact the perpetrator did not have a chipped tooth. Some hours later, participants were asked to identify the culprit in a lineup consisting of photographs of several suspects. Participants who received the misinformation were more likely to choose a person with a chipped tooth (25%) compared with those who did not receive the misinformation (6%).

Not only pre-identification misinformation (i.e., information provided before eyewitnesses make identifications from a lineup) undermines the accuracy of eyewitness memory, but also feedback after the eyewitness identification may distort eyewitness memory. In studies examining how post-identification feedback affects witnesses’ memory reports (e.g., Erickson, Lampinen, Wooten, Wetmore, & Neuschatz, 2016; Skagerberg & Wright, 2009; Smalarz & Wells, 2014; Wells, Olson, & Charman, 2003), participants are provided with either confirming feedback (e.g., “Good, you identified the suspect”) or no feedback after they identified a suspect from the lineup. The typical finding in these studies is that confirming feedback elevates participants’ confidence in their memories and they are more willing to testify in court compared with the no feedback condition. Obviously, this confidence inflation can become a serious issue when the suspect is innocent.

Steblay, Wells, and Douglass (2014) conducted a meta-analysis of this post-identification effect based on data of 21 studies involving 7,000 participants from the United States, Canada, Europe, and Australia. They found that when an innocent person was chosen from a lineup, confirming feedback increased witnesses’ memory clarity of the culprit, memory for culprit’s facial details, and their certainty in their (false) memories. The effect sizes of the post-identification effect on memory clarity and memory for facial details were medium to large in the reviewed studies (mean Cohen’s *d* of 0.69 and 0.65, respectively).

Many studies on post-identification effects have been conducted in the artificial environment of the laboratory. However, Wright and Skagerberg (2007) tested whether eyewitnesses (victims and bystanders) to real crimes would change their responses to meta-memory questions after receiving feedback from the police. The authors evaluated actual eyewitnesses in the United Kingdom and observed that after police officers told the witnesses that they identified the true culprit, witnesses claimed better memories for faces and events compared with those who were told by the police that they did not identify the true culprit.

**Misinformation from Co-witnesses**

Crimes often involve multiple witnesses and hence, discussions among co-witnesses are common. In September 2003, a famous Swedish politician, Ann Lindh was murdered in a shopping mall. Witnesses discussed and influenced each other while they were kept in a room, such that the police collected erroneuous information about the identity of the perpetrator. The perpetrator was finally caught on the basis of DNA traces, but he did not match the descriptions of the witnesses.[[3]](#footnote-3) Skagerberg and Wright (2008) studied the frequency of co-witness discussions at a UK Identification Suite. They found that 88% of the sampled eyewitnesses reported having seen co-witnesses at the crime scene and of these 58% discussed the crime with their co-witnesses on topics such as crime details and suspect details. This suggests that during such discussion, memory errors can easily be formed.

Indeed, discussions with co-witnesses can be a source of misinformation and thus influence witness’ memory reports; a phenomenon that has been called memory conformity (for possible mechanisms, see Wright, Memon, Skagerberg, & Gabbert, 2009). Gabbert, Memon, and Allan (2003) first used a novel procedure where pairs of participants watched a different video of the same event; they were later encouraged to discuss the event with each other. The large majority (71%) of witnesses falsely recalled items acquired during the discussion with other co-witnesses. Witnesses who initiated the discussion were most likely to impact the other witness’s memories (Gabbert, Memon, & Wright, 2006). Moreover, misinformation from familiar people (e.g., a friend or a romantic partner) has been shown to be more likely to be accepted than misinformation from a stranger (Hope, Ost, Gabbert, Healey, & Lenton, 2008). Recent research indicates that memory conformity is apparent in both children and adults (e.g., Otgaar, Howe, Brackmann, & van Helvoort, 2017).

Co-witness discussion can lead to eyewitness misidentification as well. Zajac and Henderson (2009) examined the impact of co-witness misinformation on lineup identification. Two witnesses viewed a video of a theft together and one witness (the confederate) falsely told the other that the thief had blue eyes when in fact the thief’s eyes were brown. The authors found that witnesses who were misinformed by their co-witnesses were twice (47.2%) as likely to identify a blued-eye suspect as those who were not misinformed (23.6%). Eisen, Gabbert, Ying, and Williams (2017) had witnesses misinformed by co-witnesses that the perpetrator had a tattoo on his neck. They manipulated the retention interval between receiving the misinformation and lineup identification. They found that wrongful identifications of the tattooed person increased significantly at longer retention intervals. After a one-week delay, there were more witnesses who chose the innocent person with a tattoo (44%) than those who chose the true culprit (34%). Even when the co-witness seemed unreliable (e.g., consumed alcohol), witnesses still accepted their co-witness’s misinformation and made wrongful identifications (Zajac, Dickson, Munn, & O’Neill, 2016).

