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3
Reasoning, Remembering, and Their Relationship: Social, Cognitive, and Developmental Issues

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In this age of specialization, the relationship between memory and reasoning-based judgments is one of the few topics that spans subdisciplines. In cognitive development, for example, much of the post-Piagetian revolution is predicated on explaining reasoning performance (i.e., the accuracy of judgments) in terms of memory constraints (e.g., Bjorklund, 1987, 1989; Brainerd, 1983a, 1983b; Bryant & Trabasso, 1971; Case, 1985; Dempster, 1981, 1985; Trabasso, 1977). At some disciplinary remove from cognitive development, social psychologists have looked to memory-judgment relationships to explain variations in attitudes and attributions (e.g., Cacciopo & Petty, 1985; Hastie & Park, 1986; Higgins & Stangor, 1988; Pratkanis, Greenwald, Leippe, & Baumgardner, 1988). Although there have been some notable exceptions in both fields (e.g., Anderson & Hubert, 1963; Brainerd & Kingma, 1984, 1985), most theorists have assumed a hand-in-glove relationship between memory and reasoning (or reasoning's product, judgment).

Fuzzy-trace theory has been developed with particular attention to the interplay between memory and reasoning (Brainerd & Reyna, 1990b; Reyna & Brainerd, 1990, 1991a). Therefore, I exploit fuzzy-trace theory here in order to discuss some perplexing results regarding reasoning-remembering relationships in the social, cognitive, and developmental literatures. The discussion is divided into two sections, one concerned primarily with short-term retention and the other with long-term retention. The focus is on retention, rather than acquisition, although differences between the two are briefly discussed. In the first section, I emphasize cognition, and illustrate conditions under which fuzzy-trace theory predicts such paradoxical findings as reasoning-remembering independence -that memory for the critical facts of a problem often has no bearing on its solution. In the subsequent section, I address the relationship between memory and social judgment, and the question of bias and suggestibility in long-term retention. Developmental considerations come into play in both sections -in the first, because age determines the nature of remembering, and in the second, through the concept of suggestibility in long-term retention. The discussion is guided by fuzzy-trace theory's fourfold distinction that can be applied to memory performance, whether short- or long-term, namely that it can be based on retrieval of gist or verbatim traces, or on reconstruction of either type of trace.

Short-Term Retention

The Paradox of Reasoning-Remembering Independence

What is the relationship between reasoning and the ability to remember critical informational inputs to reasoning? There are two classic answers to this question, answers that dispute the nature of memory itself. The first and older answer, which has the aura of common sense if not self-evidence, is that retention of decisive information is a necessary precondition for accurate reasoning. In the developmental literature, this position is well illustrated by any number of methodological tracts, some recent ones (e.g., Brainerd, 1983b; Rabinowitz, Howe, & Lawrence, 1989) and some early ones (e.g., Elkind, 1967; Smedslund, 1969) that list as a major source of error children's inability to remember critical background facts long enough to complete a sequence of reasoning operations. In research with adults, the accuracy of reasoning is said to be inherently nonoptimal because it is bound by the limitations of working memory, as well as other cognitive constraints (e.g., Nisbett & Ross, 1980; Simon, 1988). Thus, research with both children and adults assumes that correct reasoning requires, at least, the ability to remember critical information long enough to process it.

Another perspective on the reasoning-remembering relationship grows out of the Bartlett (1932) tradition and was made popular among students of development by Piaget (1968; Piaget & Inhelder, 1973). This constructivist view holds that the nature of reasoning controls what can be remembered about pertinent informational inputs (Bransford & Franks, 1971). Children, for example, can accurately remember certain types of information to the extent that they have developed the reasoning operations that process such information: "The schemata used by the memory are borrowed from the intelligence" (Piaget & Inhelder, 1973, p. 382). Research in this vein with adults is designed to demonstrate that understanding influences memory, for example by determining how information is encoded (Bransford & Johnson, 1973; Kintsch, 1974).

Despite their differences, note that both approaches to the reasoning-remembering relationship imply dependence, in one case because memory requires accurate reasoning and in the other case because reasoning requires accurate memory. In this context, the reasoning/remembering independence effect (or simply *memory independence*) is informative

because we must look beyond our usual assumptions in order to explain its existence. The basic datum is simple enough. Solutions to a variety of familiar reasoning problems are independent of short-term memory for background facts that are essential to such solutions (Brainerd, 1985; Brainerd & Kingma, 1985; Brainerd & Reyna, 1988a; Reyna & Brainerd, 1990). Because memory independence occurs across the same age spans in which performance on both reasoning problems and memory measures are steadily improving, it seems that the development of reasoning does not depend in any direct way on the development of memory, even memory for information that is purportedly used in reasoning, and conversely.

The literature on transitivity development is perhaps the best forum in which to illustrate memory independence itself and the challenges it poses for traditional views of reasoning and remembering. The standard problem involves three-term series of the form $A > B > C$. The relationships between the adjacent terms ($A > B$, $B > C$) are presented as background facts, with children then being interrogated about the relationship between the nonadjacent terms. In a recent review of this literature (Reyna & Brainerd, 1990), it was shown that extant studies can be assembled into three historical stages that vary in their assumptions about the role of children's memory for adjacent relationships in transitive inference.

Stage 1 was dominated by Piaget's (e.g., 1970; Piaget & Inhelder, 1969) analysis of transitivity, which claimed that transitive inference consists of deducing the AC relationship from the logical givens that are inherent in the AB and BC relationships. That is, transitivity was treated as a form of deductive logic in which the adjacent relationships play the role of axioms. Children's ability to remember adjacent relationships long enough to effect their deductions was not seriously questioned. So, children who failed transitivity problems were deficient in basic logical competence.

Stage 2 was characterized by an intensive concern with the role of logic versus memory. Certain investigators proposed that children might simply be unable to remember one or both of the adjacent relationships (e.g., Bryant & Trabasso, 1971; Roodin & Gruen, 1970; Trabasso, 1977). It was argued that preschoolers are not logically deficient and, instead, that their reasoning errors were rooted in short-term memory failures. For instance, Bryant and Trabasso (1971) proposed that $p(AC) = p(AB) \times p(BC)$, where $p(AC)$ is the probability of making a transitive inference and $p(AB)$ and $p(BC)$ are the probabilities of correct performance on memory probes for the relevant adjacent relationships. Such arguments were not based on the standard Piagetian transitivity paradigm, however, but on data from an overlearning variant in which children receive extensive training on adjacent relationships and transitivity problems are not posed until memory for these relationships is assured. With this procedure, it was found that inference rates significantly improved for preschoolers and were essentially perfect for older children (Reyna & Brainerd, 1990).

