Bialer, D. M., Reyna, V. F., & Brainerd, C. J. (2021). False memory: What are the effects, how does fuzzy-trace theory predict them, and how does this matter for eyewitness testimony? In A. M. Smith, M. P. Toglia, & J. M. Lampinen (Eds.), *Methods, measures, and theories in eyewitness identification tasks.* New York, NY: Taylor and Francis.

14

FALSE MEMORY

What are the Effects, How Does Fuzzy-Trace Theory Predict Them, and How Does this Matter for Eyewitness Testimony?

Daniel M. Bialer, Valerie F. Reyna, and Charles J. Brainerd

The purpose of this chapter is to explain the crucial role of theory in developing useful scientific methodologies for research on eyewitness testimony and, ultimately, in improving legal policies and practices. It is not news that legal policies and practices should be evidence-based. When policy makers and practitioners make assumptions about the factors that affect the accuracy of eyewitness testimony, innocent defendants can be convicted and guilty ones can go free. Although we are long past assuming that eyewitness testimony is prima facie accurate, there are still important mysteries about memory that affect the veracity of eyewitness testimony in surprising ways. We discuss many of those mysteries here, explaining how they are predicted by fuzzy-trace theory (FTT) and how laboratory studies translate to real-world eyewitness testimony.

Two crucial themes underlie our claims. First, theory is necessary, not just nice, in order to measure processes that affect eyewitness testimony and to translate research evidence into effective practice. Without theory, our measures often fall short because we average over or ignore countervailing forces. We present examples of such forces as follows. Some of these forces help improve eyewitness testimony and others harm it; ignoring these forces means that we miss opportunities to make the legal system more effective and more just. Measurement, therefore, never occurs in a theoretical vacuum. When we measure, we make assumptions that are theoretical—they concern causal mechanisms. Ignorance and miscarriages of justice prevail when we do not take those assumptions seriously and test them, as we do in scientific research.

Second, in the zeal to translate research into practice, researchers increasingly disparage basic laboratory research, arguing that it does not extend to real-world situations, such as the courtroom (for a discussion, see Brainerd & Reyna, 2012). This argument varies from claims that translation must be tested in field studies to

be trustworthy to the categorical assertion that "artificial" laboratory studies could not possibly apply to the real world. These claims draw on stereotypes that are not backed up by evidence. Although it is true that laboratory studies sometimes do not translate to real-world situations, they often do translate in an ecologically relevant manner (see Reyna, Mills, Estrada, & Brainerd, 2006). Well-done laboratory studies that test fundamental laws of memory always apply to the real world, just as the double helix of DNA always applies to genetics in healthcare (e.g., genetic testing). However, the real world combines many causal factors, so the effect of any one factor might not be obvious without proper measurement. Naturally, it is crucial to know where and when the factors apply and to whom, but that, too, is integral to theory. What aspects of practice cause what effects on eyewitness accuracy and how they do it—that is the province of theory. Some of the most replicated effects in the real world were first discovered by studying memory for nonsense syllables under tightly controlled conditions. That led to laws of learning and forgetting that provide powerful explanations of memory in classrooms and courtrooms.

Moreover, possessing some scientific evidence that is rigorously demonstrated is far better than possessing no evidence; we shortchange practice when we fail to connect research to practice, and instead empower superstition and speculation. All research, in the laboratory or in the field, has boundary conditions and uncertainties. The received wisdom of today will inevitably be modified by the research of tomorrow. There is no "truth" but there are tested hypotheses that explain and predict. Large effect sizes and replications help, but they are not panaceas and are a poor substitute for actually understanding (and testing) causal mechanisms.

Specifically, we discuss a series of effects that are manifested in the real world and that surprise our intuitions. Laboratory research has shown that witnesses can assert the reality of events that never happened with great confidence; that this effect can be reversed by strengthening one type of memory that is different from another type; that memory is not one thing and that one type of memory does not forget easily and the other one does; that false memory often draws on ordinary processes of meaning-making that are rife in the real world; that falsifying processes of memory are suppressed close to an event but emerge unopposed later, and contribute to inconsistencies in memory reports that seem like lies but are not lies; that "pristine" lineups under immediate testing conditions are effective to the degree that they tap one type of memory rather than another; that confidence in testimony is affected by which type of memory is accessed at the time; that talking and remembering can interfere with one another in surprising ways explained by FTT; that ordinary people will remember the suspect being the perpetrator and the suspect not being the perpetrator at the same time, and not be lying or guessing; and, finally, that age affects the types of memories that witnesses tap in ways predicted by theory.

The probability of each of these phenomena augmenting or detracting from witness accuracy can be estimated to some degree by studying dispositional and situational features of testimony, including the delay between events and memory reports as well as testing conditions (e.g., how old is the witness, how was the

memory question phrased, what cues were provided in the question, and so on). As with other kinds of forensic evidence, these considerations can increase or decrease the chances that a suspect is guilty, although they do not, especially by themselves, pinpoint the exact probability (Neumann, Kaye, Jackson, Reyna, & Ranadive, 2016; Poldrack et al., 2018). Although many of the phenomena were studied with word lists, as we discuss later, these FTT processes have been replicated in research on memory for sentences, pictures, narratives, and events (e.g., Brainerd, Reyna, & Estrada, 2006; Reyna, Corbin, Weldon, & Brainerd, 2016).

False Recognition

What Is the Effect?

The false recognition effect is a pervasive finding in the memory literature (Brainerd, Reyna, & Kneer, 1995). The basic premise of the effect is that when people are presented with new items, they are more likely to incorrectly identify them as old if they are related to previously observed items. The most common experimental paradigm in which this is observed is the Deese-Roediger-McDermott (DRM) procedure (Deese, 1959; Roediger & McDermott, 1995). In a DRM recognition procedure, participants are first presented with lists of semantically related words, or target items. For example, one list might include: APPLE, VEGETABLE, ORANGE, KIWI, CITRUS, RIPE. Following this, participants complete a test phase in which they must either accept individual words as previously presented targets or reject them as new. These test items can be split into three categories: old items (O, previously presented words, e.g., APPLE), new-similar items (NS, new and semantically similar words, e.g., FRUIT), and new-different items (ND, new and semantically different words, e.g., DOG).

In DRM experiments, the false recognition effect is observed as a pattern in which NS items are incorrectly accepted as old at significantly higher rates than are ND items. While identification of both NS and ND items as old might imply guessing, the pattern of greater acceptance of NS as compared to ND items suggests that participants are falsely recognizing certain words as old.

How Does FTT Predict This Effect?

Signal-detection theory (SDT) provides an early explanation of recognition (Green & Swets, 1966; Macmillan & Creelman, 1991; Parks, 1966). According to SDT, recognition is the result of a single retrieval process known as familiarity. When familiarity for an item is strong enough to pass a certain threshold, that item is identified as old. When familiarity is below the same threshold, it is identified as new. While this single-process theory can explain the quick decisions made when a memory is very strong or weak, it does not differentiate these decisions from the slower and more careful decisions that are made when memory strength is more

intermediate. Dual-process theories of recognition have been proposed to better account for this distinction between fast and slow recognition (Atkinson & Juola, 1973, 1974; Atkinson & Wescourt, 1975; Juola, Fischler, Wood, & Atkinson, 1971). Like single-process theories, dual-process theories propose that people will identify a test item as old if the familiarity of the item is above a certain threshold; however, they also suggest that in order to identify a test item as new, familiarity must be below a separate, lower threshold. When the strength of the memory is between these two thresholds, a second, slower process known as recollection occurs.

FTT extends dual-process theories further by explaining false memories in addition to true memories. FTT postulates that memories are stored in parallel as verbatim and gist traces. Verbatim traces are representations of the specific surface details of an item. Conversely, gist traces are "bigger picture" representations of the general meaning of an item.

For true memories, verbatim and gist traces both promote correct identification of an O test item as old. When presentation of an O test item provokes retrieval of verbatim traces of a target, a person engages in recollection by comparing the verbatim representation of the test item directly with verbatim memories of the target. In this case, the test item and target are perceived as identical and the target is identified as old. When only gist traces are available, a person will instead rely on familiarity by comparing the gist representation of the test item with the gist memory of the targets. In this case, the test item is also identified as old because it matches the general meaning of the targets.

In contrast, for false memories, verbatim and gist retrieval are considered opponent processes. When presentation of an NS test item provokes retrieval of verbatim memory of a target, a person engages in recollection rejection by comparing the verbatim representation of the test item directly with verbatim memory of the target. In this case, they are perceived as different from one another and the test item is rejected as new. When presentation of an NS test item provokes retrieval of only gist memory of a target, however, a person relies on familiarity by comparing the gist representation of the test item with the gist memory of the targets, and will thus incorrectly identify the test item as old due to shared semantic content (see Table 14.1).

TABLE 14.1 Effect of verbatim and gist trace retrieval on acceptance of old and new-similar test cues.

