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Memory Processes Underlying Misinformation Effects in Child Witnesses

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In this article, we review empirical findings that misinformation effects in children are the joint product of automatic or unconscious and intentional or conscious processes. First, we outline the extant literature on multiple systems and process models of memory. Second, we examine how dual memory processes (e.g., recollection and automaticity, verbatim-based identity, and gist-based similarity) contribute to children's acceptance of misinformation. In this regard we outline findings that show developmental change in the cognitive processes underlying acceptance of misinformation in the absence of overall changes with age in the probability of reporting a suggestion. Competing models of the misinformation effect in children are then evaluated in light of this new evidence.

Key Words: eyewitness testimony; recognition; recall; suggestibility; implicit and explicit memory; remember/know; dual memory processes; fuzzy trace theory; process dissociation procedure; conjoint recognition.

The past decade has seen an increase in the participation of young children in the legal system such that children are regularly required to give evidence in family court matters, such as custody and access disputes, or in criminal cases, such as sexual and physical abuse or domestic violence (Ceci & Bruck, 1995). Researchers investigating children's testimony have directed substantial attention to the identification of the conditions under which children are

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adversely affected by the introduction of misinformation after viewing or experiencing an event. Following the recommendations of Ceci and Bruck (1993) we have adopted a broad definition of the *suggestibility* or *misinformation* effect, which acknowledges that a range of social and psychological factors can affect ‘‘children’s encoding, storage, retrieval, and reporting of events’’ (p. 404). It is commonly agreed that children can be influenced by misinformation, with very young children disproportionately affected (Bruck & Ceci, 1999; Ceci, Bruck, & Battin, 2000).

Despite the widespread belief that memory and social demand factors are implicated in the misinformation effect in children (e.g., Brainerd & Reyna, 1998; Cassel & Bjorklund, 1995; Ceci & Bruck, 1993), the nature of the underlying mechanisms responsible for these effects continues to be debated (Brainerd & Reyna, 1998; Bruck & Ceci, 1997; Holliday & Hayes, 2000). Until recently it has been difficult to draw specific conclusions about the nature of the memory changes that occur when children accept misleading suggestions because little attention has been given to identifying the memory processes underlying the interference produced by the introduction of post-event misinformation.

In this review we report research that has applied mathematical models (e.g., process dissociation and fuzzy trace) to measure the relative contributions of intentional and automatic memory processes to children’s reporting of misinformation so as to gain a better understanding of how the fundamental cognitive processes that govern memory are linked to misinformation effects in children. An advantage of using formal process models is that such models do not require an assumption that measures obtained from direct or explicit tasks (i.e., recognition and recall) and indirect or implicit tasks (i.e., picture fragment and word fragment completion) are ‘‘pure’’ or mutually exclusive measures of underlying memory processes (Jacoby, 1991). Rather, such models allow for statistical evaluation of the relationship between theoretical processes and empirical data (Brainerd, Reyna, & Mojardin, 1999; Howe & O’Sullivan, 1997; Howe, Rabinowitz, & Grant, 1993). Recent methodological advances have focused on recognition memory studies of the child misinformation effect, principally because recognition memory paradigms have been used extensively in this literature (e.g., Ceci, Ross, & Toglia, 1987; Holliday & Hayes, 2000, 2001, in press; Lindsay, Gonzales, & Eso, 1995; Zaragoza, 1991). In the adult literature, extant models of recognition memory propose that recognition performance reflects dissociable processes such as recollection and automatic memory (e.g., Brainerd et al., 1999; Jacoby, 1991).

We begin by discussing theoretical and methodological issues and empirical findings concerning multiple systems and processes models of memory. Next, we examine recent evidence of dissociable processes (i.e., automatic and intentional recollection) in children’s reporting of misinformation and evaluate extant theories of the misinformation effect in children in the light of this evidence. We conclude with a discussion of modeling techniques that have the potential to further inform the theoretical debate concerning memory processes underlying recall of misinformation.

MULTIPLE SYSTEMS AND PROCESS MODELS OF MEMORY

Several contemporary models view memory as divided into multiple components (e.g., Graf & Mandler, 1984; Jacoby, 1991; Mandler, 1980; Reyna & Brainerd, 1995; Roediger, Weldon, & Challis, 1989; Squire, 1987; Tulving, 1983). These components have been conceptualized as multiple memory *systems* (e.g., implicit vs explicit) or as multiple memory *processes* (e.g., automatic vs intentional) operating within a single system. Most recently, models have incorporated both separable memory representations and processes (Reyna & Lloyd, 1997).

Before beginning this review a clarification of terminology is needed. The terms ‘‘explicit’’ and ‘‘implicit’’ have been used to describe types of tests, memory systems, memory processes, and memory states (Kelley & Lindsay, 1996; Reingold & Toth, 1996). Graf and Schacter (1985) introduced the concepts of ‘‘explicit’’ memory and ‘‘implicit’’ memory to describe dissociations between performances on direct (e.g., recall, and recognition) and indirect (e.g., word completion) tests of memory. They proposed that explicit memory is revealed when performance on a task requires conscious recollection of previous experiences [and] implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection (p. 501). Following Kelley and Lindsay (1996), we use the terms ‘‘direct’’ and ‘‘indirect’’ to describe *tests of memory* (that include or do not include instructions to respond on the bases of studied items, respectively) and the terms ‘‘explicit’’ and ‘‘implicit’’ to refer to influences of an event experienced with or without awareness of remembering, respectively.

Theoretical Explanations of Empirical Dissociations

Findings of performance dissociations in amnesic adults who showed intact retention of information on indirect tests of memory in the context of profound deficits in performance on direct tests of memory for the same information fueled support for functionally independent memory systems (for a review see Gooding, Mayes, & van Eijk, 2000). Warrington and Weiskrantz (1970), for example, compared amnesic and control subjects’ memory for words under a number of test conditions. On a direct test (yes/no recognition) in which subjects were asked to identify previously studied words, amnesics performed more poorly than controls. In contrast, on an indirect test (word-fragment identification and word-stem completion) in which subjects supplied the first word that came to mind, the amnesic and control subjects performed equally well.

Three broad theoretical approaches have been proposed to explain task dissociations across direct and indirect tests: (1) multiple memory systems (e.g., Squire, 1987; Tulving, 1983, 1985), (2) multiple processes models (e.g., Jacoby, 1991; Mandler, 1980; Roediger et al., 1989), and (3) models that incorporate both multiple memories and processes (e.g., Brainerd et al., 1999; Reyna, 1996, 1998; Reyna & Lloyd, 1997). In the following sections, we discuss each of these theoretical approaches along with models for estimating the contribution of intentional recollective and automatic forms of memory to performance and empirical findings in adults and children.

Multiple-Memory-Systems Models

Proponents of multiple-memory-systems models argue that dissociations between performance on direct and indirect tests reflect the operations of distinct memory systems in the brain (e.g., Hamann & Squire, 1997; Johnson, 1992; Nyberg & Tulving, 1997; Schacter & Buckner, 1998; Schacter & Moscovitch, 1984; Squire, 1987; Tulving, 1983, 1985, 1993). Evidence to support these models has, for the most part, been derived from studies of amnesic individuals that have demonstrated impaired conscious recollection on direct tests along with relatively intact priming on indirect tests (Greene, 1992; Schacter, 1987; Squire, 1987). Tulving postulated episodic and semantic memory systems with semantic memory further divided into procedural and propositional (world knowledge) subsystems. Conscious recollection or ‘‘remembering’’ on a direct test is a product of the episodic system; feelings of familiarity or ‘‘knowing’’ that an event has been experienced reflect the operation of the semantic system (Tulving, 1993).

In a similar vein, Squire (1987) proposed that dissociations between direct and indirect tests in brain-damaged patients confirm the operation of distinct systems. The ‘‘declarative’’ system contains memories for facts and specific episodes, is directly available to conscious recollection, and accounts for amnesics' impaired performance on direct tests of memory. The ‘‘procedural'' system, which underlies motor and perceptual skills learning, is unavailable for conscious recollection and accounts for intact performance on indirect tests of memory.

Multiple-Memory Systems and Development

Schacter and Moscovitch (1984) hypothesized the existence of analogous functionally independent memory systems in infants, each maturing at different rates during the first year. They proposed that the early developing system was similar to the intact memory system displayed by amnesics on indirect memory tests and the late developing system (first emerging at 8–9 months) corresponded to the impaired declarative memory in amnesics on direct memory tests.

This view has been recently criticized in the light of the substantial body of evidence which indicates that infants as young as 2 months demonstrate *both* perceptual priming *and* explicit recognition on tasks analogous to those used in studies with children and adults (for reviews see Howe, 2000;

Howe & Courage, 1997; Rovee-Collier, 1997; Rovee-Collier, Hayne, & Colombo, 2001). Such dissociations suggest that the proposed systems are operational much earlier than predicted by Schacter and Moscovitch (1984). Indeed, Rovee-Collier and Hayne (2000) argued that the mechanisms underlying memory processes in infants and adults are essentially the same.