The memory hypothesis proposed by Bryant and Trabasso, that memory for adjacent relationships wholly determined reasoning performance, was soon amended. Investigators who were more sympathetic to logic-based interpretations began exploring the possibility that memory for adjacent relationships is not sufficient for reasoning. Consistent with the insufficiency hypothesis, it was reported that children who are able to retrieve adjacent relationships on memory tests often fail to make the indicated transitive inference (see Grieve & Nesdale, 1979; Halford & Galloway, 1977; Russell, 1981). Although such results indicated that memory was not sufficient for reasoning, nevertheless, it was widely agreed that memory was necessary. Indeed, the overlearning data continued to be interpreted as showing that variations in memory were an important source of variations in reasoning performance. Thus, the essential theme of Stage 2 research was preserved, despite qualifications regarding sufficiency—memory was viewed as a critical factor in transitivity performance.

During Stage 3, the radical hypothesis that memory for adjacent relationships may not be necessary for transitive inference was introduced. The overlearning procedure was replaced because it is subject to a crucial methodological shortcoming, namely that it eliminates the very processes used to solve transitivity problems in the standard procedure (see Brainerd & Kingma, 1984; Reyna & Brainerd, 1990). That is, overlearning not only ensured memory for background facts, but it had the inadvertent effect of changing subjects' reasoning processes as well. Hence, reasoning in the standard task could not be explained by reference to results from the overlearning paradigm (Reyna & Brainerd, 1990). (Data from the overlearning paradigm remain relevant, however, to the question of how linear orderings are constructed solely from pairwise comparisons [see Reyna & Brainerd, in press].)

Therefore, Brainerd and Kingma (1984) developed an elementary modification of the standard transitivity procedure, the probe paradigm. Transitivity problems were administered in the normal way, except that memory probes for adjacent relationships were presented following children's responses to inference questions. In eight experiments with subjects in the 5- to 8-year-old range, Brainerd and Kingma discovered that children's ability to solve transitivity problems involving three-, four-, and five-term series was independent of their memory for adjacent relationships. Previously reported significant correlations between memory and reasoning performance had apparently masked underlying independence that could be detected with more direct tests of memory necessity, such as conditional analysis (Brainerd & Kingma, 1984; Reyna & Brainerd, 1990). This memory independence pattern has been replicated in several subsequent experiments (e.g., Brainerd, 1985; Brainerd & Kingma, 1985; Chapman, 1989; Chapman & Lindenberger, 1988, in press) and has been found in reanalyses of published data (see Reyna & Brainerd, 1990, 1991a).

Memory independence has also been observed in connection with other familiar reasoning tasks. Examples include class inclusion, probability judgment, conservation, and decisions about text (Brainerd, 1985; Brainerd & Kingma, 1985; Callahan, 1989; Reyna & Brainerd, 1990, 1991a; Swanson, 1990). In each case, memory independence was noted within the age range during which most of the developmental variability in the target form of reasoning occurs. Thus, the nonnecessity of memory seems to be a robust finding, both in the sense that developmental variations in memory do not appear to underlie changes in reasoning, and in the sense that problem solving does not appear to call on memory for problem facts.

Explaining Memory Independence

Fuzzy-trace theory (Brainerd & Reyna, 1988a, 1990b; Reyna & Brainerd, 1990, 1991a) was motivated by the need for a plausible explanation of the fact that reasoning, and memory for information that is critical to reasoning, so often follow independent paths during processing, and developmentally. The explanation that was eventually favored by experimentation is that although reasoning problems and memory probes seem, on first impression, to tap the same memorial substratum, they do not. In the probe paradigm, memory tests typically place a premium on verbatim retention of the background facts (e.g., retention of specific cardinal numbers in probability judgment and class inclusion). At roughly the same time, however, problem information is also mined for senses, patterns, and other cognitive distillates (Brainerd & Reyna, 1990b). Consequently, children's working memories contain an assortment of problem-relevant information that has been extracted in parallel with the encoding of the original background data, information that varies from richly elaborated traces that preserve verbatim details to fuzzy, gist-like traces that preserve only the sense or pattern of the background facts (Reyna & Brainerd, 1991b). These fuzzy-to-verbatim continua are central to understanding cognition because reasoning is predisposed to operate on traces that are as near as possible to the fuzzy extremes of such continua (Brainerd & Reyna, 1988a). One reason for this fuzzy-processing preference is that, because gist is easy to retain but verbatim information decays rapidly, reasoning is naturally engineered to operate on the types of traces that are most likely to be available (Brainerd & Reyna, 1990b). Thus, reasoning performance often develops independently of memory performance in the probe paradigm because memory errors are chiefly due to the loss of verbatim information but reasoning errors are chiefly due to random failures in gist processing (Reyna & Brainerd, 1990).

To flesh out these assumptions, I return to some of the tasks in which reasoning/remembering relationships have been investigated. As noted, the prototypical situation is that memory probes measure verbatim retention of background facts, and reasoning problems measure the processing of gist that was extracted when these facts were encoded. The probe version of probability judgment (e.g., Brainerd, 1981) is illustrative. Subjects are first presented with the cardinal numbers of sets of common objects that comprise a hypothetical sampling space (e.g., Set $A = 7$ red balls, Set $B = 2$ white balls). Experimental evidence indicates that when these numbers are presented, adults and children (as young as age 4) also encode relational gist (e.g., "more *A*s than *B*s") and nominal gist (e.g., "a lot of *A*s"). After presentation, subjects predict a series of random draws from the sampling space (probability judgments) and answer probes for the numerical information. Although the probes query verbatim number memory, results from several experiments suggest that both children and adults base their probability judgments on nominal or relational gist (Brainerd, 1981, 1983a; Brainerd & Kingma, 1985; Callahan, 1989; Estes, 1976; Reyna & Brainerd, 1991b). For example, manipulations that should affect the retention of verbatim numerical information (e.g., increasing the number of values that children must encode; providing an external store of problem information), produce large variations in probe performance but not in probability judgment (Brainerd & Kingma, 1985). The gist on which probability judgments are based is relatively immune to memorial factors. The greater memorial stability of this gist is illustrated by two findings. First, if both verbatim memory probes and probes for relational or nominal gist are administered after a short sequence of probability judgments, the gist is almost invariably present whereas the verbatim numbers have often been lost (Brainerd, 1983a). Second, across such a sequence, the accuracy of probability judgments remains relatively constant, which would not be expected if the relevant memorial substratum is unstable, but performance on verbatim memory probes declines steadily (Brainerd, 1981).

Although it is prototypical for reasoning to be gist-based and for memory probes to tap verbatim information, tasks have been studied in which gist can also be used to answer probes. Transitivity is a case in point. The objects that comprise a target array are normally presented so that their spatial and/or temporal ordering is correlated with the magnitude differences between them. It has been found that, as information about the adjacent relationships is encoded, subjects also store global patterns such as "big things start on the left" and "things get smaller to the right" (for a review, see Reyna & Brainerd, 1990). Even preschoolers encode such patterns (Brainerd & Kingma, 1984), and the patterns are highly resistant to memory failure once they are stored (Reyna & Brainerd, 1990). Subjects use these patterns both to make transitive inferences and to answer probes about adjacent relationships (Brainerd & Reyna, 1990b; Chapman & Lindenberger, 1988). In other words, they *reconstruct* adjacent relationships from stored *gist* rather than reading out stored verbatim information about those relationships. Consistent with this interpretation, probe performance is unresponsive to manipulations that should affect the availability of the latter information (e.g., varying the number of adjacent relationships that are initially encoded), and it improves across a sequence of repeated memory tests (Brainerd & Kingma, 1984; Chapman & Lindenberger, 1988).