Test Cue	*Verbatim Traces*	*Gist Traces*
Old (O)	Correct Acceptance	Correct Acceptance
New-Similar (NS)	Correct Rejection	False Memory

Note: Verbatim and gist traces work in tandem for true memory: both promote correctly accepting O test cues as old. In contrast, verbatim and gist traces operate as opponent processes in false memory: verbatim traces promote correct rejection of NS test cues and gist traces promote incorrect acceptance of NS test cues as old due to false memory.

How Does This Apply to Eyewitness Testimony?

Eyewitness identifications are often not conducted under the perfect circumstances. Resultingly, witnesses do not always have access to verbatim traces of a criminal by the time they make an identification from a lineup. When reasoning based on gist traces, witnesses may falsely recognize innocent lineup members as criminals based on shared basic features between the lineup member and the criminal. This false recognition can have significant consequences in the legal system. Since 1989, 367 people in the United States have been exonerated of crimes for which they were wrongfully convicted (Innocence Project, 2020). Eyewitness misidentifications were involved in 69% of these wrongful convictions (Innocence Project, 2020).

False Recognition Reversal

What Is the Effect?

While the false recognition effect is a pervasive finding in the literature, it does not hold universally (Brainerd et al., 1995). Based on false recognition, it would be logical to expect that increasing the degree to which a test item provokes familiarity should lead to more false alarms. This, however, is not always the case. Many studies have found, for example, that increasing a test item's physical similarity to target items can actually reduce false alarms (Brainerd & Mojardin, 1998; Israel & Schacter, 1997; Reyna & Kiernan, 1994; Schacter, Israel, & Racine, 1999; Tulving, 1981). Similarly, repetition of target words should increase familiarity for the meaning of NS test items, but it has been found to either have no effect (Shiffrin, Huber, Marinelli, 1995; Tussing & Greene, 1997, 1999) or to also reduce the number of false alarms (Brainerd et al., 1995; Hall & Kozloff, 1970; Tussing & Greene, 1999). In fact, cases in which NS items produce fewer false alarms than ND items do have been observed in the literature (Brainerd et al., 1995; MacLeod & Nelson, 1976). These studies illustrate a pattern in which the false recognition effect is reversed: those items that are less familiar produce higher false alarm rates than those that are more familiar.

How Does FTT Predict This Effect?

Recall that SDT suggests that recognition is a single-process theory where the more familiar a test item is, the more likely it will be accepted as old, regardless of whether the test item is in reality old or new (Green & Swets, 1966; Macmillan & Creelman, 1991; Parks, 1966). This theoretical approach is consistent with constructivist theory, which suggests that there is a positive dependency between reasoning and memory (Reyna & Kiernan, 1994). According to constructivism and many other information-processing theories, reasoning tasks, such as the

systematic acceptance of NS test items, are dependent on memory for inputs, such as those for the presented target items (Bryant & Trabasso, 1971; Smedslund, 1969). Resultingly, false recognition reversal cannot be explained by these theories, as reversal is defined by a pattern of greater familiarity leading to fewer false alarms (Tussing & Greene, 1999).

Conversely, it has been theorized that the dependency between reasoning and memory is negative. Numerous studies, particularly those testing the misinformation effect, have found that better memory for targets leads to fewer false alarms for NS items (Ceci, Ross, & Toglia, 1987; Howe, 1991; Loftus & Hoffman, 1989; Loftus, Levidow, & Duensing, 1992; Tousignant, Hall, & Loftus, 1986). While this theory accounts for the pattern found with false recognition reversal, it does not account for the ubiquitous finding of a pattern of more false alarms for NS than for ND test items (Brainerd et al., 1995).

FTT, in contrast, proposes that memory (when verbatim-based) and reasoning (when gist-based) are independent (Reyna & Brainerd, 1995). Consider that FTT postulates that gist and verbatim traces of a target are stored separately. Recall also that gist and verbatim traces are opposing processes in false memory (gist traces support false alarms while verbatim traces suppress false alarms; Brainerd & Reyna, 2005). When test items become more familiar, for example, due to increased physical similarity with targets or due to repetition of the target items, gist memory for the targets increases. This should lead to an increase in false alarms, which is consistent with the false recognition effect. However, these manipulations also lead to an increase in verbatim memory for target items at presentation of NS test items. This allows for a contrast between the verbatim details of the target item and NS test item to be made, leading to fewer false alarms and thus a pattern of false recognition reversal. As people favor verbatim processing over gist processing in episodic memory tasks, when verbatim memories for target items are accessible, FTT would predict that manipulations which increase verbatim memory should lead to fewer false alarms for NS items.

How Does This Apply to Eyewitness Testimony?

Research on false recognition reversal challenges the notion that test items that are more similar to targets will be falsely identified at greater rates. This information can be used to better evaluate eyewitness testimony. For example, these findings tell us that eyewitnesses who witnessed an event more recently or for a longer amount of time might be less prone to false alarms due to increased reliance on verbatim traces. In fact, they might be able to use their memory for what did happen to reject false suggestions and inferences.

Eyewitness testimony often requires memory for more complex stimuli such as sequences of events, conversations, etc. Therefore, studies that find false recognition reversal using sentence and narrative stimuli provide an even more compelling application of these results (Reyna et al., 2016). Reyna and Kiernan (1994)

tested this pattern using a paradigm in which they presented children with three-sentence-long stories and had them complete a recognition test in which they were instructed to accept only those sentences that had previously been presented in the stories. The sentences presented in the recognition test included both true and false premises and inferences which either used the original wording of the presented sentences or used novel wording (see Table 14.2). Despite being less similar to the verbatim details of the originally presented sentences, true premises and inferences with novel wording were accepted at higher rates than were false premises and inferences using the original wording both immediately and after a one-week delay. This implies that a less-familiar sentence may in some cases lead to greater false recognition. Similar results have also been found in subsequent studies (Brainerd & Mojardin, 1998; Reyna & Kiernan, 1995). It should be noted that false recognition reversal is not just lower false recognition for more familiar stimuli but, rather, the ability to reject gist-consistent claims about events because they cue related true memories (which is better than the ability to reject unrelated claims). When verbatim memory is known to be very good, interrogators can remind witnesses of true events by suggesting gist-consistent claims about events that were not directly witnessed (that ought to be rejected as factually false), but care should be taken to not inculcate gist-consistent false memories (the mere-memory testing effect; Reyna et al., 2006). For example, an interrogator might ask a witness, "Although you saw the defendant arguing with the deceased, did you see the defendant running toward the deceased's house?" The witness with

TABLE 14.2 Examples of stories and test probes from Reyna and Kiernan (1994).

Narrative Sentences	*Spatial*	*Linear*
Target Sentences	The bird is inside the cage.	The cocoa is hotter than the tea.
	The cage is under the table.	The tea is hotter than the coffee.
	The bird has yellow feathers.	The cocoa is very sweet.
True Premise Original	The bird is inside the cage.	The cocoa is hotter than the tea.
True Premise Novel	The table is above the cage.	The coffee is cooler than the tea.
True Inference Original	The bird is under the table.	The cocoa is hotter than the coffee.
True Inference Novel	The table is above the bird.	The coffee is cooler than the cocoa.
False Premise Original	The table is under the cage.	The coffee is hotter than the tea.
False Premise Novel	The bird is above the cage.	The cocoa is cooler than the tea.
False Inference Original	The table is under the bird.	The coffee is hotter than the cocoa.
False Inference Novel	The bird is above the table.	The cocoa is cooler than the coffee.

Note: Example of the three-sentence stories and each of the test probes from Reyna and Kiernan (1994). When participants were instructed to only accept previously presented sentences, they accepted true premises and inferences with novel wording more than false premises and inferences with original wording. (From "Development of Gist Versus Verbatim Memory in Sentence Recognition: Effects of Lexical Familiarity, Semantic Content, Encoding Instructions, and Retention Interval," by V. F. Reyna and B. Kiernan, 1994, *Developmental Psychology*, *30*, Appendix, p. 191. Copyright 1994 by American Psychological Association. Adapted with permission.)

good verbatim memory might say, "No, I saw him walking toward his house." As another example, consider an interrogator's statement that a crime was committed in the morning. This statement might remind a witness with a good verbatim memory that the event had actually occurred in the afternoon, and that the interrogator's statement should be rejected. A third example of this effect may be found in the Gudjonsson Suggestibility Scale, a commonly used forensic measure of individual differences in suggestibility. In the Gudjonsson Suggestibility Scale, participants listen to a crime story and are asked a series of leading questions. One such question asks: "Were the assailants black or white?" In reality, the only mention of race in the story is that one of the assailants is Asian looking (Gudjonsson, 1984). In this case, a participant with good verbatim memory may be stimulated by the question to remember this detail from the story and reject the leading question. All of these examples of using verbatim memory to edit out gist-consistent false memories are illustrations of a process called *recollection rejection* in FTT (Brainerd, Reyna, Wright, & Mojardin, 2003).

False Memory Due to Meaning, Not Association

What Is the Effect?

Each DRM list is created by taking a word, known as a critical distractor or critical lure, and generating a list of the first 12 forward associates of that word (i.e., the 12 words with the highest probability of being recalled after the word's presentation; Deese, 1959). After studying a DRM list, it is common for these critical distractors to be falsely remembered in free recall. This finding is known as the DRM illusion.