Recent findings in the adult literature have also presented difficulties for multiple-systems accounts of dissociations exhibited by brain-damaged subjects on direct and indirect tests of retention. For example, Heindel, Salmon, Shults, Walicke, and Butters (1989) reported that patients with amnesic syndrome associated with organic brain disease of the Alzheimer, Parkinson, and Huntington types do not demonstrate impaired conscious recollection on *all* direct memory tests, nor do they display intact priming on *all* indirect memory tests. Similarly, Hamann and Squire (1995) found that amnesics could acquire and retain new information over repeated study trials (see also Schacter, Cooper, Tharan, & Rubens, 1991).

A more general criticism leveled at multiple-systems models is that theorists have failed to give a detailed description of the cognitive processes that are subserved by each of the component memory systems (Kelley & Lindsay, 1996). The ''processing-model'' approach, in contrast, places less emphasis on the identification of separate memory systems and instead describes the various functional processes that give rise to performance on direct and indirect tasks.

Dual-Process Models: Transfer-Appropriate Processing

Processing models of memory propose that functional dissociations between performance on direct and indirect tests reflect the operation of different memory processes. Roediger et al. (1989) introduced the ''transfer-appropriate processing'' framework to describe and predict when such dissociations would arise. The main assumptions of this model are as follows: Direct tests require semantic or meaning-based processing and are, for the most part, conceptually driven. Indirect tests, on the other hand, demand perceptual processing and are, for the most part, data driven. The transfer-appropriate processing model also incorporates the ''encoding specificity principle'' (Tulving & Thomson, 1973) such that memory performance is facilitated when the encoding and the retrieval conditions match. According to this approach, amnesics demonstrate impaired memory on direct tests that demand conceptually driven processing but preserved memory on indirect tests that require data-driven processing (Roediger et al., 1989).

Transfer-Appropriate Processing and Development

Perez, Peynircioglu, and Blaxton (1998) presented 4- and 8-year-old children and adults with perceptual and conceptual indirect tasks (picture fragment completion) and perceptual and conceptual direct tasks (category exemplar production) after perceptual or conceptual processing during study. All participants performed better on both perceptual direct and perceptual indirect tests following orienting tasks that emphasized perceptual processing, providing some support for the transfer-appropriate processing model. Evidence was found of a developmental increase in performance on the conceptual direct task only; there was no evidence that performance on the indirect tasks improved with age.

While this pattern of results may hold for indirect tests such as picture completion that primarily engage perceptual processing, a recent study suggests that this may not be the case for indirect tests based on conceptually driven processing. Perruchet, Frazier, and Lautrey (1995) reported that 9-year-olds outperformed 7-year-olds in terms of priming on a category-exemplar generation task when target items were atypical of their categories. When target items were typical of their categories, however, no evidence of developmental change was found.

The transfer-appropriate processing framework has been criticized for failing to account for the findings of normal priming (e.g., Shimamura, 1986) on conceptually driven *indirect* tests that ask subjects to produce words cued as semantic associates or category labels (Kelley & Lindsay, 1996). A further limitation is that there are no formal procedures for specifying the nature of the processes engaged by direct and indirect tasks (Jacoby, Levy, & Steinbach, 1992; Kelley & Lindsay, 1996; Moscovitch et al., 1994).

Dual-Process Models: Automatic and Intentional Processing

Dual-process models of retrieval (e.g., Atkinson & Juola, 1974; Gardiner, 1988; Jacoby, 1991; Mandler, 1980) hold that there are two qualitatively distinct and functionally independent mechanisms that give rise to recognition of studied items. The first mechanism, ‘‘recollection,’’ has been described as an intentional, aware (Jacoby, 1991; Lindsay et al., 1995), and conscious and controlled process (Mandler, 1980; Schacter, 1987) that demands attention. Intentional recollection is predicted to be vulnerable to interference effects and forgetting (Brainerd et al., 1998; Jacoby, 1991) and invokes the use of memory strategies such as elaboration, rehearsal, and semantic memory. Familiarity, on the other hand, has been described as an automatic, fast (Hasher & Zacks, 1979; Jacoby, 1991; Mandler, 1980), unaware (Lindsay et al., 1995), and nonconscious process that does not demand attention.

Following Mandler (1980), Jacoby and his colleagues (e.g., Jacoby, 1991; Jacoby, Ste-Marie, & Toth, 1993; Jacoby, Toth, & Yonelinas, 1993; Jacoby, Yonelinas, & Jennings, 1997; Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996) argued that two distinct mechanisms contribute to recognition of test items, intentional recollection and familiarity. For Jacoby (1991), ‘‘recollection’’ is defined as ‘‘consciously controlled, intentional use of memory’’ (p. 516). Recollection reflects a discrete ‘‘threshold’’ process based on particular aspects of an item and the encoding context (Yonelinas et al., 1996). The process of ''familiarity,'' in contrast, is defined as ''relatively automatic . . . faster, less effortful, and less reliant on intention'' (Jacoby, 1991, p. 516) than recollection. Jacoby (1991) proposed that familiarity judgments mirror the effects of the prior processing of test items (e.g., whether test items have been encoded as anagrams or read as the whole word) as well as the perceptual attributes of test items. That is, consistent with global memory models (e.g., Gillund & Shiffrin, 1984), familiarity-based remembering is context specific.

Two methods for measuring the effects of conscious recollective and unconscious automatic processes on memory have been proposed, task-based separation: Direct (explicit)/indirect (implicit) tasks (e.g., Graf & Schacter, 1985) and remember/know (e.g., Gardiner, 1988) and model-based separation (e.g., Brainerd et al., 1998; Jacoby, 1991).

TASK-BASED DISSOCIATIONS: DIRECT (EXPLICIT) AND INDIRECT (IMPLICIT) TESTS

The first task-based method makes the assumption that performance dissociations on direct and indirect tests reflect the operation of *explicit* and *implicit* memory processes, respectively (e.g., Graf & Schacter, 1985; Light & Singh, 1987; Richardson-Klavehn & Bjork, 1988). That is, it is claimed that performance on a direct task (e.g., recognition, recall) represents a measure of an underlying explicit (conscious recollection) memory process; performance on an indirect task (e.g., word-stem completion) represents a measure of an underlying implicit (unconscious automatic) memory process.

Task-based dissociations in performance on direct and indirect memory tests have been reported in numerous studies involving adults with normal memory function (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981; Light & Singh, 1987). In such studies, task manipulations have been shown to affect performance on one type of memory test but to leave performance on the other type of test unaffected (i.e., single dissociations).

Direct and Indirect Task Dissociations: Development of Explicit/Implicit Memory

Some attention has been given to differences in the developmental course of performance on direct and indirect memory tests. Explicit memory performance as measured on direct tests of recognition, cued recall, and free recall is generally believed to improve markedly from 2 years of age to adolescence (Carroll, Byrne, & Kirsner, 1985; Greenbaum & Graf, 1989; Hayes & Hennessy, 1996; Naito, 1990; Parkin & Streete, 1988; Russo, Nichelli, Gibertoni, & Cornia, 1995). Such improvement is proposed to be due, in part, to increased use of intentional memory strategies such as rehearsal (e.g., Bjorklund & Douglas, 1997), increases in metamemorial competence (e.g., Sodian, Schneider, & Perlmutter, 1986), and greater proficiency in processing and storing information (e.g., Kail, 1990).

Several developmental investigations of implicit memory performance measured on indirect tests such as picture fragment completion have reported few differences in the magnitude of perceptual priming effects in children across the age range from preschool to adolescence (e.g., Anooshian, 1997; Carroll et al., 1985; Drummey & Newcombe, 1995; Greenbaum & Graf, 1989; Hayes & Hennessy, 1996; Mecklenbrauker, Wippich, & Schulz, 1998). In Hayes and Hennessy's (1996) study, for example, 4-, 5-, and 10-year-old children first named objects from either picture fragments or named complete pictures of the same objects and answered questions. Results from picture fragment completion and recognition memory tests presented 2 days later showed that while explicit memory accuracy improved with age, there was no evidence of developmental change in priming.

Performance dissociations have been used to support the notion that the systems and/or processes underlying indirect memory performance emerge and reach an asymptotic state of development at an earlier point in the life-span than do conscious or explicit memory processes (e.g., Graf, 1990; Schacter & Moscovitch, 1984).

This view is undermined, however, by other findings of developmental improvements in priming on indirect tests of implicit memory (e.g., Cycowicz, Friedman, Snodgrass, & Rothstein, 2000; Komatsu, Naito, & Fuke, 1996; Parkin, 1993; Parkin & Streete, 1988). Komatsu et al. (1996), for example, found evidence of a developmental increase in priming in children ages 7 and 11 years and adults when the encoding task required generation of the target word in response to a definition. Similarly, Cycowicz et al. (2000) reported that performance on an indirect task (picture fragment completion) and direct tasks (recall and recognition) improved across 5-, 9-, and 14-year-old children and young adults. (See Howe & Courage, 1997; Rovee-Collier & Hayne, 2000; Rovee-Collier, 1997, for reviews of similar findings with infants.)

The assumption of a relatively transparent relationship between performance on a given task and the underlying process(-es) has provoked considerable controversy (e.g., Jacoby, 1991; Jacoby, Toth, & Yonelinas, 1993; Merikle & Reingold, 1991; Rovee-Collier, 1997). In particular, the assumption of ''exclusiveness'' (Reingold & Merikle, 1990), or ''process-purity'' (Jacoby, 1991), whereby direct and indirect tests are seen as providing qualitatively different measures of memory processes has been questioned (Brainerd et al., 1998; Dunn & Kirsner, 1989; Jennings & Jacoby, 1993; Reingold & Toth, 1996; Schacter, Bowers, & Booker, 1989).

