Annu. Rev. Psychol. 2000. 51:481–537

TOWARD A PSYCHOLOGY OF MEMORY ACCURACY

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Key Words memory correspondence, false memory, memory distortion, memory illusions, memory metaphors

■ **Abstract** There has been unprecedented interest in recent years in questions pertaining to accuracy and distortion in memory. This interest, catalyzed in part by real-life problems, marks a significant departure from the quantity-oriented approach that has characterized much of traditional memory research. We outline a correspondence metaphor of memory underlying accuracy-oriented research, and show how the features of this metaphor are manifested across the disparate bodies of research reviewed here. These include work in the Gestalt tradition, spatial memory, memory for gist, schema theory, source monitoring, fluency misattributions, false recall and recognition, postevent misinformation, false memories, eyewitness research, and autobiographical memory. In examining the dynamics of memory accuracy, we highlight the importance of metacognitive monitoring and control processes. We end by discussing some of the methodological, theoretical, and metatheoretical issues inherent in accuracy-oriented research, attempting to prepare the groundwork for a more coherent psychology of memory accuracy.

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0084–6570/00/0201–0481$12.00

INTRODUCTION

Despite the enormous amount of research and theorizing on memory in the past century, there is still no consensual conceptual framework for thinking about memory. In our view, this state of affairs reflects the multifarious nature of memory itself, calling for a pluralism of approaches to the study of memory (Koriat & Goldsmith 1996b, 1997).

One approach that has dominated the experimental study of memory during the past century has followed Ebbinghaus (1895) in adopting a quantity-oriented conception. In this conception, memory is seen as a storehouse into which discrete items of information are initially deposited and then later retrieved (Marshall & Fryer 1978, Roediger 1980). Memory is then evaluated in terms of the number of items that can be recovered over some retention interval. This approach to memory underlies the traditional list-learning paradigm that continues to produce much of the data that appear in scientific journals.

More recently, however, a very different approach to memory has been gaining impetus, inspired by real-life memory phenomena. In this accuracy-oriented approach, which may be traced to the seminal work of Bartlett (1932) among others, memory is viewed as a representation or reconstruction of past experience. Hence, memory is evaluated in terms of its correspondence or fit with past events, rather than in terms of the mere number of input items that can be recovered.

The vast amount of recent work on memory accuracy and distortion has produced many new findings and also a search for theoretical frameworks that can accommodate them. Yet, only very recently has there been an emerging recognition that the new wave of accuracy-oriented research calls for the development of a metatheoretical foundation that can help in organizing the data and in motivating specifically accuracy-oriented memory theories (Koriat & Goldsmith 1996b, Payne & Blackwell 1998, Roediger 1996, Schacter et al 1998). In this chapter, we present a selective review and analysis of accuracy-oriented memory research. We first outline the basic characteristics of the accuracy-oriented approach in terms of a correspondence conception of memory. We then survey some of the main accuracy-oriented research areas, in the attempt to bring out

the common features and issues inherent in the study of memory accuracy and error. We go on to emphasize the role that metacognitive processes have come to play in current treatments of memory accuracy. Finally, we discuss some of the theoretical, metatheoretical, and methodological issues that must be faced on the road to a psychology of memory accuracy.

Basic Characteristics of the Accuracy-Oriented Approach to Memory

In order to appreciate the unique features of the accuracy-oriented approach to memory, it is helpful to contrast it with the traditional, quantity-oriented approach. These two approaches appear to reflect two fundamentally different conceptions or metaphors of memory—the storehouse and correspondence metaphors, respectively (Koriat & Goldsmith 1996a,b).

The Quantity-Oriented Storehouse Conception The quantity-oriented approach to memory, inherent in the storehouse metaphor, is well illustrated by the standard list-learning paradigm, perhaps the hallmark of traditional memory research (Neisser 1991). This paradigm essentially simulates the course of events presumed to take place when memory items are initially deposited into and then subsequently retrieved from a memory store. The contents of the store are assumed to consist of discrete, elementary units (items), whose basic characteristic is countability: Measures of memory can be based simply on the number of recovered elements. Moreover, memory is assessed in an input-bound manner: One begins with the input and asks how much of it was recovered in the output. In scoring free-recall performance as percent correct, for instance, commission errors are essentially ignored (Roediger et al 1997). Forgetting, then is conceived as simple item loss. Moreover, the items are completely interchangeable as far as the total memory score is concerned: The content of the recollected and forgotten items is immaterial. What matters is not what is remembered, but rather, how much.