**Endogenous false memories**

Apart from external misleading information, internal cognitive mechanisms can lead to the production of false memories. The typical research paradigm used to examine these endogenous false memories is the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). In the DRM paradigm, participants are shown lists of associated words, such as *bed, rest, awake*, and later they are asked to recall/recognize which words were shown to them. Participants usually remember non-presented but related critical lure words such as *sleep* as the words they had seen with very high confidence. Furthermore, they often falsely recollect these critical lures with rates that are indistinguishable from true memory rates (Roediger & McDermott, 1995). The false memory effect in the DRM paradigm has been shown to be a robust phenomenon in children and adults (Howe, 2005, 2006), using different stimuli (Hege & Dodson, 2004; Schacter, Israel, & Racine, 1999).

We term this type of memory illusions “endogenous” as the theoretical idea is that these illusions are caused by automatic spreading activation of mental representations (Howe, Wimmer, Gagnon, & Plumpton, 2009; Roediger, Balota, & Watson, 2001). That is, when witnesses view some items, related but not presented concepts will be automatically activated and this might create false memories of non-presented items. For example, Otgaar, Howe, Brackmann, and Smeets (2016) showed participants a video about a robbery in which a culprit entered the cafeteria and demanded money from the people at the cash desk. Associated items such as money, cahier, black jacket, masked hat, and a robber were shown in the video. However, without any misinformation, participants automatically formed a false memory for the presence of a gun in the video.

**Emotion and False Memory**

Emotion is one important factor that drives endogenous false memories. From a forensic perspective, this issue is relevant as people generally experience intense and/or negative emotions when facing a crime. Research found that 90% of the participants formed false memories for negative public events (e.g., the 911 terrorist attack), but only 41.7% of the participants had false memories for positive public events (Porter, Taylor, & ten Brinke, 2008). Research examining the effect of emotion on the production of spontaneous false memories present participants with different emotionally-laden lists (negative, positive) and then examine participants’ susceptibility in forming false memories. In general, research has revealed that false recognition rates for negative DRM lists are higher than for positive or neutral DRM lists (Brainerd, Holliday, Reyna, Yang, & Toglia, 2010; Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008; Howe, Candel, Otgaar, Malone, & Wimmer, 2010).

A crime scene may elicit not only a negatively valenced emotion such as fear and anger, but often also will induce high arousal. Brainerd et al. (2010) manipulated both valence and arousal of DRM lists. They found that negative emotion generated higher false memory rates than positive emotion and high arousal generated higher false memory rates than low arousal. Bookbinder and Brainerd (2017) administered negative, neutral, and positive pictures to participants while controlling the arousal level of the pictures. Negative pictures, like negative words, enhanced false memory on both an immediate and a one-week delay recognition tests. On the basis of the studies summarized in this section, we can safely conclude that both negative valence and high arousal enhance the production of false memories (Bookbinder & Brainerd, 2016; Kaplan, Van Damme, Levine, & Loftus, 2016).

**Stress and False Memory**

As negative emotional material fuels false memory formation, one might expect that stress – which is often experienced as negative – promotes false memory as well. However, studies examining the effects of stress on false memory have found mixed results. Payne, Nadel, Allen, Thomas, and Jacobs (2002) were the first to examine the effect of stress on false memory creation. In their study, participants were asked to give a speech so as to induce moderate psycho-social stress. Later, participants listened to DRM lists and then received a recognition test. Stress increased false memory rates compared with a no-stress condition.

However, this pattern has not been replicated in other studies. For example, Smeets, Jelicic, and Merckelbach (2006) followed a similar procedure as in Payne et al.’s (2002) study – a stress induction phase, a DRM study phase and a memory test phase. They also collected participants’ cortisol levels, which is a biological indicator of stress, at several times in the experiment as a check on the stress induction manipulation. In two studies, the authors did not find any evidence that stress increased false memory production. Furthermore, Smeets, Otgaar, Candel, and Wolf (2008) exposed participants to the cold pressor stress task (CPS) in which participants have to immerse their arm in ice-cold water for as long as possible. Again, there was no indication that false memory proneness was affected by levels of stress.

It seems that stress does not increase endogenous false memories, but it might impair true memories for peripheral details so that it makes witnesses highly susceptible to misinformation (i.e., creating exogenous false memories) (Kaplan et al., 2016). Morgan, Southwick, Steffian, Hazlett, and Loftus (2013) examined over 800 military personnel’s false memories for highly stressful events. Participants went through a highly stressful interrogation where they acted as a mock prisoner of war and were treated with physical assaults. Following the stressful event, a misinformation questionnaire was introduced and later participants’ memories for the aggressive interrogator were assessed. Around a half of the participants who received the misinformation identified the wrong individual as their interrogator.