There is a large degree of between-list variability in the DRM illusion. Deese (1959) proposed that the variability could be accounted for by variations in backward associative strength (BAS; i.e., the probability of list words leading to recall of the critical distractor). In this theory it was proposed that generation of list words during testing triggers false recall of their non-target associates. In support of this, both BAS and forward associative strength (FAS; i.e., the probability of critical distractors leading to recall of list words) correlate with false alarms in DRM procedures (Arndt, 2012; Brainerd & Wright, 2005).

Brainerd, Yang, Reyna, Howe, and Mills (2008), however, highlight four issues with Deese's (1959) theory. Firstly, as Deese (1959) acknowledges, other factors, such as the frequency of usage of the words, may account for a large amount of the variability in the DRM illusion. Secondly, while in free recall tests critical distractors are often preceded by recall of their associated targets, recognition tests for critical distractors also produce high false alarm rates, implying that recall of targets is not necessary for false memory of non-presented associates (Roediger & McDermott, 1995). Thirdly, BAS is stronger when a greater number of list items are correctly generated, and therefore false recall for critical

distractors should be as well. Yet, studies have found the opposite to be the case (Roediger, Watson, McDermott, & Gallo, 2001). Finally, the effect of BAS should be short-lived, and yet critical distractors are falsely remembered even months later (Seamon et al., 2002).

The true cause of the DRM illusion may instead be semantic similarity between the critical distractor and its corresponding list items. Target items and critical distractors share semantic relations for almost every target-critical distractor pair from the DRM lists used in Roediger et al. (2001) (Brainerd, Yang et al., 2008). Semantic variables such as familiarity and meaningfulness are also able to predict both variability in false recall for critical distractors and variability in BAS (Brainerd, Yang et al., 2008). In fact, simply instructing participants to process targets' meaning can increase false recall (Toglia, Neuschatz, & Goodwin, 1999). In DRM studies, semantic and associative processing are confounded, so it is difficult to conclude causality (Brainerd, Reyna, & Ceci, 2008). While all associated words must be semantically related, not all semantically related words are associates (Anisfeld & Knapp, 1968; Grossman & Eagle, 1970; Thompson-Schill, Kurtz, & Gabrieli, 1998). Therefore, if a list of low BAS words that share semantic similarity with a critical distractor produce false recall of that distractor, it would provide stronger evidence to suggest that semantic similarity produces the false recall. This pattern of results was found by Cann, McRae, and Katz (2011), implying a causal relationship. These results suggest that semantic content is a better predictor of false memory than associative relationships such as BAS and FAS.

How Does FTT Predict This Effect?

Roediger et al. (2001) proposed the activation/monitoring theory as an explanation for false memory for critical distractors. According to this theory, activation and monitoring are opponent processes in false memory. Activation of memory representations of target items spreads to critical distractors, leading to higher rates of false memory. Memory monitoring for whether a critical distractor matches a true memory also occurs, leading to lower rates of false memory. According to this theory, when BAS is stronger, activation of target items is spread to critical distractors at a greater rate, and therefore false memory is greater (Arndt, 2012). In contrast, FAS should have the opposite effect by improving memory monitoring (i.e., representation of a critical distractor should lead to more activation of target items ultimately allowing a person to recognize that a critical distractor does not match the target items; Gallo, 2004).

The activation/monitoring theory is inconsistent with evidence which shows that both BAS and FAS are correlated with false memory (Arndt, 2012; Brainerd & Wright, 2005) and with evidence that semantic similarity can predict false memory independent of association (Cann et al., 2011). FTT, however, can explain why semantic similarity predicts false memory. Remember that according to FTT, memories are stored in parallel as verbatim and gist traces, where gist

represents general meaning and verbatim represents surface detail (Brainerd & Reyna, 2005). Increasing the semantic similarity between list items and a critical distractor leads to greater gist memory for that distractor, but not greater verbatim memory. As a result, people are more likely to falsely recall and recognize the distractor because while they are unable to access verbatim traces, the gist traces that the distractor produces are consistent with those produced by the list items. As higher BAS and FAS are both correlated with semantic similarities (Brainerd, Yang et al., 2008), findings that these measures are correlated with false memory are consistent with FTT.

It should be noted that not all false memories are based on semantic factors. For example, Zeelenberg, Boot, and Pecher (2005) found that lists of nonsense words could produce false memories for critical distractors, implying that semantic similarity is not necessary for false memory—but such false memories occur at a much lower rate, are held with lower confidence, and fade rapidly (Brainerd, Reyna, & Brandse, 1995). In fact, there is often a distinction made between semantic and phonological false memories (Holliday & Weekes, 2006). Additionally, in some cases, semantic content does not predict false memory. In a study by Hutchison and Balota (2005), for example, 12-word lists which shared either one or two meanings and shared the same associative strength both produced the same amount of false memory for critical distractors regardless of whether the words sharing the two meanings were blocked separately or intermixed. While the results from this study imply that the strength of semantic similarity does not necessarily predict false memory and support activation/monitoring theory, a subsequent extension of this study has found contrasting results which are at odds with activation/monitoring theory and that favor FTT. In a study by Huff, McNabb, and Hutchison (2015), participants were also presented with 12-word lists which shared two meanings. It was found that false recall was greater when the words related to two separate meanings were blocked (words related to "bank" as a financial institution grouped separately from words related to "bank" as the side of a river) separately rather than mixing words from both categories together. Blocking has well-known effects on boosting recognition of semantic similarity. This study suggests that the processing of shared meaning does lead to an increase in false memory. These findings support FTT by implying that increasing the semantic processing of a list strengthens gist memory, which in turn leads to higher rates of false memory.

How Does This Apply to Eyewitness Testimony?

If the DRM illusion was solely based on BAS or FAS, false memory in DRM studies would not necessarily be able to translate into eyewitness procedures, as pieces of evidence learned during eyewitness testimony do not have backward or forward associates. In other words, activation/monitoring applies to word associates rather than to memories for events, as FTT does. Findings that the DRM

illusion is actually based on semantic similarity between the list items and the critical distractor, however, can make a more compelling case for applying DRM findings to legal settings. Specifically, these findings suggest that presentation of semantically similar testimony may provoke a witness to provide false information. For example, if one witness testifies that they remember waking up, eating cereal, and reading the newspaper shortly before the crime occurred, another witness may be more likely to falsely recall that the crime occurred in the morning due to the shared semantic similarity of the other witness's testimony.

Delay Effect

What Is the Effect?

Falsely remembered items were never actually experienced. It therefore seems natural to conclude that false memories would be more fleeting than true memories. However, false memories can actually persist long after they were initially produced (Brainerd & Reyna, 2005). Their persistence can be measured using a methodology in which participants complete both immediate and delayed recognition tests. By comparing the nonconditional rate of delayed false alarms to the conditional rate of delayed false alarms given an initial false alarm for the same NS item, the persistence of false memories can be measured (Brainerd et al., 1995). False memories have been found to persist at one-week (Brainerd & Mojardin, 1998; Brainerd et al., 1995; Marx & Henderson, 1996; Poole, 1995), two-week (Blair, Lenton, & Hastie, 2002; Brainerd & Reyna, 1996), and one-month (Brainerd & Mojardin, 1998) intervals.

In fact, in many cases, gist-based false memories persist longer than verbatim-based true memories. In between-subjects experiments in which participants complete recognition tests immediately and after a delay, false alarms have been found to be more persistent than true memories in adults (Howe, Candel, Otgaar, Malone, & Wimmer, 2010; Payne, Elie, Blackwell, & Neuschatz, 1996; Seamon et al., 2002). Figure 14.1 illustrates this pattern over a 24-hour delay as found by Payne et al. (1996). The figure shows a large reliable decrease in true memory for list items and a small unreliable decrease in false memory for critical distractors. False alarms have also been found to persist more than true memories in studies with children (Brainerd & Mojardin, 1998; Brainerd et al., 1995; Poole, 1995). Interestingly, false memories have been found to persist less than true memories between two-week and two-month delays, implying that the greater persistence of false over true memories is not universal (Seamon et al., 2002).

How Does FTT Predict This Effect?