One major problem with this assumption is that performance on indirect tests may reflect the *joint* operation of both automatic and conscious intentional processes (Brainerd et al., 1999; Jacoby, 1991; Toth, Reingold, & Jacoby, 1994). For example, performance on a nominally indirect task such as supplying the correct word stem on a word-stem completion test can be accomplished by consciously remembering the word from the study phase

(Toth et al., 1994). Conversely, responding on direct tests can be affected by the operation of automatic processes of which the subject is relatively unaware (Isingrini, Vazou, & Leroy, 1995). Another major difficulty is that performance on direct and indirect tests may not reflect the operation of different memory processes but instead be an artifact of task differences such as the type of cues available at retrieval (Reingold & Toth, 1996). Indirect tests such as word-stem and picture fragment completion typically present test cues in a degraded form, whereas recognition tests present such cues in entirety.

Two recent articles have presented additional problems for the interpretation of functional dissociations obtained using direct and indirect tests (e.g., Buchner & Wippich, 2000; Meier & Perrig, 2000). Meier and Perrig reported that test–retest reliability of indirect tests (i.e., picture fragment completion and word-stem completion) was significantly lower than for direct tests (i.e., recognition, recall, and cued recall). Buchner and Wippich also found that indirect tests (i.e., category-exemplar production and word-stem completion) show low levels of reliability over repeated testing. It is possible, therefore, that functional dissociations between performances on direct and indirect memory tests occur simply because of differences in measurement properties.

The Remember/Know Procedure

In the second task-based method, remember/know (e.g., Gardiner & Java, 1993; Gardiner, Ramponi, & Richardson-Klavehn, 1998; Tulving, 1985), participants report on subjective states of awareness associated with recognition memory judgments. ‘‘Remember’’ judgments are made if an item is consciously recollected from the encoding phase and ‘‘know’’ judgments are made if an item is familiar but its presentation at study cannot be recollected (Gardiner & Java, 1993). Manipulation of variables such as levels of processing, read/generate encoding, retention interval (Gardiner, 1988), and divided/full attention (Gardiner & Parkin, 1990) have been found to have an effect on remember judgments but little influence on know judgments in adult participants.

The remember/know task has been criticized for its assumption that the relation between subjective states of awareness is mutually exclusive; that remembering and knowing cannot occur together (e.g., Jacoby, Begg, & Toth, 1997; Strack & Forster, 1995). Jacoby and his colleagues (e.g., Jacoby, 1991; Jacoby et al., 1993; Jacoby, Jones, & Dolan, 1998) and others (e.g., Gruppuso, Lindsay, & Kelley, 1997) have provided substantial evidence that both conscious recollection and automatic memory processes can operate simultaneously to affect performance on a given task.

A second criticism is the reliance on subjective states of awareness as the sole basis for measurement of conscious recollection (Jacoby, Ste-Marie, & Toth, 1993; Kelley & Jacoby, 2000). Self-report data obtained using this paradigm should be viewed cautiously because they are subject to the influence of factors unrelated to awareness such as social demand and response biases (Reingold & Toth, 1996; Strack & Forster, 1995). The subjective criterion that participants use to decide whether they consciously ''remember'' a previous episode will vary across testing occasions and contexts (Reingold & Toth, 1996).

Given that *both* conscious recollective and unconscious automatic processes may operate on direct and indirect tests of retention, there is a need for methods for assessing the relative contribution of each process to performance on a given memory task.

Model-Based Separation of Recognition Memory Processes: The Process Dissociation Procedure

A major advantage of model-based approaches is that no assumption is made that measures obtained on direct and indirect tasks are process pure. In fact, quite the opposite view is taken; performance on each of these kinds of tasks is assumed to reflect the simultaneous operation of two independent processes, conscious recollection and unconscious automatic memory (Jacoby, 1991).

Jacoby (1991; Jacoby, Toth, & Yonelinas, 1993) developed a process dissociation model to assess the relative contributions of recollection and automatic processes to recognition memory performance. The two processes are assumed to differ in the degree of conscious or intentional control that can be exerted over them. Conscious control is operationally defined ''as the difference between performance when a person is trying to as compared with trying not to use information from some particular source'' (Jacoby, 1991, p. 527). The model employs two tasks, an ''inclusion'' condition, in which automatic and intentional recollective processes work together, and an ''exclusion'' condition, in which the two processes oppose each other. Jacoby (1991) asked adults to memorize two word lists presented in different modalities. At test, a third list containing words from lists 1 and 2, as well as new words, was presented. In the inclusion condition, participants were instructed to respond ''old'' to previously presented words from either list. In the exclusion condition participants were told to exclude words from List 1. Hence, in the inclusion test condition, participants can respond on the basis of conscious recollection (R) alone, automatic (A) processes alone, or on the basis of both recollection and automatic processes. In the exclusion condition, recollection and automatic processes oppose each other; conscious recollection is used to exclude words from List 1.

Estimates of the probabilities of recollection affecting performance can be calculated by subtracting the probability of responding with an old word in the Exclusion condition from the probability of responding with an old word in the Inclusion condition (Jacoby, 1991; Jacoby et al., 1993) as follows:

$$R = P\,(\text{``Old''} \mid \text{Inclusion}) - P\,(\text{``Old''} \mid \text{Exclusion}). \quad (1)$$

Recollection is operationally defined as the difference between intentionally remembering to report an item (Inclusion condition) and intentionally not reporting the item (Exclusion condition). The recollection estimate represents the probability of responding on the basis of intentional or conscious memory of an item.

Estimates of automaticity can be calculated by the following:

$$A = P\,(\text{``Old''} \mid \text{Exclusion}) \,/\, (1 - R). \quad (2)$$

Automaticity is defined on the basis of the relation between performance in the Inclusion and Exclusion conditions and not in terms of self-reported lack of awareness (e.g., Bowers & Schacter, 1990; Gardiner & Java, 1993). The automaticity estimate represents the probability that material is retrieved automatically without conscious recollection. Both estimates are assumed to be sensitive to contextual cues at study and at test (Jacoby, Toth, Lindsay, & Debner, 1992; Kelley & Jacoby, 1998).

The Process Dissociation Procedure: Empirical Evidence

The process dissociation model has been applied to a wide variety of tasks, including fame judgments (Jennings & Jacoby, 1993) and divided attention (Schmitter-Edgecombe, 1996). Process dissociations have been estimated in the elderly (Hay & Jacoby, 1998); in amnesiacs (Cermak, Verfaellie, Sweeney, & Jacoby, 1992); and clients with multiple sclerosis (Scarrabelotti & Carroll, 1998), dysphoric mood (Hertel, 1998), and schizophrenia (Kazes, Berthet, Danion, Amado, Willard, Robert, & Poirier, 1999). (See Kelley & Jacoby, 2000, for a review.)

Developmental Studies

A small number of studies have applied the process dissociation procedure to children's recognition (e.g., Anooshian, 1999; Anooshian & Siebert, 1996; Holliday & Hayes, 2000; Lindsay et al., 1995). Anooshian and Siebert, for example, examined the memory processes underlying picture recognition using a modified version of process dissociation. Four-year-old children and adults (Experiment 2) studied scenes taken from a cartoon video and were then given a two-alternative forced-choice recognition test for target items presented at study under both exclusion and inclusion test conditions. While estimates of conscious recollection were significantly lower for the children, no evidence of age differences in automatic processes was found.

Given the evidence that performance on tests of recognition memory under a variety of experimental conditions reflects the joint product of conscious recollection and unconscious automatic processes we now describe new research that has applied dual-process models of recognition memory to misinformation effects in children.

THE CHILD MISINFORMATION EFFECT AND PROCESS DISSOCIATIONS

The main advantages of using a model-based approach in misinformation studies are that an examination of the developmental course of recollection and automaticity addresses the question of whether these processes follow the same developmental trends as suggestibility that is indexed only by measures of recognition errors and avoids relying on the assumption that recognition tests provide a direct index of explicit memory processes and allows for an evaluation of the possibility that the *processes* underlying suggestibility may change even under conditions where the overall magnitude of the misinformation effect, as measured by recognition error rates, undergoes little age-related change.

Process Dissociations and the Misinformation Effect in Children

Lindsay et al. (1995) examined aware and unaware memory processes in children's suggestibility. Children were presented with a story accompanied by pictures and were then read a misleading narrative. All children were given memory tests in one of two test instruction conditions. In the ''standard'' condition, a new experimenter asked children for details regarding the story. In the ''opposition'' condition, children were instructed to exclude all details presented in the postevent summary. Lindsay et al. reported that 5- and 8-year-olds were equally likely to select the suggested alternative to the originally presented target item. Process dissociation estimates for reporting of suggestions revealed that aware and unaware processes varied developmentally such that aware memory processes made a larger contribution to the misinformation effect in the 5-year-olds. For the 8-year-olds, suggestibility was more strongly influenced by automatic, unaware memory processes.