**Prevention and Identification of False memories**

**Preventing False Memory and Promoting Accurate Memory**

The story so far is that false memories can be easily generated. However, researchers have devised several ways to prevent the occurrence of false memories and promote the retrieval of accurate memories. A general principle is to avoid giving suggestive information to witnesses during investigative interviews. One important step here is the construction of empirically validated interview protocols that maximize accurate reporting and minimize false reports. One well-studied interview protocol is the Cognitive Interview (CI). The CI is a protocol for interviewing witnesses and has been studied for more than 30 years. The CI is composed of several cognitive principles that may enhance accurate statements. During the CI, eyewitnesses undergo the following procedure (for details see Fisher & Schreiber, 2007). First, the interview starts in a friendly manner to build rapport with the witness, which will lower the stress that the witness experiences when facing a police investigator. Research has demonstrated that rapport building during CI decreases a witness’ susceptibility to misinformation for a mock-crime (Vallano & Compo, 2011). Next, the witness is encouraged to report everything recalled, without interruption from the interviewer, so the witness controls the flow of information instead of being led by the interviewer. Following this free-narrative phase, the interviewer probes the witness about the target event with open-ended questions, which, as reviewed above, leads to fewer false memories than closed questions. Memon, Meissner, and Fraser (2010) reviewed 25 years’ laboratory and field studies on the CI, and found that the CI led to a large and significant increase in correct details with only a small increase in errors compared with standard interviewing conditions.

Second, post-warnings are found to be effective in reducing false memories caused by misinformation. Post-warnings refer to warnings given to participants to the effect that some of the post-event information they received might be inaccurate. For instance, participants who received misinformation from their co-witnesses were warned later that their co-witnesses might have watched a different video, thus making the participants to reflect on their own memories (Paterson, Kemp, & Mclntyre, 2012). Blank and Launay (2014) conducted a meta-analysis of 25 studies from 1980s to 2010s on the effect of post-warnings. They found that post-warnings can reduce the original memory misinformation effect to 43% of its original (no-warning) size.

Third, using a blind lineup administration can prevent witnesses’ memories from distortion during lineup identification. In a blind lineup administration, the administrator does not know the identity of the suspect. A blind lineup can prevent the administrator from giving subtle hints such as an unconscious gesture to the witness. Thus, in a blind procedure, it is less likely that the administrator will intentionally or unintentionally lead the witness to identify a person on the basis of misinformation than during a non-blind lineup. Blind lineup administration can also reduce the post-identification effect such that witnesses’ confidence and judgements about their identifications do not escalate due to erroneous feedback (Dysart, Lawson, & Rainey, 2012).

**Distinguishing between True versus False memories**

False memories have been reported to contain fewer sensory details than true memories (e.g., Norman & Schacter, 1997), but there are also many cases where false memories are experienced as vividly like true memories (Foley, Bays, Foy, & Woodfield, 2015). With the development of brain scanning techniques such as the functional magnetic resonance imaging (fMRI), the neural differences between true and false memories provide possibilities to identify false from true memories. Neural correlates of true and false memories have been studied extensively in recent years. Slotnick and Schacter (2004; 2006) identified different activations in the sensory-processing brain areas for true and false memories. Similar to the DRM paradigm, participants in their studies viewed various shapes in the study phase, and then formed false memories for related but not presented shapes in the test phase. fMRI scanning of the test phase revealed that true memories had greater activation in early visual processing regions (Brodmann area 17, 18) than false memories. Okado, Stark, and Loftus (2010) used the misinformation paradigm where they presented participants with picture stimuli in the study phase, followed by misinformation one day later. They also found that true memories of visual stimuli were preferentially associated with early visual processing areas, which are normally involved in sensory encoding of visual stimuli (see also Atkins & Reuter-Lorenz, 2011).

Other studies showed that true memories for auditory stimuli were associated with activation in auditory sensory processing regions (e.g., left temporo-parietal cortex; Cabeza et al., 2001; Abe, Okuda, Suzuki, et al, 2008). On the basis of this type of results, Schacter, Chamberlain, Gaesser, and Gerlach (2011) proposed the *sensory reactivation hypothesis*, which holds that true memories are accompanied by retrieval of more sensory/perceptual details than false memories. This pattern would manifest itself in the reactivation of sensory/perceptual encoding brain regions that were engaged during the establishment of true but not false memories. Thus, when people have truly seen or heard target stimuli, brain areas that were engaged in processing the stimuli (e.g., early visual cortex) will be activated as soon as they try to retrieve memories of the targets. False memories lack such kind of activations as they have not been “seen” or “heard” before. The sensory reactivation hypothesis has been supported by recent studies (Dennis, Bowman, & Vandekar, 2012; Dennis, Johnson, & Peterson, 2014).