According to single-process theories, acceptance or rejection of a test item is solely based on whether that test item provokes familiarity for the targets. Therefore,

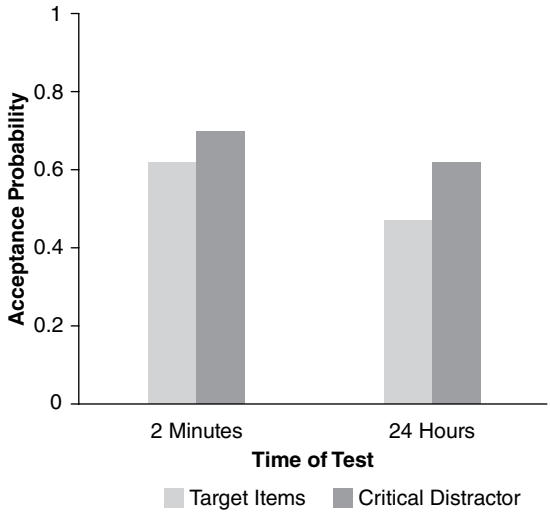

FIGURE 14.1 Recognition proportions for targets and critical distractors after a two-minute delay and after a 24-hour delay reported by Payne et al. (1996). (From "Memory Illusions Recalling, Recognizing, and Recollecting Events that Never Occurred," by D. G. Payne, C. J. Elie, J. M. Blackwell, and J. S. Neuschatz, 1996, *Journal of Memory and Language*, *35*, Table 1, p. 268. Copyright 1996 by Elsevier. Adapted with permission).

as time passes, it would be expected that both true and false memories would decrease at similar rates. Yet, at least until two months after the presentation of the targets, there appears to be a pattern in which false memories are often more robust than true memories.

This pattern can be explained by the divergent timelines of gist and verbatim traces as postulated by FTT. Verbatim traces are quick to dissipate, whereas gist traces are more long-lasting. When the verbatim traces of a target item are available, they support true memories and prevent false memories. This is because false memories do not share the same verbatim traces as the target. In contrast, the gist traces of a target item can support both true memories and gist-consistent false memories. Therefore, if the verbatim traces for target items disappear between immediate and delayed recognition tests, a decline in correct acceptances of O test items is likely because true memories can be based on both verbatim and gist traces; however, the gist traces disappear much more slowly than the verbatim traces, and therefore false memories, which are based only on gist traces, are maintained. A later reduction in false memories (between two weeks and two months in Seamon et al., 2002) can also be explained by FTT, as this may mark a timepoint in which gist traces become less accessible, albeit at a slower rate than verbatim memory (Brainerd & Reyna, 2005).

How Does This Apply to Eyewitness Testimony?

In forensic settings, inconsistencies are seen as a signal of lying or weak memory (Brainerd et al., 1995). Research on the effect of delay on false memory challenges this view. False memories can sometimes be remembered even more consistently than true memories. In a reanalysis of Poole and White's (1991) data, Poole (1995) illustrates the application of the delay effect in eyewitness testimony. In this study, participants witnessed an event involving a man and a woman and were asked questions such as "What did the man look like?" immediately, after a delay of a few minutes, and after one week. While the difference was not significant, participants repeated false information at higher rates at both delays. This implies that stability of answers is not a good proxy for measuring accuracy. Additionally, these results suggest that it is better to collect eyewitness testimony as early after a witness observes a crime as possible. As true memories can fade quicker than false memories, this will increase the likelihood of accurate testimony.

Sleeper Effect

What Is the Effect?

Not only can false memories stay consistent over time, but in some cases, they can even increase. For example, Reyna and Kiernan (1994) found that after a one-week delay, false memories increased while true memories decreased. Brainerd et al. (1995) found that repeating test items three times led to increases in false memory and decreases in true memory after a one-week delay. Similarly, in a DRM study, Brainerd, Payne, Wright, and Reyna (2003) found that when lists were repeated three times, false recall increased after one week. A sleeper effect can even be found at a two-year delay. Poole and White (1991) found that after two years, true recall decreased and false recall increased in a sample of children. A sleeper effect may also occur shortly after items are encoded. In a second study by Brainerd, Payne et al. (2003), after studying DRM lists, participants were presented with three recall tests, each with a two-minute buffer preceding them. False memories were found to increase with each subsequent test. Overall, these studies suggest that false memories persist and can even increase over time.

How Does FTT Predict This Effect?

One commonality among these studies is that they often include manipulations to increase verbatim traces, such as limiting the amount of target information (Reyna & Kiernan, 1994) or by repeating target items (Brainerd, Payne et al., 2003, Brainerd et al., 1995). Single-process models would predict that in these cases both true and false memories would be greater in the immediate test and would decrease over time due to decreasing familiarity with the test items. FTT,

however, predicts that these manipulations will lead to a decrease in true memories over time, but not necessarily a decrease in false memories. The augmented verbatim traces produced in these cases support true memories. Verbatim traces, however, fade quicker than gist traces, so after a delay, participants may instead switch to reliance on gist and true memories will decrease. False memories, however, usually rely on gist traces and therefore a decrease in verbatim memory should not decrease false memory. In fact, verbatim traces serve an additional function besides supporting true memories: suppressing gist-consistent false memories. False memories do not share verbatim traces with the target. Hence, a comparison of false memories with targets allows for correct rejection based on these divergent verbatim traces. As these false memories fit the gist of the target, in the absence of verbatim traces they will be accepted. Therefore, in a case where verbatim traces are augmented, we would expect to see fewer false memories immediately and an increase in false memories once the verbatim traces are no longer accessible (Brainerd & Reyna, 2005).

How Does This Apply to Eyewitness Testimony?

In the American judicial system, an inaccurate conviction is considered a worse outcome to the absence of a conviction (Ceci & Friedman, 2000). Resultingly, it is important to understand what factors lead people to more likely provide incorrect testimony. In this case, as in previous sections, the results tell us that eyewitness testimony is more reliable immediately after a crime is observed than after a delay. In fact, sleeper effect results make an even more compelling case for this, as these findings suggest that false memories increase over time. For a judicial system concerned with preventing wrongful convictions, it seems of utmost importance to collect testimony as early as possible and to weigh it based on the delay between when the crime was observed and the testimony was collected.

A question that often arises is whether laboratory findings can be translated to applied settings. Trials are fraught with negative emotions that are often not replicated in the laboratory. Howe et al. (2010) addressed this issue by comparing true and false recognition for neutral and negative words. They found that while true recognition decreased after a one-week delay, and false recognition for neutral words stayed stable, false recognition for negative words increased. This implies that sleeper effects may even be stronger for negatively valenced items such as those experienced during a trial.

Does Confidence Predict Accuracy?

What Is the Effect?

Intuitively, one would expect that confidence should positively correlate with memory accuracy. In fact, confidence ratings have been found to be highly

influential in convincing jurors of the accuracy of eyewitness identifications (Cutler, Penrod, & Stuve, 1988). However, the literature predicts a more nuanced relationship between confidence and accuracy. While meta-analyses do find a positive correlation across a large number of studies (Sporer, Penrod, Read, & Cutler, 1995; Wixted & Wells, 2017), in some cases the relationship between accuracy and confidence can also be negative (DeSoto & Roediger, 2014; Roediger & DeSoto, 2014; Roediger, Wixted, & DeSoto, 2012). These contradictory results, however, do not imply that confidence ratings are meaningless. Rather, confidence's predictive value may vary based on the conditions under which the memory test is conducted. Wixted and Wells (2017), for example, compiled a list of "pristine" eyewitness identification conditions under which confidence may be a better predictor of accuracy. These conditions include that there should be only one suspect per lineup, that the suspect should not stand out among the foils, that the instructions provided to the witness should caution that the offender may not be in the lineup, that testing should be conducted double-blindly, and that the confidence statement should be taken at the time of the identification.

How Does FTT Predict This Effect?

SDT predicts a strong relationship between accuracy and confidence (Mickes, Hwe, Wais, & Wixted, 2011). It suggests that each point on a confidence scale represents a place in which the strength of a memory has passed a certain threshold (Mickes et al., 2011). While this may be an accurate description of confidence ratings when testing conditions are pristine, SDT is unable to accurately predict the relationship between confidence and accuracy in non-pristine conditions, when factors other than memory strength might contribute to a witness's confidence (Wixted & Wells, 2017). Other theories, however, acknowledge that confidence and accuracy are not always positively correlated and suggest that they may be based on different memory representations (Busey, Tunnicliff, Loftus, & Loftus, 2000). In fact, FTT postulates this very distinction. According to the task calibration principle of FTT, people calibrate their memory representations to the specific requirements of a task (Corbin, Reyna, Weldon, & Brainerd, 2015). Generally, tasks that require exact numerical responses, which require precise processing (such as determining how much you are willing to spend on each of two apartments) lead to decreased reliance on gist as compared to more categorical tasks, which only require bottom-line processing (such as choosing which of the two apartments you prefer; Reyna & Brainerd, 2011).

In episodic memory tasks, such as standard recognition paradigms and source recognition paradigms (i.e., recognition tests which require participants to identify the context under which they were presented with a stimulus, often by asking them to identify which of two lists an item was presented on), people tend to favor verbatim over gist processing because verbatim traces provide more detailed information about the studied items (Brainerd & Reyna, 2005). When verbatim

traces are not available, individuals instead rely on gist processing. According to the task calibration principle, this reliance on gist should be greater for tasks that require a categorical response than for tasks that require an exact numerical response, which continue to rely on verbatim processing (Brainerd, Nakamura, Reyna, & Holliday, 2017).