The fact that memory independence has been observed with a paradigm in which reasoning and probe performance involve processing the same gist lends credence to the assumption that gist-processing errors tend to be random in such circumstances (Reyna & Brainerd, 1990). Such a conclusion is corroborated by the beneficial effects of mere practice, and by developmental improvements in performance, the ability to reliably execute operations, developmental constancy in competence, and the nature of processing in the task. Across tasks, the key commonality that seems to be associated with random errors in gist processing is the presence of an external memory support that stores the identity of verbatim elements. Thus, in transitivity, the seriation pattern must be gleaned from the informational inputs because differences in magnitude are not perceptible; however, the individual items need not be memorized, only the direction of "flow," i.e., whether the pattern is a progressively increasing or decreasing one. Problem solution involves reading off elements from the external array and combining the elements with one's memory for the seriation pattern (e.g., "The blue rod must be bigger than the red because I can see that it is on the left"). Thus, subjects apply spatial discrimination operations to the array both to answer transitivity questions (e.g., $A > C$ if A is to the left of C) and to answer memory probes (e.g., $B > C$ if B is to the left of C). Such spatial patterns, once they are extracted, are highly resistant to memory failure. Because memory for gist (the pattern of "flow") and the external array are highly reliable stores, errors are in performance, such as mishearing a question or misidentifying an item in the array. Such performance errors are, of course, random.

By removing such external supports for verbatim elements, it is possible to devise problems that are so constrained that extracted gist is insufficient for solution and, hence, the verbatim background facts must be remembered. Here, mental arithmetic is illustrative. In the mental arithmetic task, children are administered addition and subtraction problems involving small addends, followed by recall probes for the addends (Brainerd, 1983a, 1983b, 1987; Brainerd & Reyna, 1988a). The basic procedure involves presenting children with a linear array of familiar objects (e.g., a row of horses), designating one of the objects in the array as a target, assigning a number to the target, asking children to increment or decrement that target number by small amounts, and finally, following some problems, asking children to recall the number that was originally assigned to the target. Initially, arithmetic performance seemed to depend on children's ability to recall the numbers that were assigned to targets (Brainerd, 1983a, 1983b). However, subsequent research revealed that, surprisingly, recall depended on the accuracy of arithmetical reasoning rather than conversely. Specifically, it was found that children tended to answer recall probes by "working backward" from their solutions to arithmetic problems to the addends that were implied by those solutions. On a problem of the form $m + 2 = k$, for example, children answered m probes not by retrieving the value of m, but by *reconstructing* this *verbatim* value by performing the calculation $k - 2$ (Brainerd & Reyna, 1988a, Exp. 1). When manipulations were imposed that increased children's reliance on verbatim retrieval as opposed to reconstructive memory, the stochastic dependency between performance on arithmetic problems and performance on probes shrank (Brainerd & Reyna, 1988a, Exp. 2).

Therefore, when subjects are presented with problems of the form "if you had 5 cookies and I had 3 cookies, how many cookies would we have altogether," relational gist ("I have more cookies than he does"), nominal gist ("I have a lot of cookies"), and other forms of synoptic information will not support accurate reasoning. If the probe paradigm is employed with mental arithmetic problems, fuzzy-trace theory predicts pronounced reasoning/remembering dependencies because verbatim memory failures contribute to arithmetic performance as well as to probe performance, an outcome that has been consistently obtained (Brainerd, 1983b, 1987; Brainerd & Reyna, 1988a). Similarly, when the external array of verbatim elements is removed in the transitivity task, memory load (the number of premises) then affects reasoning performance (Chapman & Lindenberger, 1988). Note, again, that the external array cannot convey the transitive relationships in the series; differences in magnitude are not detectable by the subject. However, the array does index the verbatim elements (and their locations) so that the reasoner need not remember those particular facts. Everyday reasoning would seem to resemble the verbatim-supported situations, in which gist memory is combined with verbatim prosthetics, such as reference books, lists (e.g., grocery lists), on-line computer "help" options, and so on. Thus, reasoning-remembering independence would seem to be a common state of affairs, with reasoning dependence on verbatim memory requiring situations in which informational patterns and redundancies are impoverished. Whatever the nature of reasoning-remembering relationships in real life, however, it is clear across a wide array of experimental paradigms that subjects avoid reasoning with verbatim details wherever possible, operating instead on gist-like patterns, leaving their reasoning and remembering independent.

Summing up, applications of the probe paradigm have produced three types of relationships between reasoning and remembering: (a) memory independence, because reasoning performance is apparently based on gist, whereas memory performance is based on verbatim traces; (b) memory independence, because both reasoning and memory are based on gist, but errors are random, and therefore independent of one another; and (c) positive memory dependence when reasoning is compelled to tap the same verbatim substratum as memory performance. Standard problem solving paradigms tend to evoke memory independence because the differing specificity of questions allows gist processing to be sufficient for reasoning, whereas retrieval of verbatim background facts is necessary for probe performance (e.g., probability judgment, class inclusion). With such tasks, typical verbatim memory manipulations affect probe performance but not reasoning.[1] Independence is also observed when gist processing governs both reasoning and probe performance (e.g., transitivity) because gist-processing errors in such situations are uncorrelated with each other. In that case, neither reasoning nor probe performance reacts to verbatim memory manipulations. Last, positive dependence is observed in highly constrained situations where the verbatim background facts must be processed because gist will not support accurate reasoning (e.g., mental arithmetic). Research on the probe paradigm, then, argues for memory independence when reasoning involves gist processing, either because, in one class of tasks, reasoning errors are gist-processing failures and probe errors are verbatim memory failures or because, in another class of tasks, errors of both types are random gist-processing failures.

Development of Verbatim and Gist Memory

On the one hand, there is unmistakable evidence of gist extraction in both infrahumans and very young humans (for a review, see Brainerd & Reyna, 1990b). The formation of learning sets (e.g., Harlow, 1949) and cognitive maps (e.g., Tolman, 1948) are hoary illustrations of animal gist extraction. Concerning humans, infants and young children will store cross-modal analogies and other noliteral similarities in which connections between stimuli must exist at some level of abstraction (e.g., Reyna, 1981, 1985; Wagner, Winner, Cicchetti, & Gardner, 1981).

[1] Interestingly, such "classic" memory manipulations as load and delay do not necessarily affect memory rather than reasoning (Rabinowitz et al., 1989). When memory is well preserved despite added load or delay, such manipulations can nevertheless affect the complexity of processing (Reyna, 1991). As Rabinowitz et al. have shown, this relationship between "memory" manipulations and reasoning can be unmasked by fitting data with formal models that indicate whether such manipulations affect memory versus reasoning parameters.