Holliday and Hayes (2000, 2001, in press) evaluated the contribution of automatic and intentional processes to misinformation effects in 5- to 9-year-old children's recognition memory. To this end, the process dissociation equations of Jacoby (1991) and Lindsay et al. (1995) were adapted to apply to children's acceptance of misleading suggestions. In the inclusion condition children could accept misleading suggestions on the basis of intentional recollection (*R*) either because they remember the suggested item as having been presented or because they wish to comply with the experimenter who is perceived as an authoritative and credible information source (Zaragoza, 1991). Alternatively, children could accept misleading suggestions on the basis of automatic processes (*A*) (familiarity of the item), without any conscious recollection of the suggested items. In the exclusion condition, children could accept misleading suggestions only if they come to mind automatically (Jacoby et al., 1993) and if they do not remember that such suggestions were presented in the Phase 2 postevent narrative but believe that the suggestions were part of the original event. The probabilities of children accepting misleading suggestions on the basis of recollection were calculated by subtracting the probabilities of accepting a misled item in the Exclusion condition from the probabilities of accepting a misled item in the Inclusion condition as follows:

$$R = P\text{ (accept misled item} \mid \text{Inclusion)} - P\text{ (accept misled item} \mid \text{Exclusion).} \quad (3)$$

The probabilities of children accepting a suggestion on the basis of automatic processes were calculated by the following:

$$A = P\text{ (accept misled item} \mid \text{Exclusion)} / (1 - R). \quad (4)$$

Holliday and Hayes (2000, 2001) included 5-, 8-, and 9-year-old children to enable a reexamination of Lindsay et al.'s (1995) reported findings of a developmental increase in automatic responding and a corresponding decrease in conscious recollection. Holliday and Hayes (2000) also examined the implications of developmental differences in false alarm rates using a logistic-based dual-process correction model proposed by Yonelinas and Jacoby (1996) which produces estimates of recollection and automatic processes under conditions where the independence assumption is violated. The data for four of the process dissociation studies carried out by Holliday and Hayes (2000, 2001, in press) are presented in Tables 1–4 are discussed in the next section.

Holliday and Hayes' (2000, 2001, in press) studies used an encoding manipulation that aimed to differentially affect children's automatic and recollective processing of suggestions. Some suggested items were read out loud to children in a fashion that closely parallels the way in which misleading narratives have been presented in many previous developmental studies of suggestibility (e.g., Ceci et al., 1987; Zaragoza, 1991). In addition, children self-generated other suggested details in response to semantic cues given by the experimenter. This manipulation was motivated by the extensive literature concerning the ''generation effect''; the retention advantage shown by both adults (e.g., Slamecka & Graf, 1978; Toth et al., 1994) and children (e.g., Ghatala, 1981; McFarland, Duncan, & Bruno, 1983) for words that have been self-generated at study as opposed to words that have simply been read or heard.

In the next section, we review the findings relating to misinformation effects in children and examine the implications of Holliday and Hayes's (2000, 2001, in press) work for understanding children's suggestibility.

THE MISINFORMATION PARADIGM, MISINFORMATION THEORIES, AND MEMORY PROCESSES

The Misinformation Paradigm

A substantial body of empirical evidence has been accumulated using the ''standard'' three-phase recognition paradigm introduced by Loftus, Miller,

TABLE 1

Mean Proportion Acceptance[a] (''yes'' response) of Item Types for Experiments 1 and 2

	Inclusion		Exclusion	
Study 1	5-year-olds	8-year-olds	5-year-olds	8-year-olds
		Experiment 1		
Control	.68(.18)	.69(.17)	.63(.18)	.68(.16)
New	.48(.21)	.38(.10)	.43(.17)	.34(.11)
Misled-Read	.54(.18)	.44(.18)	.45(.20)	.45(.17)
Misled-Generate	.64(.15)	.57(.18)	.43(.21)	.34(.15)
		Experiment 2		
Control	.63(.23)	.60(.18)	.62(.24)	.61(.19)
New	.43(.21)	.30(.16)	.39(.22)	.30(.16)
Misled-Read	.50(.23)	.46(.20)	.51(.24)	.48(.21)
Misled-Generate	.63(.23)	.60(.22)	.45(.23)	.41(.21)

Estimates of the Contribution of Recollection and Automacity for Read and Generate Item Types in Studies 1 and 2 Using the Correction Method Suggested by Yonelinas and Jacoby (1996)

	Recollection		Automacity	
	5-year-olds	8-year-olds	5-year-olds	8-year-olds
		Experiment 1[b]		
Misled-Read	.05	−.08	.48	.43
Mislead-Generate	.17	.20	.54	.43
		Experiment 2		
Misled-Read	−.18(.66)	−.07(.40)	.50(.21)	.48(.18)
Misled-Generate	.08(.44)	.14(.40)	.55(.22)	.50(.21)

Note. Misled-Read and Misled-Generate refer to items depicting the misleading details given in Phase 2.

[a] Snodgrass and Corwin's (1988) correction method was applied to individual participant's ''yes'' responses on the Control, New, and Misled items.

[b] Estimates were calculated between groups.

and Burns (1978) and adapted for children by Ceci et al. (1987) (e.g., Holliday & Hayes, 2001, in press; Holliday, Douglas, & Hayes, 1999; Lampinen & Smith, 1995; Newcombe & Siegal, 1996; Siegal & Peterson, 1995; Toglia, Ross, Ceci, & Hembrooke, 1992; Zaragoza, 1991). In this paradigm, children first view an event, are then read a summary of this event that contains misinformation, and subsequently are asked to choose between an original event item and a picture depicting the misleading suggestion. The modified procedure was developed by McCloskey and Zaragoza (1985) and adapted for children by Zaragoza (1991) to control for social demands and response bias in the standard paradigm and resembles the standard procedure except that at test the misled item is replaced with a previously unseen novel item. This three-phase paradigm has also been adopted by researchers in-

TABLE 2
Study 3: Standard Test Mean Proportion Recognition (and Standard Deviations) as a Function of Experimental Condition and Age

	Correct recognition				Incorrect recognition[a]			
	Inclusion		Exclusion		Inclusion		Exclusion	
	5 years	9 years	5 years	9 years	5 years	9 years	5 years	9 years
Control	.71(.28)	.67(.36)	.70(.26)	.69(.36)	.37(.17)	.38(.24)	.35(.19)	.39(.24)
Misled-Read	.58(.31)	.53(.36)	.61(.29)	.62(.36)	.45(.21)	.48(.24)	.43(.19)	.42(.24)
Misled-Generate	.38(.30)	.36(.35)	.68(.32)	.60(.37)	.58(.20)	.60(.23)	.38(.22)	.44(.25)

Mean Process Dissociation Estimates and (Standard Deviations) for Read and Generate Item Types as a Function of Age

	Recollection		Automaticity	
	5-year-olds	9-year-olds	5-year-olds	9-year-olds
Misled-Read	.02(.29)	.06(.22)	.44(.16)	.45(.22)
Misled-Generate	.20(.31)	.16(.26)	.47(.18)	.52(.22)

[a] Snodgrass and Corwin's (1988) correction method was applied to individual participant's proportions incorrect response on the Misled-Read, Misled-Generate, and Control items.

TABLE 3
Study 3: Modified Test Mean Proportion Recognition (and Standard Deviations) as a Function of Experimental Condition and Age

	Correct recognition				Incorrect recognition[a]			
	Inclusion		Exclusion		Inclusion		Exclusion	
	5 yrs	9 yrs	5 yrs	9 yrs	5 yrs	9 yrs	5 yrs	9 yrs
Control	.73(.29)	.72(.30)	.69(.35)	.71(.30)	.35(.19)	.36(.20)	.37(.24)	.36(.20)
Misled-Read	.57(.27)	.68(.36)	.67(.28)	.71(.30)	.45(.18)	.38(.24)	.39(.19)	.36(.20)
Misled-Generate	.55(.29)	.71(.31)	.61(.31)	.65(.32)	.47(.19)	.36(.20)	.43(.21)	.40(.22)

Mean Process Dissociation Estimates (and Standard Deviations) for Read and Generate Item Types as a Function of Age

	Recollection		Automaticity	
	5-year-olds	9-year-olds	5-year-olds	9-year-olds
Misled-Read	.06(.23)	.02 (.21)	.41(.16)	.38 (.20)
Misled-Generate	.04(.22)	−.04*(.23)	.44(.18)	.38*(.18)

Note. Estimates marked with an asterisk * were calculated in conditions in which no suggestibility as measured by differences in Control and Misled item responding was apparent.

[a] Snodgrass and Corwin's (1988) correction method was applied to individual participant's proportions incorrect response on the Misled-Read, Misled-Generate, and Control items.

vestigating misinformation effects in children's recall (e.g., Cassel & Bjorklund, 1995; Gobbo, 2000; Howe, 1991; Marche & Howe, 1995).