In confirmation of this theory, empirical studies have provided evidence in favor of confidence ratings decreasing gist reliance. Firstly, if confidence ratings (a numerical response) decrease gist, then confidence should be lower for NS false alarms than for O hits because while targets contain verbatim traces, gist traces, and response bias, NS items contain only gist traces and response bias (Brainerd et al., 2017). This pattern is a pervasive finding in the literature (Brainerd & Reyna, 2005). In fact, it has been found that confidence-accuracy correlations are positive for true memory and negative for false memory using both item (DeSoto & Roediger, 2014; Roediger & DeSoto, 2014) and source (Brainerd et al., 2017) paradigms. Additionally, as confidence ratings rely more on verbatim traces than gist traces, individuals with high confidence in their memory should be able to better recount the specific details of items they remember with high confidence (Brainerd et al., 2017). Selmeczy and Dobbins (2014) confirmed this, finding that items remembered with high confidence were described with more realistic descriptions than were those remembered with medium confidence. Overall, this evidence suggests that the confidence-accuracy correlation can be positive, but that it is dependent on the availability of verbatim traces.

How Does This Apply to Eyewitness Testimony?

FTT can be used to theoretically discriminate between the pristine and non-pristine eyewitness conditions postulated by Wixted and Wells (2017). Pristine and non-pristine conditions likely differ on the degree to which they promote reliance on verbatim versus gist traces in decisions. For example, consider the prescription that the suspect should not stand out among the foils. Suppose that a suspect is Asian and the corresponding foils in the lineup are all White. Resultingly, an eyewitness could rely on the gist that the culprit was Asian and choose the Asian suspect without conducting a more verbatim-based comparison of the suspect from the lineup to the culprit from their memory. Thus, in a non-pristine condition, the categorical decision of identifying the culprit is based on gist traces, and the numerical decision of making a confidence rating is based on verbatim traces. As gist supports both true and false memories, this leads to positive correlations between both true and false memories and confidence, and therefore a less positive correlation between confidence and accuracy. In contrast, in a pristine condition, both the categorical and numerical decisions are made using verbatim traces, and therefore confidence and accuracy are more likely to be positively correlated (confidence will be positively correlated with true memories and negatively correlated with false memories).

Verbal Overshadowing

What Is the Effect?

Certain visual memories, such as those for faces, are indescribable in words (Schooler & Engstler-Schooler, 1990). Resultingly, researchers have questioned whether generating verbal descriptions for these stimuli will affect subsequent recognition. Read (1979) and Bartlett, Till, and Levy (1980) found that verbal descriptions could facilitate recognition of faces and pictures respectively when they could be used to discriminate between targets and distractors. When the targets and distractors were too visually similar, however, verbal descriptions did not facilitate recognition (Bartlett et al., 1980). In a series of studies, Schooler and Engstler-Schooler (1990) found that generating verbal descriptions actually impaired recognition of facial stimuli and colors from lineups. The verbal interference was found to be long-lasting, but it could be reversed by putting time limits on recognition decisions. This implies that the original memories were not eliminated, but rather overshadowed, thus the effect was termed "verbal overshadowing" (Schooler & Engstler-Schooler, 1990).

While some investigators have been unable to replicate the results found by Schooler and Engstler-Schooler (1990) (Meissner & Brigham, 2001), a large-scale replication found a robust verbal overshadowing effect (Alogna et al., 2014). The original study was limited to target-present lineups. Therefore, the corresponding reduction in recognition accuracy could have been either due to a reliance on more conservative criteria or due to decreased discriminability. In order to test this theory, Wilson, Seale-Carlisle, and Mickes (2018) replicated the Schooler and Engslter-Schooler (1990) methodology using both target-present and target-absent lineups during testing. They found that while verbal descriptions led to more conservative criteria for recognition both when the descriptions were generated immediately and at a 20-minute delay, discriminability was only impaired when they were generated at a delay.

How Does FTT Predict This Effect?

As we have already previously mentioned, SDT is a single-process theory in which increasing familiarity should increase accuracy. As verbalization of a stimulus should not decrease familiarity for that stimulus, SDT does not seem to accurately describe this process. FTT, however, provides a clear explanation for the verbal overshadowing effect. When people generate verbal descriptions for a stimulus, they generally describe the stimulus's gist rather than its verbatim details. Additionally, FTT prescribes that verbatim traces fade more quickly than do gist traces as a result of retroactive interference (i.e., reasoning tasks after encoding are more likely to interfere with verbatim traces than gist traces; Brainerd & Reyna, 1993). As verbalization involves reasoning about previously encoded stimuli, it

follows that it would likely interfere with verbatim traces more than gist traces. Taken together this information suggests that eyewitnesses who have provided a verbal description of a stimulus should favor gist traces over verbatim traces in recognition. As the foils in the recognition test are visually similar to the target, favoring gist traces should lead to higher rates of incorrect acceptance for foils, which is consistent with the verbal overshadowing effect (Schooler, 1998).

Individual difference findings in verbal overshadowing also fit an FTT explanation. For example, Ryan and Schooler (1998) found that individuals with high perceptual memory abilities and low verbal abilities had stronger verbal overshadowing effects than did individuals with low perceptual abilities and high verbal abilities. Schooler (1998) explained this finding by proposing that individuals with low perceptual abilities and high verbal abilities were already relying on gist traces and therefore would have less additional impairment from a manipulation emphasizing gist processing.

Finally, FTT can also be useful in explaining the additional findings by Wilson et al. (2018), who found that verbal overshadowing could only be explained by impairment in discriminability when the verbal descriptions were made after a 20-minute delay. As verbatim memory declines at a quicker rate than gist memory (Brainerd & Reyna, 2005), FTT's assumptions are required to understand this finding (as Wilson et al., 2018, point out). That is, verbal descriptions made after a 20-minute delay are more gist-based than those given immediately after observing a stimulus, whereas verbatim memories of a stimulus are weaker and susceptible to interference effects (Reyna & Brainerd, 1995), hence producing overshadowing.

How Does This Apply to Eyewitness Testimony?

Verbal overshadowing has a very direct application to eyewitness identification procedures. After eyewitnesses have reported a crime, it is standard for them to verbally recount what they witnessed to a police officer. This often includes providing a verbal description of the criminal. Resultingly, it would not be surprising that verbal overshadowing may occur when eyewitnesses are later asked to identify the criminal from a lineup. Therefore, these results suggest that whether a verbal description was collected should be considered during evaluation of the reliability of eyewitness identifications. The results from Wilson et al. (2018) further suggest that if verbal descriptions are needed, they should be taken as soon as possible after the crime was witnessed in order to decrease the effect of verbal overshadowing on later identifications.

Subadditivity and Complementarity

What Is the Effect?

Consider an exercise where you must randomly choose one marble from a bag of red, green, and yellow marbles. The additive law of probability theory requires

that the sum of the probabilities of choosing the three colors must be equal to one (Brainerd, Wang, Reyna, & Nakamura, 2015). Yet, when people make probability judgments, they tend to overestimate these probabilities, leading to a sum of greater than one: a logical impossibility (Brainerd et al., 2015). The term *subadditivity* refers to cases in which the sum of the probabilities is greater than one.

Subadditivity has been well documented in tests of episodic memory (Brainerd & Reyna, 2008; Brainerd, Reyna, & Aydin, 2010; Brainerd, Wang, & Reyna, 2013; Brainerd et al., 2015). Consider a DRM experiment where a test item is presented and the participant is asked one of three questions: (1) whether the test item is O (O?), (2) whether the test item is NS (NS?), or (3) whether the test item is either O or NS (O or NS?). In this case, the sum of the probabilities of (1) and (2) should be equal to the probability of (3) because O and NS are mutually exclusive reality states, and yet this sum is greater than the probability of (3), both on the individual level and on the group level (Brainerd et al., 2010). Brainerd et al. (2010) refers to this as a description dependency: when the question asks if the test item is O, the test item is perceived as O, and when the question asks if the test item is NS, the test item is perceived as NS. This overdistribution is represented in both item and source attribution recognition paradigms (Brainerd & Reyna, 2008). Figure 14.2 shows that the O? + NS? > O or NS? pattern holds for both O and NS test cues for a corpus of 372 data sets.

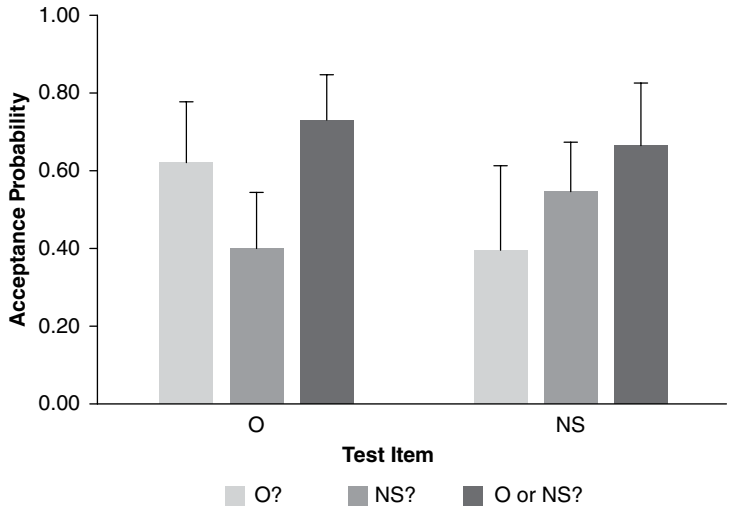

FIGURE 14.2 Subadditivity in a corpus of 372 recognition studies. For both old (O) and new-similar (NS) test items, the sum of the probabilities of acceptance for old (O?) and new-similar (NS?) questions is greater than the probability of acceptance for old or new-similar (O or NS?) questions. Error bars represent one standard deviation.