These aspects of the list-learning paradigm characterize an approach to memory in which memory is studied primarily in terms of its amount (Schacter 1989). This emphasis guides not only the way in which memory is assessed, but also the phenomena investigated, the questions asked, and the methods and theories developed to answer them. Until recently, the dominance of this approach was virtually unrivalled (Payne & Blackwell 1998, Roediger 1980).

The Accuracy-Oriented Correspondence Conception The accuracy-oriented approach, in contrast, can be illustrated by a memory paradigm common in eyewitness research, in which subjects first observe a staged event and are later asked to recount the event, or are questioned about specific details (e.g. Belli & Loftus 1996, Fisher et al 1994). This paradigm embodies a different way of thinking about memory, one in which the focus is on the correspondence between what

the person reports and what actually occurred (see Winograd 1994, Payne & Blackwell 1998). Indeed, much of the recent work inspired by real-life memory phenomena discloses a keen preoccupation with the reliability, accuracy, or faithfulness of memory that has no parallel in the traditional, quantity-oriented approach. In order to capture the essential features of this alternative view, Koriat & Goldsmith (1996b) explicated a *correspondence metaphor* of memory in terms of the following interrelated attributes:

1. Aboutness: Memory is considered to be about past events (Conway 1991). Thus, memory reports are treated as descriptions, consisting of propositional statements that have truth value, rather than as mere collections of recovered items.
2. Focus on accuracy: Interest lies primarily in the extent to which the memory report is reliable, trustworthy, and accurate, i.e. the extent to which it accords with reality (or some other criterion) (see Kruglanski 1989).
3. Forgetting: Forgetting is conceived as a loss of correspondence between the memory report and the actual event, that is, as a deviation from veridicality. Thus, in addition to a concern with information loss, this view leads to a focus on the many different types of qualitative memory distortions (e.g. Bartlett 1932, Schacter 1995)—simplification, fabrication, confabulation, and the like.
4. Content: Unlike the quantity-oriented approach, in which interest focuses on how much is remembered, in the correspondence-oriented approach (and virtually all real-life memory situations), it matters a great deal what is remembered and misremembered (Conway 1991).
5. Output-boundedness: The assessment of memory correspondence is inherently output bound. Unlike the storehouse approach, which leads one to begin with the input and ask how much of it is represented in the output, in a correspondence view of memory it is more natural to focus on the output (e.g. an eyewitness report) and examine to what extent it accords with the input (e.g. a witnessed event). In general, accuracy can be measured only for what a person reports, not for what is omitted.
6. Memory as the perception of the past: The correspondence view of memory has much in common with the way we think about perception. In perception, interest lies in the correspondence between what we perceive and what is out there (i.e. veridicality), and in the various ways in which percepts may deviate from reality (e.g. illusions). Likewise, under the correspondence metaphor, memory may be conceived as the perception of the past, and the question then becomes, To what extent is this perception veridical or illusory (Roediger 1996)?

Collectively, these ingredients of the correspondence conception characterize an accuracy-oriented approach to memory. This way of treating memory has become increasingly salient in memory research and theorizing, particularly in work prompted by real-life memory phenomena (e.g. Intons-Peterson & Best

1998, Lynn & McConkey 1998, Ross et al 1994, Schacter 1995, Winograd & Neisser 1992).

Expressions of the Correspondence Conception in Accuracy-Oriented Memory Research

Even a cursory survey of the recent wave of accuracy-oriented memory research reveals fundamental differences from traditional quantity-oriented research. In this section, we point out some of these differences as a backdrop for considering the specific research areas that will be reviewed later.