Misinformation Theories

Theoretical explanations of the misinformation effect may generally be classified as one of two alternative approaches: *Memory interference hypoth-*

TABLE 4
Study 4: Mean Proportion Recognition (and Standard Deviations) as a Function of Experimental Condition

	Correct recognition		Incorrect recognition[a]	
	Inclusion	Exclusion	Inclusion	Exclusion
Control	.79(.32)	.80(.26)	.31(.21)	.30(.17)
Misled-Read	.64(.37)	.64(.36)	.40(.24)	.40(.23)
Misled-Generate	.58(.35)	.75(.30)	.44(.24)	.33(.20)

	Recollection	Automaticity
Misled-Read	.00(.12)	.40(.23)
Misled-Generate	.11(.24)	.38(.21)

[a] Snodgrass and Corwin's (1988) correction method was applied to individual participant's proportions incorrect response on the Misled-Read, Misled-Generate, and Control Items.

TABLE 5
Automatic and Intentional (Recollection) Memory Processes and Models of the Misinformation Effect

Misinformation Model	Automatic/Intentional processing of suggestions?	Implications for misinformation models
Trace-alteration (e.g., Loftus et al., 1978)	Automatic	Not supported
Trace strength	Automatic and intentional	Supported
Trace competition (e.g., Bekerian & Bowers, 1983; Chandler & Gargano, 1998; Morton, 1991)	Automatic	Not supported
Social demands/Response bias (e.g., McCloskey & Zaragoza, 1985)	Intentional	Not supported
Source-monitoring (e.g., Johnson et al., 1993)	Automatic (and intentional[a])	Not supported

[a] Mitchell and Johnson (2000) proposed that participants may intentionally deliberate the source of their memories.

eses and *social demand/response bias hypotheses.* The assumptions made by each of these theoretical interpretations are quite distinct. In the former, it is assumed that postevent misinformation interferes with the storage and/or retrieval of event details; the latter assumes no memory interference at all as a result of postevent misinformation. These theories may also be differentiated according to the assumptions they make about the roles of automatic and intentional processing (see Table 5). In the following sections we evaluate the empirical evidence for each of these theoretical approaches.

Memory Interference Theories

Trace-alteration models. Proponents of storage-based models such as trace alteration/trace overwriting (e.g., Loftus & Hoffman, 1989; Loftus et al., 1985, 1978) argue that memory traces for originally witnessed events are altered, degraded, or updated by the introduction of postevent misinformation.

Trace-alteration model: Empirical evidence. When asked to choose between the original event and the postevent misinformation, research with adults (e.g., Loftus et al., 1978) and with children (e.g., Ceci et al., 1987; Holliday et al., 1999; Holliday & Hayes, 2001; Lampinen & Smith, 1995) has consistently found that misled participants are significantly more likely than controls who have not been misled to mistakenly select the misinformation. Ceci et al. (1987), for example, found evidence of a misinformation effect across the age range from 3 to 12 years, but the magnitude of this effect was larger for 3- and 4-year-olds than for older children. Ceci et al.

(1987) also reported that the magnitude of the effect was reduced when children were given a modified test and concluded that both memory interference and social demand factors are implicated in misinformation effects in children. Likewise, Newcombe and Siegal (1996) reported that 4-year-old children given pragmatic cues at test were less likely to report misinformation, demonstrating that the original memories of these children were not permanently altered by the introduction of misleading suggestions.

Strong versions of the trace alteration hypothesis explain the misinformation effect as an unconscious or automatic memory process. Indeed, Loftus (1997) wrote: ‘‘The new [post-event] information invades us, like a Trojan horse, precisely because we do not detect its influence’’ (p. 177). Misleading suggestions create an automatic updating of the original information resulting in permanent loss of this information from storage. Evidence from Holliday and Hayes’s (2000, 2001, in press) research does not, however, support a strong version of trace alteration. Although a large automatic component to suggestibility was found in all their studies, the additional finding that children were able to intentionally exclude misinformation demonstrates that the original event memory traces were not permanently affected. The fact that this effect was also found in a reversed misinformation design in which misleading suggestions were given *before* the original event details (Holliday & Hayes, in press) provides evidence against the proposal that new information alters or overwrites the old information.

Trace-strength models. Trace-strength models of the misinformation effect, such as fuzzy-trace theory (e.g., Brainerd & Reyna, 1998; Brainerd et al, 1998; Reyna & Brainerd, 1998; Reyna & Titcomb, 1997), hold the view that children report misleading suggestions on the basis of either intentional recollection (e.g., verbatim traces of a misled item’s surface form) or automatic memory processes (e.g., gist traces representing a misled item’s semantic, relational, and elaborative attributes). The strength of verbatim and gist traces are differentially affected by factors such as length of the retention interval, age, and encoding manipulations (Brainerd & Reyna, 1998; Howe & Brainerd, 1989; Howe & O’Sullivan, 1997; Reyna & Brainerd, 1995). Manipulations that strengthen the level of the encoded features of the memory trace in storage will also increase the recollection component (Brainerd et al., 1998; Reyna, 1995).

Trace-strength models: Empirical evidence. Several researchers (e.g., Howe, 1991; Marche & Howe, 1995) have measured the intrusions of misinformation into children’s recall of an original event. Howe (1991), for example, examined the proposal that developmental trends in misinformation are related to the strength of original story details. Five- and 7-year-old children were read a story with half recalling story details once and the remainder recalling the details repeatedly until they achieved perfect accuracy on two successive recall trials. Some children then heard a statement or were asked questions containing biasing information. After an interval of 2 or 9 days, 5-year-olds recalled fewer original story details than 7-year-olds, and accuracy was lower in the single trial condition. Howe found that when children reported misinformation this was largely due to rate of storage-based forgetting. Howe concluded that weak memory traces are not more susceptible to misleading suggestions. The results of subsequent studies, however, have provided modest support for a link between memory trace strength for original event details and the reporting of misinformation in younger, preschool-age children. Marche and Howe (1995) and Marche (1999) examined the effects of misinformation on 4-year-old children's memories when the strength of encoding of original information (Marche, 1999; Marche & Howe, 1995) and postevent misinformation (Marche, 1999) was controlled. Half of the children recalled the slide details once with the remainder recalling the details until they were correct on two successive recall trials. Children were more likely to report misinformation when the trace for original story details was weak, although like Howe (1991) such effects were rare. Application of a formal trace-integrity model revealed that while storage failures had the greatest impact on recall, little evidence of memory impairment of the original story details was found. It should be noted, however, that there is some evidence that recall reports underestimate children's level of acceptance of misleading suggestions (e.g., Cole & Loftus, 1987).

A number of researchers have investigated memory trace strength effects using recognition tests. Pezdek and Roe (1995), for example, manipulated the trace strength of the original details by repeating these details either once or twice to 4- and 10-year-old children before the children were exposed to misinformation. Enhancement of the trace strength of the original event reduced misinformation acceptance on the standard recognition test, and this effect was age invariant. As no controls for response biases and demand characteristics (cf. Zaragoza, 1991) were used it is unclear whether children's suggestible responses were due to changes in memories for the original story details or to social demands and/or response biases. A recent study by Holliday et al. (1999) examined trace strength effects using both the standard and modified recognition tests. Holliday et al. investigated the effects of the relative encoding strengths of both original and postevent misleading details on 5- and 9-year-old children's acceptance of misinformation. They found that repeated presentation of misinformation increased the misinformation effect on both the standard and modified tests. Similarly, Marche reported that children presented with the misinformation three times were more likely to recall this misinformation than children exposed once to the misinformation.

Further evidence in support of a trace-strength theory of misinformation has come from studies that have assessed children's memory using recall. In Cassel and Bjorklund's study (1995), for example, 6- and 8-year-old children and adults viewed a short video depicting an argument over a bicycle. Participants were interviewed three times regarding their memories of the event: immediately and at 1 week and 1 month following the video; misleading questions were asked on the two latter occasions. Six-year-olds were found to be more suggestible to leading questions than 8-year-olds and adults, but only when interviewed 1 month following the original event. When interviewed after a retention interval of 1 week, both 6- and 8-year-old children were more suggestible than college students. Cassel and Bjorklund argued that the finding that 6-year-olds were the most vulnerable to suggestive questioning is consistent with fuzzy-trace theory; younger children are more reliant on verbatim traces that decay rapidly. In Gobbo's (2000) studies, 4- and 7-year-old children participated in a staged event and were then asked misleading questions about the event. Gobbo reported that 4-year-olds were more suggestible than the 7-year-olds and that children reported more misinformation when asked misleading questions than when they were asked nonmisleading questions. Gobbo's finding that children were more suggestible when suggestions were repeated is consistent with a memory trace-strength account. Holliday and Hayes's (2000, 2001, in press) findings that self-generated suggestions potentiated children's acceptance of misinformation supports the trace-strength prediction that the magnitude of the suggestibility effect is related to conditions that affect the relative strength of original and postevent memory traces.

Retrieval interference models. Retrieval interference models explain the misinformation effect in terms of retrieval failure (Bekerian & Bowers, 1983; Chandler & Gargano, 1998; Morton, 1991; Morton, Hammersley, & Bekerian, 1985).

One influential version of the retrieval interference account, Headed Records (Morton, 1991; Morton et al., 1985), assumes that both the original and postevent misinformation is represented in memory by two discrete permanent headed records. For a record to be retrieved its description must be matched with its heading. In the case of the misinformation paradigm, both the original and postevent details are represented in memory by two distinct unalterable headed records. As only one of these may be retrieved at a time, the record with the heading that most closely matches the retrieval cues present at memory testing will be the one retrieved. According to Morton (1991), retrieval of a specific record is an automatic process that occurs outside of awareness.