Researchers have explored the unique neural signature that is associated with false memories as well. In a recent study, Chadwick, Anjum, Kumaran, Schacter, Spiers, and Hassabis (2016) used fMRI to search for a neural code for false memories in the DRM paradigm. They manipulated the semantic overlap between studied items and critical lures from low to high. The computational analysis enabled them to test the neural overlap between DRM items and critical lures, corresponding to the semantic overlap between them. They found that patterns of activity in the temporal pole can predict false memories and that subject-specific temporal pole neural coding can predict individual false memories.

However, researchers are cautious when it comes to applying neuroimaging techniques in the courtroom to identify an individual’s memory as true or false. First, neuroimaging studies in the lab normally examine true and false memories for simple stimuli such as words and pictures, and brain activations induced by simple stimuli might be very different from activations of rich events such as a crime (Schacter & Loftus, 2013). What’s more, although researchers found neural differences between true and false memories, those differences are based on the summaries of brain activities in a group of participants, making it hard to apply the results to a single participant (Van de Ven, Otgaar, & Howe, in press). Recently there are studies showing neural decoding of individual (false) memories (e.g., Chadwick et al., 2016), but the differentiation between false and true memories is at present far from 100% accurate. Still, as neuroimaging techniques develop and more complex stimuli are examined, it looks promising to distinguish false from true memories at the neural level, particularly because it is almost impossible to distinguish false from true memories at the behavioral level (Bernstein & Loftus, 2009).

**Conclusions and Future Directions for China**

We reviewed two types of false memories (exogenous vs. endogenous) and their possible consequences in eyewitness testimony. Exogenous false memories may occur after people receive external misinformation, which can be suggestive questions or gestures during interview, misleading information pre- or post-lineup identification, or false information from a co-witness. Endogenous false memories are generated by internal cognitive mechanisms without external misleading information, and can be inflated by negative emotion and high arousal. Overall, false memories can lead to wrong descriptions of the perpetrator or the crime that may guide the investigation into a wrong direction, or more directly, cause eyewitnesses to misidentify an innocent person as the perpetrator. We also reviewed that designated interview protocols such as the CI, blind lineup administration, and post-warnings could prevent or lower the chance of false memory occurrence.

In returning now to the cases that were presented at the beginning, we may find several factors very relevant to what we have reviewed here. For example, Haisheng Zhang was not only misidentified by the victim, but also by three other teenage girls who lived in the same village. Being co-witnesses who knew each other well, the girls probably talked to each other and reached memory conformity in the end. Moreover, Zhang’s lawyer presented evidence at the court that the police said to the girls to “look carefully at the shoes” during the lineup identification, which might be a suggestive hint, but the court seems to have overlooked this and convicted Zhang as guilty of rape.

In the case of Jibin Xu, the court relied heavily on the statements of the victim witness that Xu was the perpetrator. At Xu’s first trial, he proposed that the victim was lying to imprison him, yet the court was not convinced by this alternative explanation. It is unknown whether the witness was lying or merely had a false memory, but this case is very similar to the many cases archived in the Innocence Project ([www.innocenceproject.org](http://www.innocenceproject.org)) where witnesses had false memories about the perpetrators. If the risk of false memory had been widely acknowledged by practitioners in the legal system at that time, Xu might have avoided the destiny of spending 8 years in prison.

Fortunately, lessons have already been learnt by countries in North America and Europe, and those lessons might inform police and local courts in China about what are the best to protect innocent people from being criminalized by false memories. For instance, in the United States, the supreme court of New Jersey issued a ruling that the unreliability of memory should be taken into account when evaluating eyewitness identification evidence in court (State v. Henderson, 2011). The Criminal Procedure Law of the P.R. China has been revised in 2012, in which eyewitness testimony is listed as one of the main categories of evidence (Article 42) and the testimony of a witness may be used as a basis in deciding a case under certain circumstances (Article 47), but no specific rule is written in regulating eyewitness identification processes such as lineup administration. In practice, the Public Security Organs and the People’s Procuratorate provide provisions that the identification should be hosted by investigation or prosecution personnel, and 97% of the identifications in China are carried out by investigators who undertook the case (Chen, 2015). The aforementioned situations may be prone to the risk factors of false memories such as unintentional misinformation and suggestion. In our opinion, several steps are needed to increase awareness concerning the importance of eyewitness testimony and false memories in Chinese legal cases.