On the other hand, there is equally unmistakable evidence that the ability to distill and store gist from the incoming flow of verbatim information develops. Behavioral and neurological evidence favor distinct developmental paths for verbatim memory and gist memory (Brainerd & Reyna, 1990b; Reyna & Brainerd, 1990, 1991a). Fuzzy-trace theory assumes, in connection with such evidence, that early in life human memory is specialized for storing and retrieving verbatim representations of encoded information. (This is not to say that gist is not extracted during early development, as noted above.) Hence, fuzzy-trace theory's basic claims are simply (a) that the memory systems that support retention of verbatim information exhibit rapid maturation and complete their ontogenesis rather early, (b) that the corresponding systems that support retention of senses and patterns exhibit slow maturation and complete their ontogenesis rather late, and (c) that there is a point (probably in early adolescence for most individuals) when verbatim systems begin to deteriorate while gist systems continue to improve.

The behavioral evidence for such claims is broad, but it is especially compelling when it comes to memory for verbal information. Evidence regarding the astonishing verbatim memory of younger children comes from sources ranging from experimental studies of verbal memory to naturalistic observations of children's memory in oral cultures (e.g., Hirsch, 1988). Brainerd and Reyna (1990b) concluded that the literature on first language acquisition supports the contention that such memory systems mature rapidly, and that the literature on second language acquisition supports the related contention that such systems begin to deteriorate rather early. In the former case, the fact that young children acquire a vocabulary comprised of thousands of new words during such a short period of time, roughly 14 new words per day by some estimates (Miller, 1981), attests to their powerful verbatim memory capabilities. In the latter case, the fact that the ability to acquire the vocabulary of a second language decreases steadily after about age 8, and is very limited after early adolescence (see Johnson & Newport, 1989), strongly suggests that verbatim memory systems begin to deteriorate as a consequence of central nervous system maturation (Lenneberg, 1967).

Concerning the development of memory for gist, there is a wealth of studies documenting the increasing tendency of older children to derive gist-like patterns from information, and to utilize those patterns in reasoning (Brainerd & Reyna, 1990b; Reyna & Brainerd, 1991a). For example, a number of studies have addressed developmental trends in the false recognition paradigm developed by Bransford and colleagues (Bransford, Barclay, & Franks, 1972; Bransford & Franks, 1971). In this paradigm, subjects are presented with propositions that can be integrated, for example into a spatial pattern, as in "Three turtles rested on a floating log and a fish swam beneath *it*." The result of principal interest is that adults are unable to distinguish the gist that they have constructed (that the fish swam beneath the *turtles*) from the verbatim sentences. Therefore, subjects falsely recognize story-consistent distractors at high levels of confidence, often at higher levels of confidence than sentences that were actually studied. A variant of this procedure has been used in several developmental studies (e.g., Johnson & Scholnick, 1979; Liben & Posnansky, 1977; Paris & Carter, 1973; Paris & Mahoney, 1974; Prawat & Cancelli, 1976). Like adults, children tend to falsely recognize true inferences that are consistent with the gist of a story. However, this tendency develops, with Weismer (1985), for instance, reporting that kindergarteners and second graders falsely recognized 63% and 75% of the true inferences, respectively. Of course, because younger children are *less* likely to respond on the basis of gist (as opposed to verbatim memory which the task requires), they are *less* prone to err on true inferences. Moreover, by unconfounding certain surface cues, Liben and Posnansky (1977) were able to show that, when younger children did falsely recognize true inferences, they did so based on verbatim cues rather than gist, whereas the reverse was true for older children. This and other research across varied tasks and stimuli suggests that the shift toward gist-based processing begins between kindergarten and second grade (the redoubtable five-to-seven shift, Stevenson, 1972), and predominates by age 9 or 10.

The most incisive evidence about verbatim-gist developmental trends, however, comes from studies in which the two are directly compared. Such studies by Marx (1985, 1986), Schmidt and her associates (e.g., Schmidt & Welch, 1989), Perner and Mansbridge (1983), and others converge on the conclusions that the relevant gist-memory systems evolve slowly and that they are still developing as verbatim systems begin their decline (Reyna & Brainerd, 1991a).

In memory for frequency, for example, Marx (1985, 1986) compared the development of a verbatim strategy (counting) to the development of a gist strategy (forming impressions of strength). He found that use of the verbatim strategy peaked sometime before age 10 and decreased thereafter. Use of the gist strategy continued to increase throughout adolescence and young adulthood. Similarly, Schmidt and her associates devised a technique for classifying children in terms of their ability to retain verbatim details of sentences relative to their ability to retain gist. With kindergartners, a majority of the children retained verbatim information better than gist. With second graders, the reverse was true. Comparing similar age groups, as noted earlier, Liben and Posnansky (1977) demonstrated that older children falsely recognized inferences because they were consistent with the gist of a story, but younger children responded to memory probes on the basis of verbatim similarity to actually presented sentences. Indeed, when verbatim information was a reliable cue, younger children were able to outperform older ones. Last, Perner and Mansbridge (1983) found that retention of verbatim information about ordered pairs peaked by age 7 and declined between early adolescence and young adulthood. However, memory for global magnitude patterns, ordered pairs that formed a series, improved steadily between age 5 and young adulthood. Yet another type of task, quite unlike memory for verbal information or frequency memory, namely face recognition, shows a similar developmental trend through similar age ranges: Memory for piecemeal stimulus characteristics is supplanted by an emphasis on configurational patterns (Carey & Diamond, 1977; Carey, Diamond, & Woods, 1980).

Behavioral evidence suggesting verbatim memory specialization during early development and gist memory specialization later on would make more sense, of course, if it could be demonstrated that the host neurological structures for verbatim and gist representations were different. Preliminary data of this sort are available in the neuropsychological literature (Granger & McNulty, 1986; Staubli, Ivy, & Lynch, 1984). Further, consistent with fuzzy-trace theory, the host structures for verbatim information are developmentally more primitive than those for gist (Brainerd & Reyna, 1990b). One specific type of lesion, of the connection between the dorsomedial nucleus of the thalamus and the frontal cortical system, prevents the acquisition of learning sets in discrimination tasks. According to Granger and McNulty, these rats are "learning specific memories" for correct responses, "but are failing to learn the template information" about the task (p. 42). Disconnection, or lesions, of the hippocampus, on the other hand, produces an apparent inverse of this result. Rats acquire learning sets, but, for a given discrimination, they cannot recall the right specific response if delays of more than 5 min are interposed between trials. Thus, the first group has specific memories, but lacks the gist, and the second group can acquire the gist, but forgets the details after short delays. The ease of acquisition of learning sets, and other kinds of abstract transfer of learning, increases phylogenetically and ontogenetically, that is, from animals to humans, and from younger to older children (Reyna & Brainerd, in press).