Holliday and Hayes's (in press) finding of misinformation effects in 5- and 6-year-old children in a reversed misinformation design is inconsistent with the view that new information ''blocks'' retrieval of the original event details. Howe (1991) also reported that the small misinformation effects found in his study could not be explained by a blocking account. An intentional component to the acceptance of suggestions based on self-generated items (Holliday & Hayes, 2000) is also inconsistent with this account and demonstrates that misinformation effects are not based entirely on automatic competition between traces at retrieval. Nevertheless, Holliday and Hayes' (2000, 2001, in press) findings that self-generated misinformation was more likely to be excluded by children than read misinformation does support the general assumption that is shared by trace-strength and retrieval interference models that both the original event and postevent memory traces coexist at the point of retrieval.

Some researchers have questioned whether retrieval interference models provide a complete account of misinformation effects in children. For example, Howe (1991) showed that when a formal trace-integrity model was applied to recall data, kindergarten children who were misled evidenced more storage-based forgetting than children who were not misled although such effects were rare. Howe's modeling suggests that retrieval interference and trace alteration are not necessarily mutually exclusive processes; both may contribute to children's reporting of suggested information.

The Source-Monitoring Hypothesis

According to source-monitoring accounts of the misinformation effect, misleading suggestions are reported due to source misattribution errors (Ackil & Zaragoza, 1995; Johnson, Hashtroudi, & Lindsay, 1993; Multhaup, de Leonardis, & Johnson, 1999). Participants may adopt an undifferentiated or a strict decision criterion when making a source-monitoring judgment, and the quality of that judgment is dependent on the amount of source-specifying information about the target item and the encoding context (e.g., perceptual, spatial, temporal, and semantic details) available in memory (Dodson & Johnson, 1996; Johnson et al., 1993; Mitchell & Johnson, 2000). Participants will be less likely to accept misinformation if they are oriented toward source-monitoring judgments and when the sources of the original event and postevent suggestions are highly discriminable (Johnson et al., 1993; Mitchell & Johnson, 2000; for exceptions to this source discriminability effect, see Titcomb & Reyna, 1997; Reyna & Brainerd, 1995; Reyna & Lloyd, 1997).

Several studies have reported that young children are prone to making source misattributions and that source monitoring accuracy improves across the childhood years (e.g., Ackil & Zaragoza, 1995; Ceci, Huffman, Smith, & Loftus, 1994; Lindsay, Johnson, & Kwon, 1991; for a review see Roberts, 2000). Only a handful of studies have examined the implications of source monitoring on misinformation effects in children (e.g., Bruck, Melnyk, & Ceci, 2000; Ceci et al., 1994; Poole & Lindsay, 1995; Thierry, Spence, & Memon, 2000). In Bruck et al.'s study, 5-year-olds took part in a magic show before being given correct and misleading details about the show. Children were then required to draw or were asked questions about the postevent details. Bruck et al. found that children in the drawing condition were more accurate in identifying the source of the postevent information than children in the question condition. However, children in both conditions were equally likely to report that the postevent misinformation had actually occurred. In Thierry et al.'s study (2000), however, 4- and 5-year-olds who were asked questions relating to the source of their memories prior to interview were less likely than those in a control condition to provide inaccurate responses to misleading questions.

In many misinformation studies, conditions encourage a high level of discrimination between sources. For example, in the Holliday and Hayes' (2000, 2001, in press) studies, a different experimenter was employed to provide misleading suggestions, and in Holliday and Hayes (2000, in press), children were given the misleading suggestions one day after presentation of the original event. The exclusion condition used by Holliday and Hayes (2000, 2001, in press) resembles a source-monitoring test in that under exclusion instructions participants identify the source of the misinformation in order to exclude it. Indeed, Johnson et al. (1993) and others (e.g., Buchner, Erdfelder, Steffens, & Martensen, 1997; Dodson & Johnson, 1996) have proposed that participants will be less likely to report misinformation if they are directed toward making source-monitoring judgments on the basis of intentional recollection rather than on the basis of the familiarity of the information. Holliday and Hayes reported that children were more likely to intentionally exclude suggestions that were self-generated, providing some support for this view.

According to the source-monitoring account, participants rely on cues such as memories of internal cognitive operations used to generate items so as to correctly exclude the items. Importantly, however, Holliday and Hayes (2000, 2001, in press) found that children were still more likely to accept suggestions that were read aloud to them even when they were explicitly asked to exclude such items, an effect that was almost entirely due to automatic memory processes. As has been reported by other researchers (e.g., Lindsay et al., 1995; Poole & Lindsay, 1995), misinformation effects persist in tests that direct children to make source-monitoring judgments.

As predicted by source monitoring (e.g., Johnson et al., 1993), Holliday and Hayes (2001, in press) found that on the standard test children were just as likely to misattribute the source of their memories to the misinformation instead of to the original event information when it was presented before the original event as when it was presented after the original event information (i.e., in a reversed misinformation paradigm). However, contrary to the predictions of source monitoring an intentional recollection component was found for suggestions that were self-generated in a reversed misinformation design (Holliday & Hayes, in press). (See Reyna & Lloyd, 1997, for other false-memory findings that are difficult to reconcile with the source-monitoring framework.)

Social Demands/Response Biases Hypotheses

Alternative models of the misinformation effect in children claim that misleading suggestions are intentionally reported because of the social demands of the experimental situation, such as compliance with the information provided by adult questioners who are perceived as authoritative and trustworthy sources (Cassel, Roebers, & Bjorklund, 1996; Ceci et al., 1987; Lampinen & Smith, 1995). Children may also report misleading suggestions due to response biases (because the misinformation is the most recently presented) inherent in the standard (Loftus et al., 1978) paradigm (Zaragoza, 1991).

In a series of studies with 3- to 6-year-old children, Zaragoza and her colleagues (1987, 1991; Zaragoza, Dahlgren, & Muench, 1992) found an effect of misinformation on recognition accuracy when children were assessed using a standard test but no such effect when children were tested using the modified test. These results were maintained even when the same stimulus materials that were used by Ceci et al. (1987) were employed. Zaragoza concluded that social demand factors and response biases inherent in the standard paradigm were responsible for the misinformation effect in children. Similarly, Newcombe and Siegal (1996) reported evidence of a misinformation effect when 4-year-old children were given a standard test but that this effect was eliminated when children were tested with the modified procedure. Holliday and Hayes (2001) reported that misinformation effects for 9-year-olds found on the standard test were eliminated when these children were given a modified test.

Other researchers have found a reduced but reliable misinformation effect in the modified paradigm (e.g., Holliday et al., 1999; Holliday & Hayes, 2001; Toglia et al., 1992). Holliday et al., for example, investigated the relationship between memory trace strength of the original event details, post-event misinformation, and 5- and 9-year-old children's suggestible responding on either a standard or a modified forced-choice recognition test. Evidence was found of a significant negative effect of misinformation on recognition accuracy in *both* test conditions. Similarly, Holliday and Hayes (2001) reported that 5-year-olds were suggestible when given a modified test, an effect that was, for the most part, due to automatic processes. Taken together, findings of misinformation effects in studies using a modified test that provides a stringent control on social demand factors and response biases strongly suggests that memory changes of some kind contribute to many instances of the misinformation effect in children.

Further evidence indicating that children remain suggestible when the social and pragmatic demands to accept misinformation are reduced has come from research employing yes/no recognition tests (e.g., Lindsay et al., 1995; Pezdek & Roe, 1995). In Pezdek and Roe's (1995) study, for example, 4- and 10-year-old children responded ''yes'' or ''no'' to recognition target sentences that described three types of information, control (original), misleading, and novel target details. Both groups of children were equally suggestible when a comparison of control and misled responses was made.

Young children frequently perceive an adult interviewer as an authoritative and trustworthy source of information (Ceci & Bruck, 1995). Accordingly, young children often change their answers to repeated misleading questioning by adults (e.g., Bjorklund, Bjorklund, Brown, & Cassel, 1998;

Cassel et al., 1996). However, children are less likely to accept suggestions provided by a child or a discredited adult (e.g., Ceci et al., 1987; Lampinen & Smith, 1995). In Cassel et al.'s (1996) study, for example, 5-, 7-, and 9-year-old children and adults watched a short video, followed by free recall and a series of misleading questions and one forced-choice question 1 week later. Five-year-olds were more likely to change their answers to misleading questions than the other age groups. Ceci et al. (1987) found that the misinformation effect in 3- to 4-year-old children was reduced but not eliminated when a 7-year-old child rather than an adult provided suggestions, indicating that young children's suggestible responses were partly influenced by a belief in information provided by adult authority figures. Similarly, Lampinen and Smith (1995) reported that 3- to 5-year-olds were suggestible when the misinformation was provided by a credible adult but not when presented by a young child or a discredited adult.