We contend that improving awareness of false memories in the legal arena is perhaps the first step to start. Memories are more prone to errors than many people think. It is especially important for judges, lawyers, and the police to be *aware* of that. Knowledge about how memory works and how to prevent false memories can be shared in ways of workshops and seminars (Loftus, 2003). This is important as many legal professionals possess flawed ideas concerning the functioning of memory (i.e., memory is like video-taping). A first direction could be to educate legal professionals such as the police about the science of memory and its relevance to courts of law. Such interventions might help legal professionals to get rid of their biases regarding the functioning of memory (Lilienfeld, Ammirati, & Landfield, 2009). A second important follow-up step would be to collaborate closely with legal professionals and attempt to launch several actions in investigative and juridical processes to *prevent* false memories, such as the use of empirically-validated interview protocols and blind lineup identification and launching new laws and regulations on organization and administration of eyewitness identification. Such actions have already taken place in countries such as the UK and the Netherlands.

Finally, other measures can be taken by actively *recognizing* the possibility of false memory occurrence in legal practice. An ideal route to accomplish this is when triers of fact more often consult memory experts in legal cases. In many countries, expert witnesses who are memory researchers as well are called upon to provide their expert opinion concerning a memory-related issue in a case such as the disclosure of child’s statements on sexual abuse (Otgaar & Howe, in press). Such experts might considerably assist judges and lawyers in such and might help judges in reaching legal decisions grounded in memory science. For instance, Wise and Safer (2012) designed a toolkit to analyze the trustworthiness of eyewitness testimony by evaluating the risky factors step by step that we have reviewed above.

The rapid urbanization in China is making this issue even more urgent and challenging. According to the data from the National Bureau of Statistics of China[[4]](#footnote-4), up to 2016, there are 156 cities in China with populations more than one million, in which 13 cities have populations over ten million. Up to 2016, there are 792 million people inhabiting cities with different scales. China has more than 50 ethnic groups with different cultures and religions, such as Uygur, Tibet, and Mongolian. Misinformation and stereotypes of people from different ethnicities and backgrounds may boost the malleability of memory leading to wrong convictions, since criminal proceedings are to a large extent dependent on what eyewitnesses report. Nevertheless, the purpose of the review is not to leave the impression that eyewitnesses are wrong all the time or even most of the times. Eyewitnesses may often attain impressive accuracy and in many cases, eyewitnesses contribute critically to fair and just legal proceedings. Our review of the literature was an attempt to further increase the trust that triers of fact can place in eyewitnesses by excluding conditions that promote false memories.

**Acknowledgement**

This paper has been supported by a fellowship from the China Scholarship Council (CSC) to Jianqin Wang [No. 201406100057], and by a grant from the Ministry of Education in China (MOE) Project of Humanities and Social Sciences [No. 11YJA190026] to Chu Zhou.

References

Abe, N., Okuda, J., Suzuki, M., Sasaki, H., Matsuda, T., Mori, E., ... & Fujii, T. (2008). Neural correlates of true memory, false memory, and deception. *Cerebral Cortex*, *18*, 2811-2819.

Atkins, A. S., & Reuter-Lorenz, P. A. (2011). Neural mechanisms of semantic interference and false recognition in short-term memory. *NeuroImage*, *56*, 1726-1734.

Bernstein, D. M., & Loftus, E. F. (2009). How to tell if a particular memory is true or false. *Perspectives on Psychological Science*, *4*, 370-374.

Blank, H., & Launay, C. (2014). How to protect eyewitness memory against the misinformation effect: A meta-analysis of post-warning studies. *Journal of Applied Research in Memory and Cognition*, *3*, 77-88.

Bookbinder, S. H., & Brainerd, C. J. (2016). Emotion and false memory: The context–content paradox. *Psychological Bulletin, 142*, 1315-1351.

Bookbinder, S. H., & Brainerd, C. J. (2017). Emotionally negative pictures enhance gist memory. *Emotion, 17*, 102-119.

Brainerd, C. J., Holliday, R. E., Reyna, V. F., Yang, Y., & Toglia, M. P. (2010). Developmental reversals in false memory: Effects of emotional valence and arousal. *Journal of Experimental Child Psychology, 107*, 137-154.

Brainerd, C. J., Stein, L. M., Silveira, R. A., Rohenkohl, G., & Reyna, V. F. (2008). How does negative emotion cause false memories? *Psychological Science, 19*, 919-925.

Cabeza, R., Rao, S. M., Wagner, A. D., Mayer, A. R., & Schacter, D. L. (2001). Can medial temporal lobe regions distinguish true from false? An event-related functional MRI study of veridical and illusory recognition memory. *Proceedings of the National Academy of Sciences*, *98*, 4805-4810.

Chadwick, M. J., Anjum, R. S., Kumaran, D., Schacter, D. L., Spiers, H. J., & Hassabis, D. (2016). Semantic representations in the temporal pole predict false memories. *Proceedings of the National Academy of Sciences*, *113*, 10180-10185.