Thus, the early elementary years seem to be characterized by a verbatim-to-gist shift across a variety of stimulus domains from memory for faces to memory for stories. Interestingly, increasing gist-based processing does not necessarily lead to deterioration on verbatim tasks, unless tasks are designed so that gist information is orthogonal to verbatim information. In other words, gist memory can facilitate performance on what are ostensibly tests of verbatim memory. For example, recall of nonsense syllables can be vastly improved if they form a meaningful pattern (Glaze, 1928). As pointed out earlier, it is difficult to render a task gist-neutral. Memory probes that seem to tap only verbatim information can often be answered in at least two ways, in principle—simple readout of verbatim traces or reconstruction of information based on remembered gist. Thus, especially with meaningful material, subjects often have the option of verbatim retrieval or (at least some) gist reconstruction in order to correctly answer "verbatim" probes. Therefore, older children are acquiring an approach to thinking with broader utility, compared to a verbatim system, one that can apply to both gist and verbatim memory tasks (see Estes, 1980, for arguments supporting the superiority of fuzzy over precise memory for thinking).

These two claims, that there is a verbatim-to-gist developmental shift and that "verbatim" memory performance can be improved by gist memory, lead to two additional predictions. First and obviously, the tendency to rely on verbatim readout versus reconstruction will depend on the current state of memory specialization, with readout being favored during the years of verbatim specialization and reconstruction being favored thereafter. So, performance on tests that seem, on the surface, to be measuring verbatim retention (e.g., old-new recognition) ultimately come to be governed by reconstruction from gist. Second, relying on readout versus reconstruction when answering probes about verbatim information has consequences for accuracy, and those consequences vary as a function of the state of developmental specialization of memory. At first glance, it would seem natural to suppose that simply reading out verbatim traces would be more accurate than attempting to reconstruct verbatim information from gist. Developmental data suggest otherwise, however.

Here, the studies of Marx (1985, 1986), Perner and Mansbridge (1983), and Schmidt and her associates (e.g., Schmidt & Welch, 1989) are again apropos. As mentioned, Marx found that use of the verbatim strategy peaked and began to decline many years before the gist strategy had finished developing. In addition, however, he found a developmental crossover of the sort that is anticipated by fuzzy-trace theory. Among elementary schoolers, memory for verbatim frequency was in fact better in subjects who relied on the verbatim strategy than among subjects who relied on the gist strategy. Among adolescents and young adults, however, the reverse was true. Schmidt's data provide even broader support for the basic claim. After classifying children in terms of their preference for retaining verbatim information versus gist, the children were administered a series of verbatim memory tests (recalling sentences) and series of reasoning tests (inferences from stories). At both the kindergarten and second grade levels, children who had been classified as having high gist preference performed better on the reasoning tests. On the verbatim memory tests, however, there was a developmental crossover of the type that Marx obtained. Kindergarten children who were classified as having high verbatim preference performed roughly 65% more accurately than kindergarten children who were classified as having high gist preference. But, second grade children who were classified as having high gist preference were roughly 30% more accurate than second grade children who were classified as having high verbatim preference.

The most parsimonious explanation for the difficulty younger children have processing gist is that the presence of verbatim detail in memory interferes with the extraction of gist-like patterns (Brainerd & Reyna, 1990; Reyna & Brainerd, 1991a). To "see" global patterns, one must suppress irrelevant minutiae. Theorists have made a similar point about the relative advantages to cognition of an abstract code such as language, as opposed to pictures that specify irrelevant concrete details (Clark & Clark, 1977). The very superiority of younger children's rote memory, then, might cause them to be bound up in superficial details in ways that interfere with their reasoning (Reyna & Brainerd, 1991a).

In sum, data such as these make a presumptive case for the view that the memorial consequences of relying on verbatim readout versus reconstruction from gist depend on the current state of specialization of memory. Although readout may be more effective in the presence of verbatim specialization, reconstruction may be more effective in the presence of gist specialization. Thus, gist systems eventually become preeminent, even to the extent of controlling performance on what are ostensibly tests of verbatim memory.

Conclusions

In general, the relationship between reasoning and remembering is predicted in fuzzy-trace theory by three assumptions: (a) problem solution must be classified as primarily gist- or verbatim-based, with gist the default option; (b) the nature of retrieval must be determined, whether readout or reconstruction; (c) the extent of environmental support for verbatim information must be known, for example, whether elements are displayed or must be memorized. Table 3.1 shows the four possible combinations of gist versus verbatim bases for memory and reasoning, and the circumstances under which independence and dependence are predicted. Table 3.2 shows the predictions for reasoning-remembering relationships based on whether retrieval is readout or reconstruction. In connection with both Tables 3.1 and 3.2, two crucial assumptions must be underlined for valid prediction. First, the predictions hold only if "all other factors are equal." For example, if the reasoning and memory tasks are given at different delays after the presentation of information, all other factors are not equal, and the stated predictions might not hold. The other caveat is that when matching values in the table are indicated, for example if both memory and reasoning are designated "verbatim," then for the stated relationship to hold, the underlying substratum must be the same. For example, the verbatim information should be the same verbatim information, the reconstructive operations should be the same sort of processes, and so on. (The latter issue will be discussed at greater length in the following section.) A variety of factors have been identified as affecting the probability that gist versus verbatim memory, or reconstruction as opposed to simple readout, will be used in problem solving (Brainerd & Reyna, 1990b; Reyna & Brainerd, 1990). Important among these is age, which plays a significant role in determining the reasoner/rememberer's approach to a task, with a major developmental shift from verbatim to gist processing occurring in the early elementary years. In the next section, I exploit the same assumptions we have used to discuss short-term retention to account for the seemingly complex relationships between thinking and memory over the long term.

TABLE 3.1. The effects of gist versus verbatim memory on the reasoning-remembering relationship.

Reasoning	Remembering	Relationship
Gist	Verbatim	Independence
Verbatim	Gist	Independence
Gist	Gist	Dependence/Independence
Verbatim	Verbatim	Dependence

Note. The predictions regarding relationships assume that all other factors are equal. Where verbatim memory is used for both reasoning and remembering, the same verbatim substrate is assumed for both tasks. Gist-gist relationships turn on whether errors are random.

TABLE 3.2. The effects of readout versus reconstruction on the reasoning-remembering relationship

Reasoning	Remembering	Relationship
Reconstruction	Readout	Independence
Readout	Reconstruction	Independence
Readout	Readout	Independence
Reconstruction	Reconstruction	Dependence

Note. The predictions regarding relationships assume that all other factors are equal. Where reconstruction is used for both reasoning and remembering, the same reconstructive processes are assumed for both tasks. Significant dependence also requires conditions that produce memory (not performance) failures; for example, item displays generally discourage memory failures, but delays encourage memory failures.