A notion that is closely related to the social demands account is the proposal that misinformation effects may arise because of children's misunderstanding of the test questions (e.g., Ackerman, 1998; Mulder & Vrij, 1996; Newcombe & Siegal, 1996; Siegal & Peterson, 1995). Young children are inexperienced with the conventions governing interactions between themselves and adults and are likely to misinterpret the intent of the interviewer in tests of eyewitness memory (Newcombe & Siegal, 1996; Siegal & Peterson, 1995). Newcombe and Siegal (1996) claimed that, unlike older children and adults, young children might not realize that the purpose of misinformation experiments is to ignore misleading suggestions. They found that the size of the misinformation effect was reduced for 4-year-old children who were explicitly questioned regarding the time of the presentation of the original story. Although such conclusions may hold for very young children, findings of a robust misinformation effect in children as old as 8 years (e.g., Ceci et al., 1987; Lindsay et al., 1995) undermines the view that misinformation effects in all children arise because of a lack of experience with pragmatic conventions.

The social demands/response biases hypotheses predict that the misinformation effect has a large recollective or intentional memory component in that children are seen to make a deliberate, conscious decision to report the suggested item based on the social context and/or pragmatic cues present at the time of testing. In other words, if young children believe that the experimenter is a reliable source of information, or if children wish to be viewed favorably by the experimenter, they may consciously ''deliberate'' that the suggested item is the correct item.

In the Hayes and Holliday (2000, 2001, in press) studies, the absolute magnitude of the contribution of intentional processing to acceptance of misleading suggestions was rather small in comparison to that of automatic processes. Nevertheless, the contribution of intentional processing to misinformation acceptance was found to increase under generate conditions that promoted elaborative encoding of suggestions. Hence, ''intentional suggestibility,'' which may be motivated by social and/or pragmatic influences, may be determined by the specific conditions that hold when suggestions are encoded and retrieved. When children are directed to engage in more elaborative encoding of suggestions, the contribution of intentional processing to subsequent acceptance of suggestions appears to increase.

In sum, social demand/response biases theories are only tenable in certain situations (e.g., in the standard recognition testing paradigm, when the encoding conditions promote the elaborative processing of suggestions and in very young children) and are rarely the primary cause of recognition errors.

DEVELOPMENTAL CHANGE IN MEMORY PROCESSES UNDERLYING THE MISINFORMATION EFFECT

Numerous studies have reported that children in a very wide age band are adversely affected by misleading postevent suggestions (e.g., Bruck, Ceci, & Melnyk, 1997; Ceci & Bruck, 1993; Roebers & Schneider, 2000). Studies that have included preschool children in developmental comparisons with older children have generally found that very young preschoolers (3- to 4-year-olds) are disproportionately affected by postevent misinformation (Bruck & Ceci, 1999; Bruck et al., 1997, 1998; Ceci & Bruck, 1993; Ceci, Crossman, Gilstrap, & Scullin, 1998).

While the evidence for young preschoolers is reasonably clear cut, a consensus with regard to age-related differences in suggestibility for children ages 5 to 12 years old has yet to be reached (Bruck & Ceci, 1999; Cassel & Bjorklund, 1995; Ceci et al., 1998). Several studies have reported developmental differences, with young school-aged children (i.e., 6-year-olds) being the most adversely affected (e.g., Ackil & Zaragoza, 1995; Cassel & Bjorklund, 1995; Cassel et al., 1996; Roebers & Schneider, 2000). Other studies have found young school-aged children to be no more suggestible than older children and adults (e.g., Ceci et al., 1987; Flin, Boon, Knox, & Bull, 1992; Holliday et al., 1999; Lindsay et al., 1995).

Ordinarily, we could conclude that findings of developmental differences trump null effects for the usual methodological reasons (namely, that null effects are simply failures to detect differences that might be present). However, it is difficult to reconcile the disparate results from these studies because of marked inconsistencies in their methodology and testing procedures (see also Howe, 1991). The studies differed considerably with regard to the age of participants, sample size, the type of test materials (e.g., staged live event, video, and story with pictures), presentation mode of the misleading information (e.g., leading questions and narrative), linguistic complexity and number of misleading suggestions, length of retention intervals between each experimental phase (e.g., 20 min, 1 week, or 1 month), and the methods used to test children's memories (e.g., free and cued recall and recognition).

Consistent with previous research in which few developmental differences in levels of suggestibility have been found for elementary school-age children, the Holliday and Hayes (2000, 2001) studies found only minimal evidence of age-related changes in 5-, 8-, and 9-year-old children's suggestible responses across a wide range of recognition tests. In the modified testing paradigm, however, age-related changes in levels of suggestibility were found. Specifically, for misleading suggestions that were self-generated in response to semantic and other linguistic cues, only the 5-year-old children demonstrated a misinformation effect. Because the modified test effectively eliminates the possibility of deliberate or intentional processes influencing suggestibility this set of findings suggests that the younger children are *more* likely than the older children to accept suggested items automatically on the basis of familiarity.

Holliday and Hayes (2000, Experiment 2) reported that although the overall probability of accepting misinformation did not vary across 5- and 8-year-olds, the process dissociation analysis did yield an interesting developmental trend in the processes underlying children's reporting of suggestions. Specifically, the contribution of automatic processing to acceptance of misinformation declined with age while the role of intentional processing remained relatively stable; misinformation acceptance in 5-year-olds was more likely to be the result of an automatic process. This pattern of findings is particularly significant in that it shows that age invariant misinformation effects can actually be mediated by different kinds of underlying memory processes. More importantly, this result demonstrates that there was still evidence of a developmental change in the cognitive processes underlying acceptance of suggestions despite the absence of such a pattern in the raw data. These findings suggest that models that posit ''automatic'' acceptance of misleading suggestions may be somewhat more applicable to the recognition responses of younger as opposed to older children. Notably, Holliday and Hayes's (2000) results are consistent with developmental improvements in priming on indirect tests of implicit memory (e.g., Cycowicz et al., 2000; Komatsu et al., 1996).

The process dissociation model has proven a valuable tool for measuring the relative contribution of intentional recollection and automatic reporting of misinformation in children. The procedure has, however, been the focus of debate.

CONTROVERSY SURROUNDING THE PROCESS DISSOCIATION PROCEDURE

The validity of the process dissociation assumption that recollection and automaticity represent independent processes has attracted some debate (e.g., Brainerd et al., 1998, 1999; Curran & Hintzman, 1995; Dodson & Johnson, 1996; Jacoby & Shrout, 1997). As this discussion has been covered elsewhere (e.g., Brainerd et al., 1999; Holliday & Hayes, 2000; Kelley & Jacoby, 2000), we present a brief outline of the debate as it relates to the developmental data presented earlier in this review.

Curran and Hintzman (1995) reported evidence of violations of the assumption of independence such that significant positive correlations were found between estimates of recollection and automaticity resulting in an underestimation of the contribution of automaticity to recognition. Jacoby and Shrout (1997), however, found that when the estimates of recollection and automaticity were calculated *within participants* rather than *across participants or items*, correlations between estimates did not affect the size of the estimates obtained. Holliday and Hayes (2000, 2001, in press) calculated the estimates of automaticity and recollection within participants, and hence, the likelihood of problematic violations of the independence assumption was reduced.

Dodson and Johnson (1996) reported evidence of a violation of the process dissociation assumption that the contribution of recollection and automaticity to recognition is invariant across inclusion and exclusion conditions. They argued that the process dissociation equations imply that correct recognition of an item on the exclusion test for which no misinformation is given must be the result of recollection alone or familiarity in the absence of recollection. More formally:

$$P \text{ (correct recognition of original control item} \mid \text{exclusion test)} = R + F\,(1 - R). \quad (5)$$

This means that, if the assumption of process independence is correct, the probability of correctly recognizing control items in the inclusion condition should equal the probability of correctly recognizing control items in the exclusion condition. In the Holliday and Hayes (2000, 2001) studies the predicted equivalence of recognition of control items across inclusion and exclusion conditions was generally upheld.

A further difficulty for the process independence assumption arises when there is a difference between levels of response bias in the inclusion and exclusion test conditions (Brainerd et al., 1999; Buchner, Erdfelder, & Vaterrodt-Plunnecke, 1995; Yonelinas & Jacoby, 1996) or between participant groups being compared (Graf & Komatsu, 1994; Roediger & McDermott, 1994). Under such conditions, response bias effects may be erroneously attributed to either recollection or automatic memory processes.

Yonelinas et al. (1995) proposed that false alarms are made on the basis of preexperimental familiarity (automaticity) and not on the basis of overall recognition, which, they argued, reflects the dual processes of automaticity *and* recollection. Yonelinas et al. (1995) developed a logistic signal-detection procedure in which corrections for response bias are applied only to estimates of automaticity. Holliday and Hayes (2000) applied the logistic-based correction model (Yonelinas & Jacoby, 1996) to examine possible response bias differences between experimental conditions. In general, the obtained pattern of findings resembled that obtained with the Jacoby (1991) method.