How Does FTT Predict This Effect?

Classic single-process models, such as signal detection theory, assume an additive relationship (O? + NS? = O or NS?) (Brainerd & Reyna, 2008). FTT, however, provides a theoretical explanation for the subadditive relationship between O? and NS? questions. When a test item provokes retrieval of verbatim traces, people are able to accept O? and reject NS?, as they are able to unequivocally remember that the test item was previously presented. When a test item only provokes retrieval of gist traces, however, those traces support acceptance of both O? and NS? because O and NS items share semantic similarity. In this case, the type of question will determine the response. If participants are presented with O? questions, they will identify test items as O, and if they are presented with NS? questions, they will identify test items as NS, ultimately leading to overdistribution (Brainerd et al., 2010). In support of this theory, manipulations that reduce gist reliance, such as replacing categorical judgments with confidence ratings (Brainerd et al., 2017) or decreasing the delay before testing (Brainerd et al., 2015), also reduce overdistribution.

How Does This Apply to Eyewitness Testimony?

Subadditivity has a direct application to eyewitness identification procedures because they, too, are recognition tests that are concerned with oldness and newness. Imagine a case in which a witness is presented with the face of a suspect and is asked "Is this the perpetrator of the crime?" If the crime occurred recently, the eyewitness may be able to access verbatim traces for the perpetrator and be able to definitively accept the face as the true criminal or reject the face as a false suspect. However, if only gist traces are available and the suspect fits the general description of the perpetrator (regardless of whether the suspect actually committed the crime), the suspect will be identified as being the perpetrator or as not being the perpetrator, depending on what question is asked (i.e., eyewitnesses will answer affirmatively to both "Is this the guilty suspect?" and "Is this an innocent suspect?").

Aging and Cognitive Impairment

What Is the Effect?

Memory does not stay constant over a person's lifetime. In fact, the prevalence of true and false memories varies as a function of age. In episodic memory tasks requiring participants to recognize or recall previously presented stimuli, older adults both correctly identify fewer target items and falsely identify more NS items than do younger adults (Balota et al., 1999; McCabe, Roediger, McDaniel, & Balota, 2009; Norman & Schacter, 1997). The difference between

susceptibility to false memory for older and younger adults has been found to vary based on the testing procedures. Tun, Wingfield, Rosen, and Blanchard (1998), for example, found that in DRM tests which emphasized semantic content (by excluding NS test probes other than the critical distractor), younger and older adults each exhibited the same number of false alarms to the critical distractors. In contrast, when NS test probes were included (thus requiring item-based judgments), younger adults exhibited significantly fewer false alarms to the critical distractors than did older adults. Similarly, Koutstaal and Schacter (1997) found that increasing the number of target items that represented a category (thus increasing the strength of semantic information) led to a larger increase in false memory prevalence for older than for younger adults. However, the correct recognition rates for both groups were equal. In a study by Kensinger and Schacter (1999), false memory in older adults was also not reduced by manipulations that typically reduce false memory in younger adults, such as repetition of target lists and tests.

How Does FTT Predict This Effect?

As decline in true memory during aging is a ubiquitous finding (Balota et al., 1999; McCabe et al., 2009), one-process theories predict that false memories should also decrease (Gomes, Cohen, Desai, Brainerd, & Reyna, 2014). Comparisons of younger and older adults, however, reveal that older adults often have more false memories than do younger adults (Balota et al., 1999; McCabe et al., 2009; Norman & Schacter, 1997). This pattern is found most prominently in cases in which verbatim processing becomes more useful for the task (Tun et al., 1998) or more salient (Kensinger & Schacter, 1999). FTT postulates that older adults are more heavily relying on gist processing, whereas younger adults are able to rely on verbatim processing. As gist and verbatim are opponent processes in false memory, where gist processing promotes acceptance of and verbatim processing promotes rejection of NS items, a pattern appears in which older adults produce more false memories (Brainerd & Reyna, 2005).

Evidence in support of FTT's prediction of cognitive impairment in aging also comes from neuroscience. When discriminating between target items and NS items, older adults do not differentially use the early occipital cortex (Bowman & Dennis, 2015; Dennis, Bowman, & Peterson, 2014), a brain region associated with verbatim processing (Buckner & Wheeler, 2001). Conversely, when creating false memories, older adults activate lateral middle temporal gyrus and superior temporal gyrus (Dennis et al., 2014; Dennis, Kim, & Cabeza, 2007, 2008), regions associated with gist processing (Simons et al., 2005; Wise & Price, 2006). This suggests that in recognition tests, older adults do rely on gist over verbatim traces more than younger adults do, and this pattern is likely the cause of the greater rate of false memories in older adults.

How Does This Apply to Eyewitness Testimony?

Older adults (aged 65 and older) made up 14.5% of the population in the U.S. in 2014 and are expected to make up 23.5% of the population in 2060 (Office of Disease Prevention and Health Promotion, 2018). As a result, it is increasingly necessary for older adults to provide eyewitness testimony. As it is important for courts to be able to correctly weigh the accuracy of testimony, research on the effects of age on memory is valuable in this context. Research has found that older adults are generally less reliable eyewitnesses as compared to younger adults due to a trend of fewer true memories and greater false memories (Gomes et al., 2014). Older adults are also often perceived as being less credible than younger adults, particularly in cases in which the older eyewitness is not individuated (Ross, Dunning, Toglia, & Ceci, 1990) and cases in which the individual making the judgment holds more ageist stereotypes (Mueller-Johnson, Toglia, Sweeney, & Ceci, 2007). Despite this issue, testimony from older adults still contains clear value, and FTT provides a solution for improving the testimony of older adults: by encouraging reliance on verbatim-based judgments (Gomes et al., 2014). Improving the eyewitness testimony of older adults may also help improve juror perception of older eyewitnesses, which would help mitigate the effect of ageist stereotypes in juror assessments of testimony.

Conclusions

Throughout this chapter, we have reviewed a series of often counterintuitive empirical findings of false memory. FTT provides predictions which can more accurately describe the pattern of findings than predictions from single-process theories can. In each case, reliance on semantic content (gist traces) and on surface details (verbatim traces) both support true memory. In contrast, gist and verbatim processing are opponent processes in false memory. Gist promotes more false memory, but verbatim reduces it. The accuracy of memory reports, whether in the laboratory or the courtroom, are further compromised by predictable effects of delay, question wording, age, and other features of eyewitness interviews, as we have detailed throughout this chapter.

The purpose of eyewitness testimony is to assist a court in determining the truth. Therefore, assessing the accuracy of testimony in order to more accurately weigh information is important. An understanding of human memory allows us to better make these assessments. Memory theory provides an empirically backed framework which can replace policy makers' and practitioners' otherwise misleading intuitions. It allows us to make discoveries about memory patterns that might not otherwise be initially perceivable in eyewitness testimony, but are nonetheless important. FTT is able to predict many legally relevant findings and therefore has implications for improving assessment of eyewitness testimony. Research using sentences, narratives, and events has provided further confirmation of FTT's

applications in forensic settings. Overall, it is important to remember that laboratory research can have meaningful implications in real-world settings and that it often makes more accurate predictions than untested assumptions can.

References

Alogna, V. K., Attaya, M. K., Aucoin, P., Bahník, Š., Birch, S., Birt, A. R., . . . Zwaan, R. A. (2014). Registered replication report: Schooler and Engstler-Schooler (1990). *Perspectives on Psychological Science*, *9*, 556–578.

Anisfeld, M., & Knapp, M. (1968). Association, synonymity, and directionality in false recognition. *Journal of Experimental Psychology*, 77, 171–179.

Arndt, J. (2012). The influence of forward and backward associative strength on false recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*, 747–756.

Atkinson, R. C., & Juola, J. F. (1973). Factors influencing speed and accuracy in word recognition. In S. Kornblum (Ed.), *Attention and performance IV* (pp. 583–611). New York, NY: Academic Press.

Atkinson, R. C., & Juola, J. F. (1974). Search and decision processes in recognition memory. In D. H. Krantz, R. C. Atkinson, R. D. Luce, & P. Suppes (Eds.), *Contemporary developments in mathematical psychology: Learning, memory, and thinking* (Vol. 1, pp. 243–293). San Francisco, CA: Freeman.

Atkinson, R. C., & Wescourt, K. T. (1975). Some remarks on a theory of memory. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 485–498). London: Academic Press.

Balota, D. A., Cortese, M. J., Duchek, J. M., Adams, D., Roediger, H. L., III, McDermott, K. B., & Yerys, B. E. (1999). Veridical and false memories in healthy older adults and in dementia of the Alzheimer's type. *Cognitive Neuropsychology, 16*, 361–384.