Long-Term Retention

Gist versus Verbatim Memory

The memory-judgment relationship may be one of the most theoretically overdetermined relationships in modern psychology. To select but a sample of diverse theories that predict a significant relationship, Bartlett's (1932) view would indicate that memory is at the mercy of efforts to make sense of what is remembered, and, therefore, reasoning would profoundly affect memory. Freudian and cognitive dissonance theories offer multiple means (e.g., motivated forgetting) by which memories and judgments could be distorted in order to be brought in line with one another. Information processing theories have posited such mechanisms as selective encoding, special processing, and selective retrieval in explaining how attitudes (reflected in judgments) might influence memory (e.g., Hastie & Kumar, 1979; Snyder & Uranowitz, 1978). Too, there are a variety of circumstances in which memory is thought to influence judgments, rather than the other way around, for example, via the availability heuristic (Hastie & Park, 1986; Nisbett & Ross, 1980).

Surprisingly, however, empirical evidence paints a different picture. Careful analysis generally reveals that memory and judgment are independent (e.g., Anderson & Hubert, 1963; Brainerd & Kingma, 1984, 1985). As Hastie and Park (1986) note, "In on-line tasks, . . . the memory-judgment relationship is equivocal but usually follows the independence model prediction of zero correlation" (p. 258). Taken together, the hodgepodge of positive, negative, and null relationships between memory and judgment might seem to imply random fluctuation (see Hastie & Park, 1986, for a review). Thus, surveying the empirical and theoretical landscapes provides a stark contrast. An important question for any theory, then, is how to explain the empirical elusiveness of memory-judgment relationships in the face of apparent theoretical overdetermination.

By situating memory with respect to such constructs of fuzzy-trace theory as retrieval versus reconstruction and gist versus verbatim representation, factors that affect the probability of observing memory-reasoning relationships can be identified. Fuzzy-trace theory stipulates conditions under which memory-judgment relationships should (e.g., Brainerd & Reyna, 1988a; Reyna, 1988) and should not (e.g., Reyna & Brainerd, 1990; Reyna, Brainerd, & Woodruff, 1987) be observed (see Tables 3.1 and 3.2). The denouement of the analysis is that undifferentiated outcome measures of reasoning or of memory may not correlate, despite the intuitive appeal of the necessity or dependency hypotheses (Reyna & Brainerd, 1990). Instead, leverage can be gained on the question of dependence by specifying the representations and retrieval operations leading to reasoning and memory performance.

Fuzzy-trace theory assumes that information is redundantly encoded in representations that vary along a fuzzy-to-verbatim continuum (Brainerd & Reyna, 1990b; Granger & McNulty, 1986; Reyna & Brainerd, 1991b; Staubli, Ivy, & Lynch, 1984). Such multiple encoding is globally consistent with the idea of distributed memory, and with notions of redundant representations of memories in the brain dating back to Lashley, although, in

fuzzy-trace theory, the multiple versions of remembered information are obviously not taken to be replicas of one another. Behavioral correlates of the verbatim-gist continuum include an effect observed in both animals and humans that memory at one end of the continuum (for gist) is more stable than memory for verbatim detail (Harlow, 1949; Kintsch, 1974). Thus, as retention intervals increase, or other factors that degrade memory are added, memory for gist seems to be relatively more resilient, making it an increasingly likely substrate for memory-based judgments. Ironically, the reliance on gist-based memory in judgments, and more generally the cognitive flexibility afforded by different memory systems, can obscure significant memory-judgment relationships in several ways.

First, delays between measures of memory and measures of judgment can do more than attenuate the memory-judgment relationship. Measurements taken at different times can sample different memory representations. Thus, judgments made immediately after the presentation of evidence, or made on-line using verbatim traces from working memory, might not correlate with later memory measures based on gist. The converse can also be true, namely that later judgments are based on gist, but memory performance draws on verbatim representations. Whenever differential delays produce reliance on different memory systems, independence is predicted (see Table 3.1).

According to fuzzy-trace theory, a major predictor of the kind of memory representation employed in thinking is the goal the subject is attempting to achieve, the overriding consideration being to operate at the lowest possible (most vague) level on a hierarchy of gist (Reyna et al., 1987; Reyna & Brainerd, 1991b). Thus, the nature of the response required in a task, even when it is elicited early after information presentation, significantly determines the nature of the representation used to solve the task. It is often the case that the social judgment task requires only a crude dichotomization (e.g., forced choice) or a global impression (e.g., rated likableness), whereas the memory test queries precise details of presented information. According to fuzzy-trace theory, therefore, such experimental methods favor observing a dissociation between memory and judgment measures.

In both of the scenarios just presented, because different memory systems would underlie memory and judgment, fuzzy-trace theory would predict that there should be no necessary relationship between them. The argument made here is similar to that made by Anderson (e.g., Anderson & Hubert, 1963) in suggesting a two-memories explanation for null or variable results regarding memory-judgment relationships. Fuzzy-trace theory further shares with Anderson's approach the assumption that reproductive memory for arbitrary details is qualitatively different from representations called up because of functional considerations, such as problem solving. (Unlike Anderson's dichotomy, however, fuzzy-trace theory assumes an underlying continuum of representations that vary in fuzziness.) As noted in the discussion of short-term memory, it is difficult to constrain the tasks that subjects perform, and the conditions under which performance occurs, in ways that compel reliance on a verbatim memorial substrate (Brainerd & Reyna, 1988a). Thus, performance in social judgment tasks will typically depend on memory for gist that is independent of memory for the verbatim details of encoded information.

Readout versus Reconstruction

Contrary to traditional theories, fuzzy-trace theory treats both retrieval and storage failure as two thresholds in an underlying continuous process (Brainerd & Reyna, 1990a; Brainerd, Reyna, Howe, & Kingma, 1990; Howe & Brainerd, 1989). Two major findings support such a conception. First, storage failure is more likely than retrieval failure (Brainerd & Reyna, 1988b; Brainerd et al., 1990). This result is at odds with the conventional interpretation of storage and retrieval. If, as the standard view suggests, retrieval requires both availability plus accessibility, but storage implicates only availability, then retrieval failure cannot be less probable than storage failure. The second crucial result is that storage failure can be reversed; traces can be brought back over the zero recall probability barrier (Brainerd et al., 1990; Howe & Brainerd, 1989). The latter finding, replicated repeatedly, challenges the conception of storage failure as the permanent loss of a trace.

These and other results inspired a view of forgetting as a gradual loss of cohesion among bonds that hold features of a trace together (Brainerd & Reyna, 1991; Brainerd, et al., 1990; Howe & Brainerd, 1989; see also Howe, Kelland, Bryant-Brown, & Clark, this volume). As forgetting occurs, the integrity of the trace becomes compromised (it becomes fuzzier), and it cannot be discerned against a background of competing traces. This process of disintegration can sometimes be reversed, however, producing redintegration, because elements are "diffused" rather than lost. Redintegration accounts for the ability of traces to migrate back across the threshold of availability. Thus, memory representations are fuzzy as a result of disintegration of featural bonds, an evolutionary process that affects a trace, or representations can be fuzzy because they were encoded that way to begin with. I have argued elsewhere that this proliferation of fuzzy traces is not coincidentally related to the fuzzy-processing preference in problem solving (e.g., Reyna & Brainerd, 1990).