First, the assumptions underlying the traditional use of the list-learning paradigm provide quantity-oriented research with memory measures of very broad applicability. The standard measures of percent recall and recognition, based on the assumption of item interchangeability, provide a common denominator that allows a broad spectrum of quantity-oriented research findings to be compared and integrated. In contrast, accuracy-oriented research has yielded a plethora of paradigm-specific dependent measures that allow less cross-talk between different areas at the level of memory assessment. This situation derives from features of the correspondence conception. Because the study of memory accuracy is concerned with the content of the information reported, it is less amenable to global memory measures. Moreover, the many qualitative ways in which memory of the past can deviate from veridicality call for memory measures that are tailored to individual dimensions of miscorrespondence. The focus of quantity-oriented research on only one dimension of miscorrespondence, omission, helped circumvent the many serious methodological and metatheoretical issues facing the study of memory correspondence (see Methodological, Theoretical, and Metatheoretical Issues).

Second, the focus on memory accuracy has led to a far more extensive analysis of the memory output than has been customary in traditional quantity-oriented research (e.g. Bartlett 1932; Brewer 1988a,b; Neisser 1981). The dramatic increase of interest in commission errors and false memories in recent years epitomizes the departure from the input-bound storehouse conception of forgetting as loss of studied items. That conception has particular difficulty accommodating the idea that memory can be supplemental, i.e. that some of the changes that occur between study and test involve ''memory'' for information that was not contained in the input. As noted by Roediger et al (1998), false recall and false recognition responses have generally been considered a mere methodological nuisance in the study of memory, rather than an object of interest in their own right.

Third, the treatment of memory reports as propositional descriptions that have truth value brings to the fore relational aspects of correspondence and miscorrespondence that cannot easily be accommodated within a conception of memory as a store of elementary units. The treatment of list-learning memory responses as propositional-relational statements played an insignificant role in traditional memory theorizing and was essentially optional. In contrast, propositional relations

have figured prominently in the study of semantic memory (e.g. ''a canary is a bird'') and now they constitute a core of interest in the accuracy-oriented study of episodic and autobiographical memory as well. Such relational judgments as when or where an event took place (e.g. Winograd & Neisser 1992), whether the source of a memory is perception or imagination (e.g. Johnson 1997), and so forth, are now integral both to memory assessment procedures and to theorizing about underlying memory mechanisms. Indeed, deficits in binding together the various features of complex events have been proposed to underlie such varied memory errors as the effects of postevent misinformation and confabulations resulting from frontal lobe pathologies (see Schacter et al 1998).

Fourth, the affinity between memory and perception inherent in the correspondence metaphor is apparent in much research and theorizing about memory accuracy and distortion. Several researchers have stressed the similarity between memory illusions and perceptual illusions (Roediger 1996), proposing that ''we should consider the study of sensing and perceiving as a model for studying remembering'' (Roediger et al 1998:238). Such an affinity is perhaps most clear in the study of visual and spatial memory, in which principles governing perception have often been extended to apply to memory (e.g. Shepard 1978). However, it is also evident in other research areas, for example in the application of Gestalt principles to describe changes in memory for depicted events (Allport & Postman 1945), and in cognitive social-psychological research on person perception and person memory (e.g. Wyer & Srull 1989). The affinity between perception and memory is incorporated in the perception/reperception framework (Payne & Blackwell 1998), which applies similar concepts to the analysis of perception and memory, as well as in the study of ''memory psychophysics'' (Algom 1992). In addition, the attributional approach of Jacoby and his associates (e.g. Kelley & Jacoby 1998), affords an analysis of perceptual and memory illusions within the same conceptual framework.