Chen, X. (2015). *Eyewitness identification research: from the perspectives of Law and Psychology* (*pp.*83–84). Beijing, China: China Procuratorate Press. (in Chinese)

Chen, Y. (2007). A perspective on miscarriage of justice in China: An analysis based on 20 famous wrongful convicted cases. *China Legal Science, 3,* 45-61. (in Chinese)

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology,* *58*, 17–22.

Dennis, N. A., Bowman, C. R., & Vandekar, S. N. (2012). True and phantom recollection: an fMRI investigation of similar and distinct neural correlates and connectivity. *Neuroimage*, *59*, 2982-2993.

Dennis, N. A., Johnson, C. E., & Peterson, K. M. (2014). Neural correlates underlying true and false associative memories. *Brain and Cognition*, *88*, 65-72.

Dysart, J. E., Lawson, V. Z., & Rainey, A. (2012). Blind lineup administration as a prophylactic against the postidentification feedback effect. *Law and Human Behavior*, *36*, 312-319.

Eisen, M. L., Gabbert, F., Ying, R., & Williams, J. (2017). “I think he had a tattoo on his neck”: How co-witness discussions about a perpetrator's description can affect eyewitness identification decisions. *Journal of Applied Research in Memory and Cognition*.

Erickson, W. B., Lampinen, J. M., Wooten, A., Wetmore, S., & Neuschatz, J. (2016). When snitches corroborate: effects of post-identification feedback from a potentially compromised source. *Psychiatry, Psychology and Law*, *23*, 148-160.

Fisher, R. P., & Schreiber, N. (2007). Interviewing protocols to improve eyewitness memory. *The handbook of eyewitness psychology*, *1*, 53-80.

Foley, M. A., Bays, R. B., Foy, J., & Woodfield, M. (2015). Source misattributions and false recognition errors: Examining the role of perceptual resemblance and imagery generation processes. *Memory*, *23*, 714-735.

Frenda, S. J., Nichols, R. M., & Loftus, E. F. (2011). Current issues and advances in misinformation research. *Current Directions in Psychological Science*, *20*, 20-23.

Gabbert, F., Memon, A., & Allan, K. (2003). Memory conformity: Can eyewitnesses influence each other's memories for an event?. *Applied Cognitive Psychology*, *17*, 533-543.

Gabbert, F., Memon, A., & Wright, D. B. (2006). Memory conformity: Disentangling the steps toward influence during a discussion. *Psychonomic Bulletin & Review*, *13*, 480-485.

Garrett, B. L. (2011). *Convicting the innocent*. Cambridge, MA: Harvard University Press.

Gurney, D. J., Ellis, L. R., & Vardon-Hynard, E. (2016). The saliency of gestural misinformation in the perception of a violent crime. *Psychology, Crime & Law*, *22*, 651-665.

Gurney, D. J., Pine, K. J., & Wiseman, R. (2013). The gestural misinformation effect: skewing eyewitness testimony through gesture. *The American Journal of Psychology*, *126*, 301-314.

Gurney, D. J., Vekaria, K. N., & Howlett, N. (2014). A nod in the wrong direction: Does non-verbal feedback affect eyewitness confidence in interviews *Psychiatry, Psychology and Law*, *21*, 241-250.

Hege, A. C., & Dodson, C. S. (2004). Why distinctive information reduces false memories: evidence for both impoverished relational-encoding and distinctiveness heuristic accounts. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 787-795.

Hope, L., Ost, J., Gabbert, F., Healey, S., & Lenton, E. (2008). “With a little help from my friends…”: The role of co-witness relationship in susceptibility to misinformation. *Acta Psychologica*, *127*, 476-484.

Howe, M. L. (2005). Children (but not adults) can inhibit false memories. *Psychological Science*, *16*, 927-931.

Howe, M. L. (2006). Developmentally invariant dissociations in children’s true and false memories: Not all relatedness is created equal. *Child Development*, *77*, 1112-1123.

Howe, M. L., Candel, I., Otgaar, H., Malone, C., & Wimmer, M. C. (2010). Valence and the development of immediate and long-term false memory illusions. *Memory*, *18*, 58-75.

Howe, M. L., & Knott, L. (2015). The fallibility of memory in judicial processes: Lessons from the past and their modern consequences. *Memory, 23*, 633–656.

Howe, M. L., Knott, L. M., & Conway, M. A. (2018). *Memory and miscarriages of justice.* Abingdon, UK: Routledge.

Howe, M. L., Wimmer, M. C., Gagnon, N., & Plumpton, S. (2009). An associative-activation theory of children’s and adults’ memory illusions. *Journal of Memory and Language*, *60*, 229-251.

Kaplan, R. L., Van Damme, I., Levine, L. J., & Loftus, E. F. (2016). Emotion and false memory. *Emotion Review, 8*, 8-13.

Kebbell, M. R., & Giles, D. C. (2000). Some experimental influences of lawyers' complicated questions on eyewitness confidence and accuracy. *The Journal of Psychology*, *134*, 129-139.