The idea of forgetting, or memory failure, is typically applied to the memory-judgment relationship by noting that forgotten information cannot figure in memory-based judgments. Thus, the fallibility of memory is thought to provide an inroad for memory-judgment relationships. Such reasoning seems hermetically sealed from possible falsification, a logical necessity. As we have seen, however, one can escape from the circle by acknowledging the existence of more than one type of memory. Memory for gist can compensate for humans' poor verbatim memory, especially because gist suffices in a broad array of circumstances (Estes, 1980). However, the fallibility of verbatim memory can also be circumvented by reconstituting traces.

As noted above, one of the ways memory is reconstituted is through redintegration. Redintegration is item-based, minimally strategic, and developmentally invariant, supplying about 10% recovery across retention tests. As such, redintegration is a basic memory process that is unlikely to be the locus of strong memory-judgment relationships. Memories are also refurbished, however, by reconstructive processes that involve calculation, inference, or other reasoning operations. In contrast to redintegrative processes, reconstruction can involve units larger than a single trace, for example whole episodes, and it can be highly strategic, highly knowledge dependent, and subject to considerable developmental variation. For example, reconstruction can involve using plausibility to infer experienced events, as in "It must have happened in the morning because I was having breakfast at the time." Or, one might work backward in a series of calculations in order to "retrieve" original background facts in problem solving (Brainerd & Reyna, 1988a).

When reconstruction is used, as opposed to simple readout, remembering is essentially a reasoning process, strictly speaking (Kolodner, 1983). Because reasoning processes overlap between memory and judgment, the probability of dependency is increased. Tasks differ in the degree to which they tap reconstruction as opposed to readout. Recall, for example, elicits more reconstruction than recognition does. Because reconstruction is basically a reasoning process, recall tends to elicit gist. Therefore, recall and reasoning with respect to a given stimulus (e.g., a story) may both involve applying information processing operations to gist. (The situation is analogous to the mental arithmetic example of reasoning-remembering dependency, except that gist rather than verbatim memory is involved.) Reconstruction, however, is not inevitable across tasks. Fuzzy-trace theory summarizes the conditions under which one would expect memory to be reconstructive, as opposed to being based on simple readout (see Brainerd & Reyna, 1990b; Reyna & Brainerd, 1990).

Although reconstruction can occur when memory representations are accessible for simple readout, the probability of reconstruction is increased when readout is not an option. Thus, if a task crucially depends on verbatim information that can no longer be recalled, the reasoner may have no choice but to turn to reconstruction. Similarly, we might expect a pattern in which memory-judgment relationships are absent when relevant information is first acquired, but are present after a long interval (Reyna, 1988; Reyna et al., 1987). In other words, after a delay, people are more likely to have to resort to reconstruction, and memory and judgment performance may then share a common denominator of cognitive processes. Such a pattern of acquisition-retention asymmetry is well documented (Brainerd & Reyna, 1990a; Brainerd, et al., 1990), and has been obtained in social judgment tasks (Pratkanis et al., 1988; Reyes, Thompson, & Bower, 1980; Reyna, 1988; Reyna et al., 1987).

The role of reconstruction at acquisition versus long-term retention is illustrated in a series of experiments on memory and attitude change (Reyna, 1988; Reyna et al., 1987). At acquisition, for example, case history information relevant to a social issue was found to be more memorable than comparable statistical information. That is, narrative, anecdotal accounts of juvenile delinquents who did or did not grow up to be criminals as adults were more memorable than statistical reports citing adult outcomes across many juvenile offenders. Of course, case histories were rated as higher in concreteness and imagery value, factors that are well known facilitators of acquisition, but their greater vividness did not translate into greater persuasiveness. Indeed, the acquisition pattern was a crossover type such that the less memorable stimuli, the statistical arguments, were significantly more persuasive than the more memorable arguments. (Taylor and Thompson, 1982, make a similar argument about vividness effects on memory, as opposed to judgment, for case histories versus statistics.) Order effects also displayed a differential pattern for memory and judgment, namely a crossover, with primacy advantages for persuasiveness, but recency advantages for recognition (see also Anderson, 1981; Anderson & Hubert, 1963).

After a delay in which significant forgetting occurred, however, memory-judgment relationships were observed among the same group of subjects that had evinced independence at acquisition. Sleeper effects for judgment occurred; conditions that facilitated retention over the interval were associated with additional opinion change consistent with the better remembered stimulus. Judgment effects on memory were also detected. Memory for opinion-congruent arguments was selectively enhanced, but only when subjects had been asked for their opinions immediately after arguments were presented. Thus, when judgments were not solicited after arguments presentation, memory loss did not fall along the lines of prior opinion. When those opinions were solicited, however, memory for supportive arguments was superior on a subsequent long-term retention test. The latter effects were enhanced if opinions were requested again before, as opposed to after, the retention test.

These and similar results led to the following conclusions: (a) memory changes across a long-term retention interval, 2 weeks in these experiments, did appear to have a reverberative effect on judgments, and (b) solicited opinions seemed to act as retrieval cues around which presented arguments could be reconstructed. Note that the critical opinions were solicited after the arguments were presented, and opinion-change measures obtained at that time showed that the arguments were, in part, the basis for those opinions. Thus, it is not implausible that those opinions, more recent than the arguments, might be used to recover the arguments from which they come. If arguments are reconstructed around opinions, so the reasoning goes, it is no wonder that supportive arguments would be more fully remembered. Initial opinion, however, does not appear to play an ongoing organizing role in memory such that opinion-consistent information is spontaneously favored. This can be inferred because, despite strong initial opinions, opinion biases on memory were absent except when opinions were solicited after argument presentation.

The first phenomenon, that better remembered arguments exert additional effects on opinion, suggests that memory differences continue to coalesce in the long-term retention interval. The second phenomenon, that opinion-consistent arguments are favored in memory when opinions have been solicited, is but one example of retrieval-based distortion in which cues and context at retrieval, for example opinions or leading questions, can determine how memories are reconstructed (Howe & Brainerd, 1989; see also Howe et al., this volume). Retrieval in the absence of reconstruction, however, does not usually lead to memory-judgment correlations. If information for judgments and for memory tests are simply read out, without reconstruction, independence is predicted because retrieval failure is typically stochastic, specifically, a two-stage Markovian process (e.g., Flexser & Tulving, 1978). As in gist-processing failures, random errors do not correlate (Reyna & Brainerd, 1990). Thus, judgments should be independent of memory performance when information for both is simply retrieved rather than reconstructed (Table 3.2).

Despite reconstruction, the results from the experiments on memory-judgment relationships illustrate the pitfalls in demonstrating significant dependencies, although it is simultaneously apparent from these findings that memory and judgment interact (Reyna, 1988; Reyna et al., 1987). One of these pitfalls is the search for dependencies at acquisition, before sufficient forgetting, and consequent restorative processes, have begun to operate. These results are also instructive in showing, consonant with other research, that simply correlating opinion with memory is not apt to reveal significant dependencies. This is because bias does not appear to typically operate at the encoding stage, nor is processing predictably related to opinions or beliefs, but, rather, bias operates on memory through selective retrieval. And, even retrieval is not consistently biased, for example when simple readout occurs. Instead, bias encroaches on memory when the trace must be rebuilt using retrieval cues that, by their nature, are apt to systematically recruit certain kinds of information.