A further concern is that some participants may exhibit ‘‘perfect’’ recollection of Phase 2 information in the inclusion and exclusion conditions leading to scores of one and zero across test items. While a number of commentators have expressed concerns about the inclusion of such participants in data analyses (e.g., Russo et al., 1998), others (e.g., Curran & Hintzman, 1995; Horton & Vaughan, 1999) have suggested that removing participants with perfect recollection on the inclusion and exclusion conditions (one and zero, respectively) in within-subjects designs results in biased process estimates. Because the deletion of children with scores of one or zero on inclusion or exclusion tests would have resulted in a significant attrition of participants, Holliday and Hayes (2000, 2001, in press) opted to include all children who complied with test instructions. Participants' individual scores were first ‘‘corrected’’ to set scores of one and zero just below one and just above zero, respectively (cf. Hayes & Hennessey, 1996; see also Horton & Vaughan, 1999). The fact that this practice did not result in a systematic bias in the derivation of automaticity and recollection estimates is indicated by the similarity between the estimates for studies 2–4 and the group-based estimates derived in the first study where the problem of individual ceiling-level performance did not arise.

ALTERNATIVE MODEL-BASED SEPARATION OF MEMORY PROCESSES: CONJOINT RECOGNITION

The conjoint recognition model differs fundamentally from Jacoby's process dissociation approach and was designed to address problems of independence, goodness-of-fit, response bias, and other issues (e.g., Brainerd & Reyna, 1998; Brainerd et al., 1998, 1999). In contrast to process dissociation, the conjoint recognition model identifies a larger outcome space, which makes it possible to test whether the model fits the data. Although process dissociation assumes invariance over both presentation and instructional conditions, conjoint recognition assumes only invariance over instructions and then tests that assumption. In addition, conjoint recognition incorporates fuzzy-trace theory's core distinction between verbatim representations of actual experience and gist representations of its meaning or interpretation. Last, conjoint recognition adopts fuzzy-trace theory's distinction between the judgment processes of identity versus similarity (Reyna, 1996, 1998; Reyna & Lloyd, 1997; Reyna & Titcomb, 1997). Similarity is a graded judgment applied to gist representations that yields feelings of global resemblance between memory and tested items. Identity, however, is an all-or-none judgment of match or mismatch between memory and tested items. Naturally, verbatim representations lend themselves to all-or-none judgments of match or mismatch because surface form either is or is not the same as a test probe (Reyna & Brainerd, 1995). However, recent evidence suggests that very strong gist memories are also subject to all-or-none identity judgments under conditions predicted by fuzzy-trace theory (e.g., Brainerd et al., in press; Reyna & Lloyd, 1997). Thus, conjoint recognition also differs from process dissociation in that familiarity in process dissociation is a catchall that includes similarity and many other things, whereas similarity in conjoint recognition captures a specific relation (with other factors estimated in the bias parameter). In sum, the conjoint-recognition model estimates the independent contributions of verbatim-based identity judgment and gist-based similarity judgment to children's recognition, but the association between memory representations and judgments is not one to one (Reyna, 1996, 1998; Reyna & Lloyd, 1997): Very strong gist memories can be also associated with identity judgments.

This conjoint recognition model has been evaluated with adult (Brainerd et al., 1999) and developmental data (Brainerd et al., 1998). Brainerd et al. (1998), for example, gave 7- and 10-year-old children a continuous yes/no word recognition task in which a response was made as each word was presented. Children listened to a list of concrete nouns and nonsense words and then responded in one of two instructional conditions; ''accept only target items'' or ''accept only related items.'' Evidence was reported of validation of the model with regard to goodness-of-fit, invariance of estimates of identity and similarity both within and between conditions, and invariance of such estimates according to instruction conditions. Brainerd et al. (1999) concluded that the conjoint-recognition model holds an advantage over the process dissociation model because the former incorporates goodness-of-fit tests and can measure conscious and unconscious processes for false alarms to new items (see also Brainerd et al., 1998).

Brainerd and Reyna (1998) outlined a modified version of the conjoint-recognition model, ''MISINFORM'' for modeling data obtained from misinformation studies. In the conjoint-misinformation paradigm children respond ''yes'' or ''no'' under three instruction conditions; ''accept only target items (T),'' ''accept only related items (R),'' and ''accept targets and related distractors'' (T + R) (Brainerd et al., 1998). Traditional misinformation designs employ only the ''T'' instructions when examining children's acceptance of misinformation. Using simulated data generated from misinformation studies with children aged 4 and 10 years (i.e., Pezdek & Roe, 1995, 1997; Warren & Lane, 1995), Brainerd et al. (1998) showed that misinformation acceptance was made on the bases of identity (cf. recollection) and similarity (cf. familiarity) and that similarity judgments increased with age.

Although conjoint recognition preserves many of the strengths of process dissociation while redressing some of its shortcomings, some have argued that ''R'' instructions—the instruction to give a ''yes'' response to a related distractor and a ''no'' response to an unrelated distractor—may cause young children to become confused (Cowan, 1998). In essence, ''R'' instructions require children to make judgments concerning an item's physical and semantic relatedness to a target item (Brainerd et al., 1998). Although this task requires clear instructions and concrete examples, it has been used successfully with children as young as 6 years old (Brainerd et al., 1998; Reyna & Brainerd, 1998).

Similarly, using the process dissociation paradigm, Holliday and Hayes (2000) found that some 5-year-olds had difficulty following the test instructions to include items for which they had been given misleading details (i.e., ''yes'' response to a misled item) when these instructions were given *after* they had been informed that the experimenter had made some errors in their postevent narrative. The effect of such confusions is one of artificially lowering acceptance of misleading details in an inclusion condition. Given these concerns, further research is necessary to clarify the limitations of applying either the conjoint recognition or process dissociation paradigm to preschoolers.

Recall Models: The Trace-Integrity Framework

Most recently, researchers in the adult and developmental literature have been concerned with modeling the contributions of recollective and automatic processes in recognition memory. There are however, two corresponding techniques for recall. Howe and Brainerd (1989), for example, developed a formal trace-integrity model to evaluate the functions of storage and retrieval processes in forgetting and recovery of memory traces (Howe & O'Sullivan, 1997). In this framework, storage and retrieval processes are located on a continuum of trace integrity. Retrieval of a particular memory is dependent upon the degree of integration or strength of the trace's features (Howe, 1991).

This model has been applied to children's recall in a misinformation paradigm (e.g., Howe, 1991; Marche, 1999; Marche & Howe, 1995). Briefly, Howe (1991) showed that when a formal trace-integrity model was applied to recall data, children who were misled evidenced more storage-based forgetting than the control group. Howe showed that the small misinformation effects obtained were due to both rate of forgetting and retrieval interference, with the former exerting a stronger influence on children's recall. Howe's modeling suggests that retrieval interference and trace alteration are not necessarily mutually exclusive processes; both may contribute to children's reporting of suggested information. It is notable, however, that trace integrity is a global (i.e., single process) model of memory in which memory traces are characterized as unitary structures (Howe, 1991) and differs significantly from dual-process models such as fuzzy-trace and process dissociation (e.g., Brainerd & Reyna, 1998; Jacoby, 1991).

Dual-Retrieval Model of Recall

Brainerd, Wright, Reyna, and Payne (in press) recently introduced a paradigm derived from the Estes (1960) RTTT (R = ''reinforce'' and T =

‘‘test’’) procedure and a modeling procedure to quantify the relative contributions of direct access and reconstruction processes to free recall. The dual-retrieval model assumes that an item can be recalled by direct access to its verbatim trace, or by reconstruction through semantic processing and metamemorial judgment. Brainerd et al. (in press) evaluated the model in a series of studies with adults. Evidence was reported of validation of the model such that direct access and reconstruction and metamemorial judgment were shown to be unique processes in free recall. A challenge for researchers is to adapt this model to recall of misinformation in children.

CONCLUSIONS AND GENERAL IMPLICATIONS

In the preceding sections we have shown that formal modeling techniques are particularly useful in child eyewitness research. Most importantly, model-based separation of recognition processes clearly demonstrated evidence of developmental change in the memory processes underlying acceptance of misinformation in the absence of developmental change in the probability of reporting a suggestion.

The finding that both automatic and intentional memory processes (whether recollection/familiarity or verbatim identity/gist similarity) contribute to the acceptance of misinformation has a number of important implications for children’s testimony. First, the fact that automatic memory change following presentation of suggested items occurred more frequently for the younger children indicates that professionals involved in questioning children about events in which they have been participants or witnesses need to be especially careful about the presentation of misleading information to these children. Evidence from specific cases (e.g., Ceci & Bruck, 1995) indicates that children can be exposed to repeated and/or suggestive questioning and negative feedback regarding their performance on multiple occasions by a variety of law enforcement officials, therapists, and legal representatives. This review clearly shows that questioning techniques that inadvertently encourage children to generate a suggested detail may be even more detrimental to the accuracy of subsequent testimony than the overt provision of a suggestion by the questioner. Finally, Holliday and Hayes’s (in press) findings that children remained suggestible in a reversed misinformation design in which misinformation was presented *prior* to the original event information is somewhat analogous to the situation faced by many child eyewitnesses. In the 1987 death row case of *Frederico Macias* in Texas (Ceci & Bruck, 1995), for example, the child’s eyewitness reports of a murder were clearly influenced by negative information about the suspect provided to the child by her parents *prior* to the episode that the child was alleged to have witnessed.

Misinformation research has identified certain conditions that affect the magnitude of obtained suggestibility effects (e.g., retention interval, whether standard or modified recognition or recall tests are given, repeated suggestions, repeated questioning, and memory trace strength of original and post-event details). Future research in this field, therefore, should focus on applying formal modeling techniques to variables that are known to affect recognition and recall in children.

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