Kebbell, M. R., Evans, L., & Johnson, S. D. (2010). The influence of lawyers' questions on witness accuracy, confidence, and reaction times and on mock jurors' interpretation of witness accuracy. *Journal of Investigative Psychology and Offender Profiling*, *7*, 262-272.

Kebbell, M. R., & Johnson, S. D. (2000). Lawyers' questioning: The effect of confusing questions on witness confidence and accuracy. *Law and Human Behavior*, *24*, 629-641.

Lilienfeld, S. O., Ammirati, R., & Landfield, K. (2009). Giving debiasing away: Can psychological research on correcting cognitive errors promote human welfare? *Perspectives on Psychological Science, 4*, 390-398.

Loftus, E. F. (1975). Leading questions and the eyewitness report. *Cognitive Psychology*, *7*, 560-572.

Loftus, E. (2003). Our changeable memories: Legal and practical implications. *Nature Reviews. Neuroscience*, *4*, 231-234.

Loftus, E. F. (2004). Memories of things unseen. *Current Directions in Psychological Science*, *13*, 145-147.

Loftus, E. F. (2005). Planting misinformation in the human mind: A 30-year investigation of the malleability of memory. *Learning & Memory*, *12*, 361-366.

Loftus, E. F. (2013). 25 years of eyewitness science…… finally pays off. *Perspectives on Psychological Science*, *8*, 556-557.

Memon, A., Meissner, C. A., & Fraser, J. (2010). The Cognitive Interview: A meta-analytic review and study space analysis of the past 25 years. *Psychology, Public Policy, and Law, 16*, 340-372.

Morgan, C. A., Southwick, S., Steffian, G., Hazlett, G. A., & Loftus, E. F. (2013). Misinformation can influence memory for recently experienced, highly stressful events. *International Journal of Law and Psychiatry, 36*, 11-17.

Norman, K. A., & Schacter, D. L. (1997). False recognition in younger and older adults: Exploring the characteristics of illusory memories. *Memory & Cognition*, *25*, 838-848.

Otgaar, H., Candel, I., Merckelbach, H., & Wade, K. A. (2009). Abducted by a UFO: Prevalence information affects young children's false memories for an implausible event. *Applied Cognitive Psychology*, *23*, 115-125.

Otgaar, H., & Howe, M.L. (in press). *Finding the truth in the courtroom: Dealing with deception, lies, and memories*. Oxford University Press.

Otgaar, H., Howe, M. L., Brackmann, N., & Smeets, T. (2016). The malleability of developmental trends in neutral and negative memory illusions. *Journal of Experimental Psychology: General, 145*, 31.

Otgaar, H., Howe, M. L., Brackmann, N., & van Helvoort, D. H. (2017). Eliminating age differences in children’s and adults’ suggestibility and memory conformity effects. *Developmental Psychology*, *53*, 962-970.

Otgaar, H., Sauerland, M., & Petrila, J. P. (2013). Novel shifts in memory research and their impact on the legal process: introduction to the special issue on memory formation and suggestibility in the legal process. *Behavioral Sciences & the Law*, *31*, 531-540.

Paterson, H. M., Kemp, R., & McIntyre, S. (2012). Can a witness report hearsay evidence unintentionally? The effects of discussion on eyewitness memory. *Psychology, Crime & Law*, *18*, 505-527.

Peterson, J. L., Hickman, M. J., Strom, K. J., & Johnson, D. J. (2013). Effect of forensic evidence on criminal justice case processing. *Journal of Forensic Sciences, 58*, 78-90.

Payne, J. D., Nadel, L., Allen, J. J., Thomas, K. G., & Jacobs, W. J. (2002). The effects of experimentally induced stress on false recognition. *Memory, 10*, 1-6.

Porter, S., Taylor, K., & ten Brinke, L. (2008). Memory for media: Investigation of false memories for negatively and positively charged public events. *Memory, 16*, 658-666.

Roediger III, H. L., Balota, D. A., & Watson, J. M. (2001). Spreading activation and arousal of false memories. In H. L. Roediger III, J. S. Nairne, I. Neath, & A. M. Surprenant (Eds), *The nature of remembering: Essays in honor of Robert G. Crowder* (pp. 95-115). Washington DC: American Psychological Association.

Roediger, H.L., & McDermott, K.B. (1995). Creating false memories: remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *21*, 803–14.

Schacter, D. L. (2012). Adaptive constructive processes and the future of memory. *American Psychologist*, *67*, 603–613.

Schacter, D.L., Chamberlain, J., Gaesser, B. & Gerlach, K. Neuroimaging of true, false, and imaginary memories. in *Memory and Law* (ed. L. Nadel & W.P. Sinnott-Armstrong) 233-262. (Oxford University Press, New York, NY, 2012).