The familiar dichotomy of reconstructive versus reproductive memory, then, does not seem to capture the multifaceted nature of human memory. And, although most theories grudgingly acknowledge the existence of one or the other type of memory, there is an overweaning tendency to emphasize the one at the expense of the other. Rarer still is there an attempt to assign a major role to each, and show how they might operate in tandem. Much predictive power is gained, however, by granting representations that vary in vagueness, along with retrieval operations that vary in their invasiveness with respect to the trace. More importantly, the interplay between availability of alternative levels of representation and task requirements, as well as trade-offs between readout and reconstruction, constrain theoretical explanation (Brainerd & Reyna, 1990b). Thus, despite the fact that fuzzy-trace theory does, in some sense, come down squarely on both sides of the question of whether memory is essentially reproductive or (re)constructive, flexibility is not so great as to obviate prediction under specified conditions.

Still, the inclusion of a concept such as reconstruction, especially as a source of distortion, raises the nettlesome issue of the line between construction and reconstruction in memory. This is a line that is difficult to draw both empirically and theoretically, empirically because people are unable in many cases to differentiate for themselves between mental products and memories of actual experiences (Johnson, 1988). For practical purposes, for example when witnesses to a crime testify as to what they remember, constructive memory is a frightening prospect (Ceci, Ross, & Toglia, 1987a, 1987b). Constructive memory raises the possibility of distorting, or worse, inventing, material facts. The lesson drawn by those interested in maximizing memorial accuracy, then, has been to minimize (re)construction. However, research based on fuzzy-trace theory suggests that reconstruction often enhances accuracy, an enhancement that can be overlooked because successful reconstructions are mistakenly attributed to simple readout (Brainerd, Kingma, & Howe, 1985; Brainerd & Ornstein, 1991; Brainerd & Reyna, 1988b, 1990a; Brainerd, et al., 1990; Howe & Brainerd, 1989).

Also, if the course of remembering naturally turns to reconstruction after an interval, there is no reason to suppose that memory performance will be better if simple readout is used. On the contrary, there is evidence that reconstruction allows us to squeeze additional performance increments from a limited memory system (Brainerd & Ornstein, 1991; Reyna & Brainerd, 1990). Moreover, it is not clear that instructions or limiting the questions asked in memory interviews can diminish the tendency to engage in reconstruction (Kolodner, 1983). The request to remember may unavoidably elicit reconstruction, and it may be impossible for people to separate, and filter out, constructions as opposed to reconstructions.

Therefore, rather than disturbing memories, repeated questioning after a long retention interval can lead to consistent gains in accurate retrieval, including a host of different test-induced enhancement effects (e.g., Brainerd & Ornstein, 1991; Brainerd et al., 1990). Reconstruction in the sense of cautious application of inferences and calculations would be

especially warranted where simple readout has failed. Such a reconstructive interview would, ideally, minimize leading or misleading questions, and, more generally, minimize introduction of information, implicitly or explicitly, by the interviewer (Brainerd & Ornstein, 1991; Ceci et al., 1987a, 1987b). Cues and connections employed by the subject should be made explicit so that they can be open to scrutiny, although these are sometimes unavailable to consciousness. Finally, it should be borne in mind that, although people engage in reconstructive processing in order to augment accuracy, and it often does have such an effect, constructions are an inevitable by-product. In some circumstances risking constructions is worthwhile, however, especially if information leads to additional evidence that can corroborate reconstructed memories, for example when vague clues provided by witnesses lead to the apprehension of both a suspect as well as additional incriminating evidence. The decision to encourage reconstructive processing must be weighed against, among other considerations, the need for information and the possibility of corroboration.

When Reconstructive Memory Does Not Lead to Memory-Judgment Dependencies

Reconstructive memory, on the other hand, does not guarantee memory-judgment relationships. It is entirely possible that memory could be reconstructive and unrelated to judgments. First, relevant memories could be reconstructed and judgments retrieved (Table 3.2). The direct retrieval of judgments that were made on-line apparently accounts for the independence of memories for evidence on which the on-line judgment was based, and the judgment itself (Hastie & Park, 1986). Second, both memory and judgments could be based on inferential or computational processes, but they need not be based on the same processes (see the note to Table 3.2). In such cases, the choice of factors to examine can determine whether memory-judgment relationships are observed. For example, large individual differences affecting the efficiency of all information processing might affect both memory and judgment, even though specific processing operations for memory and judgment differed. On the other hand, if measures were sensitive enough to detect subtle differences in processing operations, memory and judgment could be shown to be independent.

Finally, memory-judgment correlations will depend on the nature of measures being related. Brainerd and Kingma (1984, 1985) have found, for example, that representation and processing probably overlap for reasoning and remembering in transitive inference problems, but their measures are stochastically independent. This is because the nature of the representation and the reconstructive heuristic are not significant sources of errors. Instead, errors occur as children's attention wanders, items in questions are misidentified, and the like, and these are random errors. (These performance errors decrease in adults, producing developmental differences in the overall level of performance, but the underlying representation and process does not appear to change in any fundamental way [Reyna & Brainerd, 1990; Trabasso, Riley, & Wilson, 1975].) Thus, paradoxically, stochastic independence can occur when the underlying processes are the same for memory and judgment. The remedy in all three scenarios for detecting the true state of affairs appears to be closer attention to the locus of effects for memory and judgment manipulations, and assessment, or active manipulation, of whether memory and judgment performance are based on readouts or reconstructions.

Summary

Far from being a foregone conclusion, as Tables 3.1 and 3.2 make obvious, a confluence of factors must be in place for reasoning-remembering dependence to be observed. Empirically, independence is the typical finding, both in short- and long-term retention. The door to dependence is opened when, for example, reasoning and remembering must tap a common verbatim substrate in memory, as in experiments involving memory probes for quantities in mental arithmetic problems (Brainerd & Reyna, 1988a). Even in mental arithmetic, however, memory performance depends on reasoning, rather than, as is often assumed, reasoning depending on memory. Moreover, for young children, better verbatim memory may interfere with reasoning, leading to lower performance on tasks that require seeing global patterns.

Like verbatim memory, reconstructive retrieval also increases the probability of reasoning-remembering dependence. Because reconstructive processing can enhance performance, however, insufficient memory failures may occur, and dependencies will not be detected. In transitivity, for example, external arrays store item identities, as well as their locations, in a graded series. Reconstruction of gist in such circumstances generally produces few errors, and the errors that are produced are nonsystematic performance lapses; therefore, reasoning and memory errors are uncorrelated. In contrast, if information must be accessed after an extended delay, in the absence of external memory supports, reconstruction can produce memory-judgment relationships. Again, dependence is far from inevitable, and depends partly on whether judgments are used as cues with which memories are reconstructed.

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Part II
Pragmatic Aspects of Retention