Bartlett, J. C., Till, R. E., & Levy, J. C. (1980). Retrieval characteristics of complex pictures: Effects of verbal encoding. *Journal of Verbal Learning and Verbal Behavior, 19*, 430–449.

Blair, I. V., Lenton, A. P., & Hastie, R. (2002). The reliability of the DRM paradigm as a measure of individual differences in false memories. *Psychonomic Bulletin & Review*, *9*, 590–596.

Bowman, C. R., & Dennis, N. A. (2015). Age differences in the neural correlates of novelty processing: The effects of item-relatedness. *Brain Research*, *1612*, 2–15.

Brainerd, C. J., & Mojardin, A. H. (1998). Children's and adults' spontaneous false memories: Long-term persistence and mere-testing effects. *Child Development, 69*, 1361–1377.

Brainerd, C. J., Nakamura, K., Reyna, V. F., & Holliday, R. E. (2017). Overdistribution illusions: Categorical judgments produce them, confidence ratings reduce them. *Journal of Experimental Psychology: General, 146*, 20–40.

Brainerd, C. J., Payne, D. G., Wright, R., & Reyna, V. F. (2003). Phantom recall. *Journal of Memory and Language, 48*, 445–467.

Brainerd, C. J., & Reyna, V. F. (1993). Memory independence and memory interference in cognitive development. *Psychological Review, 100*, 42–67.

Brainerd, C. J., & Reyna, V. F. (1996). Mere memory testing creates false memories in children. *Developmental Psychology, 32*, 467–478.

Brainerd, C. J., & Reyna, V. F. (2005). *The science of false memory*. New York, NY: Cambridge University Press.

Brainerd, C. J., & Reyna, V. F. (2008). Episodic over-distribution: A signature effect of familiarity without recollection. *Journal of Memory and Language, 58*, 765–786.

Brainerd, C. J., & Reyna, V. F. (2012). Reliability of children's testimony in the era of developmental reversals. *Developmental Review, 32*, 224–267.

Brainerd, C. J., Reyna, V. F., & Aydin, C. (2010). Remembering in contradictory minds: Disjunction fallacies in episodic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*, 711–735.

Brainerd, C. J., Reyna, V. F., & Brandse, E. (1995). Are children's false memories more persistent than their true memories? *Psychological Science, 6*, 359–364.

Brainerd, C. J., Reyna, V. F., & Ceci, S. J. (2008). Developmental reversals in false memory: A review of data and theory. *Psychological Bulletin, 134*, 343–382.

Brainerd, C. J., Reyna, V. F., & Estrada, S. (2006). Recollection rejection of false narrative statements. *Memory*, *14*(6), 672–691. doi:10.1080/09658210600648449

Brainerd, C. J., Reyna, V. F., & Kneer, R. (1995). False-recognition reversal: When similarity is distinctive. *Journal of Memory and Language, 34*, 157–185.

Brainerd, C. J., Reyna, V. F., Wright, R., & Mojardin, A. H. (2003). Recollection rejection: False-memory editing in children and adults. *Psychological Review*, *110*, 762–784.

Brainerd, C. J., Wang, Z., & Reyna, V. F. (2013). Superposition of episodic memories: Overdistribution and quantum models. *Topics in Cognitive Sciences, 5*, 773–799.

Brainerd, C. J., Wang, Z., Reyna, V. F., & Nakamura, K. (2015). Episodic memory does not add up: Verbatim-gist superposition predicts violations of the additive law of probability. *Journal of Memory and Language, 84*, 224–245.

Brainerd, C. J., & Wright, R. (2005). Forward association, backward association, and the false-memory illusion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*, 554–567.

Brainerd, C. J., Yang, Y., Reyna, V. F., Howe, M. L., & Mills, B. A. (2008). Semantic processing in "associative" false memory. *Psychonomic Bulletin & Review, 15*, 1035–1053.

Bryant, P. E., & Trabasso, T. (1971). Transitive inferences and memory in young children. *Nature*, *232*, 456–458.

Buckner, R. L., & Wheeler, M. E. (2001). The cognitive neuroscience of remembering. *Nature Reviews Neuroscience*, *2*, 624–634.

Busey, T. A., Tunnicliff, J., Loftus, G. R., & Loftus, E. F. (2000). Accounts of the confidence-accuracy relation in recognition memory. *Psychonomic Bulletin & Review, 7*, 26–48.

Cann, D. R., McRae, K., & Katz, A. N. (2011). False recall in the Deese-Roediger-McDermott paradigm: The roles of gist and associative strength. *Quarterly Journal of Experimental Psychology, 64*, 1515–1542.

Ceci, S. J., & Friedman, R. D. (2000). The suggestibility of children: Scientific research and legal implications. *Cornell Law Review*, *86*, 33–108.

Ceci, S. J., Ross, D. F., & Toglia, M. P. (1987). Suggestibility of children's memory: Psycholegal implications. *Journal of Experimental Psychology: General*, *116*, 38–49.

Corbin, J. C., Reyna, V. F., Weldon, R. B., & Brainerd, C. J. (2015). How reasoning, judgment, and decision making are colored by gist-based intuition: A fuzzy-trace theory approach. *Journal of Applied Research in Memory and Cognition, 4*, 344–355.

Cutler, B. L., Penrod, S. D., & Stuve, T. E. (1988). Juror decision making in eyewitness identification cases. *Law and Human Behavior, 12*, 41–55.

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., & Peterson, K. M. (2014). Age-related differences in the neural correlates mediating false recollection. *Neurobiology of Aging, 35*, 395–407.

Dennis, N. A., Kim, H., & Cabeza, R. (2007). Effects of aging on true and false memory formation: An fMRI study. *Neuropsychologia, 45*, 3157–3166.

Dennis, N. A., Kim, H., & Cabeza, R. (2008). Age-related differences in brain activity during true and false memory retrieval. *Journal of Cognitive Neuroscience, 20*, 1390–1402.

DeSoto, K. A., & Roediger, H. L., III. (2014). Positive and negative correlations between confidence and accuracy for the same events in recognition of categorized lists. *Psychological Science, 25*, 781–788.

Gallo, D. A. (2004). Using recall to reduce false recognition: Diagnostic and disqualifying monitoring. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 120–128.

Gomes, C. F. A., Cohen, B. R., Desai, A., Brainerd, C. J., & Reyna, V. F. (2014). Aging and false memory: Fuzzy-trace theory and the elderly eyewitness. In M. P. Toglia, D. F. Ross, J. Pozzulo, & E. Pica (Eds.), *The elderly eyewitness in court* (pp. 137–166). New York, NY: Psychology Press.

Green, D. M., & Swets, J. A. (1966). *Signal detection theory and psychophysics*. New York, NY: Wiley-Blackwell.

Grossman, L., & Eagle, M. (1970). Synonymity, anonymity, and association in false recognition responses. *Journal of Experimental Psychology, 83*, 244–248.

Gudjonsson, G. H. (1984). A new scale of interrogative suggestibility. *Personality and Individual Differences*, *5*, 303–314.

Hall, J. W., & Kozloff, E. E. (1970). False recognition as a function of number of presentations. *American Journal of Psychology, 83*, 272–279.

Holliday, R. E., & Weekes, B. S. (2006). Dissociated developmental trajectories for semantic and phonological false memories. *Memory, 14*, 624–636.

Howe, M. L. (1991). Misleading children's story recall: Forgetting and reminiscence of the facts. *Developmental Psychology, 27*, 746–762.

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.

Huff, M. J., McNabb, J., & Hutchison, K. A. (2015). List blocking and longer retention intervals reveal an influence of gist processing for lexically ambiguous critical lures. *Memory & Cognition, 43*, 1193–1207.

Hutchison, K. A., & Balota, D. A. (2005). Decoupling semantic and associative information in false memories: Explorations with semantically ambiguous and unambiguous critical lures. *Journal of Memory and Language, 52*, 1–28.

Innocence Project. (2020). *DNA exonerations in the United States*. Retrieved January 31, 2020. www.innocenceproject.org/dna-exonerations-in-the-united-states/

Israel, L., & Schacter, D. L. (1997). Pictorial encoding reduces false recognition of semantic associates. *Psychonomic Bulletin & Review, 4*, 577–581.

Juola, J. F., Fischler, I., Wood, C. T., & Atkinson, R. C. (1971). Recognition time for information stored in long-term memory. *Perception & Psychophysics, 10*, 8–14.

Kensinger, E. A., & Schacter, D. L. (1999). When true memories suppress false memories: Effects of ageing. *Cognitive Neuropsychology, 16*, 399–415.

Koutstaal, W., & Schacter, D. L. (1997). Gist-based false recognition of pictures in older and younger adults. *Journal of Memory and Language, 37*, 555–583.

Loftus, E. F., & Hoffman, H. G. (1989). Misinformation and memory: The creation of new memories. *Journal of Experimental Psychology: General, 118*, 100–104.