Schacter, D. L., Israel, L., & Racine, C. (1999). Suppressing false recognition in younger and older adults: The distinctiveness heuristic. *Journal of Memory and Language, 40,* 1-24.

Schacter, D. L., & Loftus, E. F. (2013). Memory and law: what can cognitive neuroscience contribute? *Nature neuroscience*, *16*, 119-123.

Searcy, J., Bartlett, J. C., & Memon, A. (2000). Influence of post‐event narratives, line‐up conditions and individual differences on false identification by young and older eyewitnesses. *Legal and Criminological Psychology*, *5*, 219-235.

Sharman, S. J., & Powell, M. B. (2012). A comparison of adult witnesses' suggestibility across various types of leading questions. *Applied Cognitive Psychology*, *26*, 48-53.

Skagerberg, E. M., & Wright, D. B. (2008). The prevalence of co-witnesses and co-witness discussions in real eyewitnesses. *Psychology, Crime & Law*, *14*, 513-521.

Skagerberg, E. M., & Wright, D. B. (2009). Susceptibility to postidentification feedback is affected by source credibility. *Applied Cognitive Psychology*, *23*, 506-523.

Slotnick, S. D., & Schacter, D. L. (2004). A sensory signature that distinguishes true from false memories. *Nature Neuroscience*, *7*, 664-672.

Slotnick, S. D., & Schacter, D. L. (2006). The nature of memory related activity in early visual areas. *Neuropsychologia*, *44*, 2874-2886.

Smalarz, L., & Wells, G. L. (2014). Post-identification feedback to eyewitnesses impairs evaluators’ abilities to discriminate between accurate and mistaken testimony. *Law and Human Behavior*, *38*, 194-202.

Smeets, T., Jelicic, M., & Merckelbach, H. (2006). The effect of acute stress on memory depends on word valence. *International Journal of Psychophysiology, 62*, 30-37.

Smeets, T., Otgaar, H., Candel, I., & Wolf, O. T. (2008). True or false? Memory is differentially affected by stress-induced cortisol elevations and sympathetic activity at consolidation and retrieval. *Psychoneuroendocrinology, 33*, 1378-1386.

Stark, C. E., Okado, Y., & Loftus, E. F. (2010). Imaging the reconstruction of true and false memories using sensory reactivation and the misinformation paradigms. *Learning & Memory*, *17*, 485-488.

State v. Henderson (2011), 208 N.J. 208.

Steblay, N. K., Wells, G. L., & Douglass, A. B. (2014). The eyewitness post identification feedback effect 15 years later: Theoretical and policy implications. *Psychology, Public Policy, and Law, 20*, 1-18.

Vallano, J. P., & Compo, N. S. (2011). A comfortable witness is a good witness: Rapport‐building and susceptibility to misinformation in an investigative mock‐crime interview. *Applied Cognitive Psychology*, *25*, 960-970.

Van de Ven, V., Otgaar, H., & Howe, M. L. (2017). A neurobiological account of false memories. In *Finding the truth in the courtroom: Dealing with deception, lies, and memories*. Oxford University Press.

Wells, G. L., Olson, E. A., & Charman, S. D. (2003). Distorted retrospective eyewitness reports as functions of feedback and delay. *Journal of Experimental Psychology: Applied*, *9*, 42-52.

Wise, R. A., & Safer, M. A. (2012). A method for analyzing the accuracy of eyewitness testimony in criminal cases. *Court Review, 48*, 22-34.

Wright, D. B., & Skagerberg, E. M. (2007). Postidentification feedback affects real eyewitnesses. *Psychological Science*, *18*, 172-178.

Wright, D. B., Memon, A., Skagerberg, E. M., & Gabbert, F. (2009). When eyewitnesses talk. *Current Directions in Psychological Science*, *18*, 174-178.

Zajac, R., Dickson, J., Munn, R., & O'neill, S. (2016). Trussht me, I know what I sshaw: The acceptance of misinformation from an apparently unreliable co‐witness. *Legal and Criminological Psychology*, *21*, 127-140.

Zajac, R., & Henderson, N. (2009). Don't it make my brown eyes blue: Co-witness misinformation about a target's appearance can impair target-absent line-up performance. *Memory*, *17*, 266-278.

1. http://news.sina.com.cn/c/2005-04-14/04075642673s.shtml [↑](#footnote-ref-1)
2. http://news.sina.com.cn/c/2007-03-20/120311454076s.shtml [↑](#footnote-ref-2)
3. https://en.wikipedia.org/wiki/Memory\_conformity [↑](#footnote-ref-3)
4. http://data.stats.gov.cn/easyquery.htm?cn=C01&zb=A0B01&sj=2016 [↑](#footnote-ref-4)