Loftus, E. F., Levidow, B., & Duensing, S. (1992). Who remembers best? Individual differences in memory for events that occurred in a science museum. *Applied Cognitive Psychology, 6*, 93–107.

MacLeod, C. M., & Nelson, T. O. (1976). A nonmonotonic lag function for false alarms to associates. *American Journal of Psychology, 89*, 127–135.

Macmillan, N. A., & Creelman, C. D. (1991). *Detection theory: A user's guide*. New York, NY: Cambridge University Press.

Marx, M. H., & Henderson, B. B. (1996). A fuzzy trace analysis of categorical inferences and instantial associations as a function of retention interval. *Cognitive Development, 11*, 551–569.

McCabe, D. P., Roediger, H. L., III, McDaniel, M. A., & Balota, D. A. (2009). Aging reduces veridical remembering but increases false remembering: Neuropsychological test correlates of remember-know judgments. *Neuropsychologia, 47*, 2164–2173.

Meissner, C. A., & Brigham, J. C. (2001). A meta-analysis of the verbal overshadowing effect in face identification. *Applied Cognitive Psychology, 15*, 603–616.

Mickes, L., Hwe, V., Wais, P. E., & Wixted, J. T. (2011). Strong memories are hard to scale. *Journal of Experimental Psychology: General, 140*, 239–257.

Mueller-Johnson, K., Toglia, M. P., Sweeney, C. D., & Ceci, S. J. (2007). The perceived credibility of older adults as witnesses and its relation to ageism. *Behavioral Sciences and the Law, 25*, 355–375.

Neumann, C., Kaye, D., Jackson, G., Reyna, V. F., & Ranadive, A. (2016). Presenting qualitative information on forensic science evidence in the court room. *CHANCE*, *29*(1), 37–43. doi:10.1080/09332480.2016.1156365

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.

Office of Disease Prevention and Health Promotion. (2018). *Older adults*. Retrieved October 3, 2018, from www.healthypeople.gov/2020/topics-objectives/topic/older-adults

Parks, T. E. (1966). Signal-detectability theory of recognition: Memory performance. *Psychological Review, 73*, 44–58.

Payne, D. G., Elie, C. J., Blackwell, J. M., & Neuschatz, J. S. (1996). Memory illusions: Recalling, recognizing, and recollecting events that never occurred. *Journal of Memory and Language, 35*, 261–385.

Poldrack, R. A., Monahan, J., Imrey, P. B., Reyna, V. F., Raichle, M., Faigman, D., & Buckholtz, J. W. (2018). Predicting violent behavior: What can neuroscience add? *Trends in Cognitive Sciences*, *22*(2), 111–123. doi:10.1016/j.tics.2017.11.003

Poole, D. A. (1995). Strolling fuzzy-trace theory through eyewitness testimony (or vice versa). *Learning and Individual Differences, 7*, 87–93.

Poole, D. A., & White, L. T. (1991). Effects of question repetition on the eyewitness testimony of children and adults. *Developmental Psychology, 27*, 975–986.

Read, J. D. (1979). Rehearsal and recognition of human faces. *American Journal of Psychology, 92*, 71–85.

Reyna, V. F., & Brainerd, C. J. (1995). Fuzzy-trace theory: An interim synthesis. *Learning and Individual Differences, 7*, 1–75.

Reyna, V. F., & Brainerd, C. J. (2011). Dual processes in decision making and developmental neuroscience: A fuzzy-trace model. *Developmental Review, 31*, 180–206.

Reyna, V. F., Corbin, J. C., Weldon, R. B., & Brainerd, C. J. (2016). How fuzzy-trace theory predicts true and false memories for words, sentences, and narratives. *Journal of Applied Research in Memory and Cognition, 5*, 1–9.

Reyna, V. F., & Kiernan, B. (1994). Development of gist versus verbatim memory in sentence recognition: Effects of lexical familiarity, semantic content, encoding instructions, and retention interval. *Developmental Psychology, 30*, 178–191.

Reyna, V. F., & Kiernan, B. (1995). Children's memory and metaphorical interpretation. *Metaphor and Symbolic Activity, 10*, 309–331.

Reyna, V. F., Mills, B. A., Estrada, S. M., & Brainerd, C. J. (2006). False memory in children: Data, theory, and legal implications. In M. P. Toglia, J. D. Read, D. F. Ross, & R. C. L. Lindsay (Eds.), *The handbook of eyewitness psychology: Memory for events* (pp. 473–510). Mahwah, NJ: Erlbaum.

Roediger, H. L., III, & DeSoto, K. A. (2014). Confidence and memory: Assessing positive and negative correlations. *Memory, 22*, 76–91.

Roediger, H. L., III, & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 803–814.

Roediger, H. L., III, Watson, J. M., McDermott, K. B., & Gallo, D. A. (2001). Factors that determine false recall: A multiple regression analysis. *Psychonomic Bulletin & Review, 8*, 385–407.

Roediger, H. L., III, Wixted, J. T., & DeSoto, K. A. (2012). The curious complexity between confidence and accuracy in reports from memory. In L. Nadel & W. Sinnott-Armstrong (Eds.), *Memory and law* (pp. 84–117). Oxford: Oxford University Press.

Ross, D. F., Dunning, D., Toglia, M. P., & Ceci, S. J. (1990). The child in the eyes of the jury. *Law and Human Behavior, 14*, 5–23.

Ryan, R. S., & Schooler, J. W. (1998). Whom do words hurt? Individual differences in susceptibility to verbal overshadowing. *Applied Cognitive Psychology, 12*, S105–S125.

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.

Schooler, J. W. (1998). The distinctions of false and fuzzy memories. *Journal of Experimental Child Psychology, 71*, 130–143.

Schooler, J. W., & Engstler-Schooler, T. Y. (1990). Verbal overshadowing of visual memories: Some things are better left unsaid. *Cognitive Psychology, 22*, 36–71.

Seamon, J. G., Luo, C. R., Kopecky, J. J., Price, C. A., Rothschild, L., Fung, N. S., & Schwartz, M. A. (2002). Are false memories more difficult to forget than accurate memories? The effect of retention interval on recall and recognition. *Memory & Cognition, 30*, 1054–1064.

Selmeczy, D., & Dobbins, I. G. (2014). Relating the content and confidence of recognition judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*, 66–85.

Shiffrin, R. M., Huber, D. E., & Marinelli, K. (1995). Effects of category length and strength on familiarity in recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 267–287.

Simons, J. S., Lee, A. C. H., Graham, K. S., Verfaellie, M., Koutstaal, W., Hodges, J. R., . . . Budson, A. E. (2005). Failing to get the gist: Reduced false recognition of semantic associates in semantic dementia. *Neuropsychology, 19*, 353–361.

Smedslund, J. (1969). Psychological diagnostics. *Psychological Bulletin, 71*, 237–248.

Sporer, S. L., Penrod, S., Read, D., & Cutler, B. (1995). Choosing, confidence, and accuracy: A meta-analysis of the confidence-accuracy relation in eyewitness identification studies. *Psychological Bulletin, 118*, 315–327.

Thompson-Schill, S. L., Kurtz, K. J., & Gabrieli, J. D. E. (1998). Effects of semantic and associative relatedness on automatic priming. *Journal of Memory and Language, 38*, 440–458.

Toglia, M. P., Neuschatz, J. S., & Goodwin, K. A. (1999). Recall accuracy and illusory memories: When more is less. *Memory, 7*, 233–256.

Tousignant, J. P., Hall, D., & Loftus, E. F. (1986). Discrepancy detection and vulnerability to misleading postevent information. *Memory & Cognition, 14*, 329–338.

Tulving, E. (1981). Similarity relations in recognition. *Journal of Verbal Learning and Verbal Behavior, 20*, 479–496.

Tun, P. A., Wingfield, A., Rosen, M. J., & Blanchard, L. (1998). Response latencies for false memories: Gist-based processes in normal aging. *Psychology and Aging, 13*, 230–241.

Tussing, A. A., & Greene, R. L. (1997). False recognition of associates: How robust is the effect? *Psychonomic Bulletin & Review, 4*, 572–576.

Tussing, A. A., & Greene, R. L. (1999). Differential effects of repetition on true and false recognition. *Journal of Memory and Language, 40*, 520–533.

Wilson, B. M., Seale-Carlisle, T. M., & Mickes, L. (2018). The effects of verbal descriptions on performance in lineups and showups. *Journal of Experimental Psychology: General, 147*, 113–124.

Wise, R. J. S., & Price, C. J. (2006). Functional neuroimaging of language. In R. Cabeza & A. Kingstone (Eds.), *Handbook of functional neuroimaging of cognition* (2nd ed., pp. 191–227). Cambridge, MA: MIT Press.

Wixted, J. T., & Wells, G. L. (2017). The relationship between eyewitness confidence and identification accuracy: A new synthesis. *Psychological Science in the Public Interest, 18*, 10–65.

Zeelenberg, R., Boot, I., & Pecher, D. (2005). Activating the critical lure during study is unnecessary for false recognition. *Consciousness and Cognition, 14*, 316–326.