Fifth, perhaps also part of the legacy of perception in the study of memory correspondence, is the increased interest in the phenomenal qualities of recollective experience. Experiential, subjective qualities attracted little interest in traditional quantity-oriented memory research. In contrast, many current studies of memory accuracy incorporate measures of various subjective characteristics similar to those used in imagery research, such as vividness and perceptual-contextual detail (Conway et al 1996, Johnson 1997, Lampinen et al 1998). Also included are measures of the state of awareness accompanying remembering (the know-remember distinction) (Tulving 1985; see also Gardiner & Java 1993, Gardiner et al 1998), as well as metacognitive feelings like the sense of familiarity, the feeling of knowing, the feeling of recall imminence, and subjective confidence (Benjamin & Bjork 1996, Koriat & Levy-Sadot 1999, Schwartz 1998). Such subjective measures have been examined in connection with reality and source monitoring (Suengas & Johnson 1988), autobiographical memories (Brewer 1992), false recall (Payne et al 1997, Roediger & McDermott 1995, Schacter et al 1996), postevent misinformation (Zaragoza & Mitchell 1996), flashbulb mem-

ories (Conway 1995), and eyewitness testimony (Fruzzetti et al 1992). No longer mere epiphenomena, experiential qualities have been treated as an integral component of the process of remembering (e.g. Johnson 1997, Norman & Schacter 1996) and in particular, as diagnostic clues used by both rememberers and observers in the attempt to distinguish genuine from false memories (e.g. Conway et al 1996, Koriat 1995, Ross 1997, Schwartz 1998). The assumption is that the quality of phenomenal experience may be critical in leading the rememberer to accept a memory as true.

Finally, the conception of memory as being about something has spawned a departure from the passive storehouse conception toward a more active view, in which remembering is an intentional, goal-directed ''effort after meaning'' (Bartlett 1932:20). This, of course, is the hallmark of Bartlett's reconstructive approach, in which ''remembering is not the re-excitation of innumerable fixed, lifeless and fragmentary traces. It is an imaginative reconstruction or construction'' (1932:213). Thus, a vast amount of accuracy-oriented research has been devoted to examining the consequences of the assumption that information is not simply deposited into a memory store, but is assimilated and integrated into cognitive structures (e.g. schemas) and later recreated from those structures. More recently, the active role of the rememberer has also been gaining prominence in the expanded notion of retrieval processes (e.g. Norman & Schacter 1996) and in work emphasizing the metacognitive processes of monitoring and control that mediate accurate memory performance (Goldsmith & Koriat 1999, Koriat & Goldsmith 1996c). Many authors have emphasized complex evaluative and decisional processes used to avoid memory errors or to escape illusions of familiarity (e.g. Burgess & Shallice 1996, Kelley & Jacoby 1996, Koriat 2000, Schacter et al 1998). The operation of these processes is particularly crucial in real-life situations (e.g. eyewitness testimony) in which a premium is placed on accurate reporting.

The preceding list represents a rough attempt to characterize some of the unique features of the correspondence-oriented study of memory. We now turn to an examination of how these features manifest themselves in specific research areas.

ACCURACY-ORIENTED RESEARCH: HOW AND WHY MEMORY CAN GO WRONG

The following survey brings together and examines somewhat disparate lines of accuracy-oriented memory research. Because one of our aims is to demonstrate the broad scope and diversity of accuracy-oriented research, it is simply not possible to be comprehensive. Instead, this survey is both selective and deliberately biased to highlight the issues, experimental paradigms, and phenomena that are distinctive of the study of memory correspondence. The sections have been orga-

nized to preserve as much as possible the coherence of different bodies of research. Following this survey, we go on to an analysis of some of the common issues and challenges facing these various lines of research.

The Gestalt Approach to Memory Changes Over Time

Although Bartlett (1932) is generally credited as being the founder of the qualitative, accuracy-oriented approach to memory, many facets of this approach were already apparent in the study of memory by Gestalt psychologists (see Koffka 1935, Riley 1962). Rejecting the Ebbinghaus-type focus on the number of remembered nonsense syllables, they revived the emphasis on qualitative aspects of memory that had been pioneered as early as the late nineteenth century by several students of memory for visual form (see Estes 1997, Woodworth 1938, for reviews). These latter researchers found, for example, that observers' reproductions from memory were characterized not only by loss of detail, but also by substitution of new detail, and object assimilation—a tendency of reproductions to shift toward the typical form of familiar objects.

Gestalt psychologists, extending the Gestalt principles from perception to memory (see Koffka 1935, Riley 1962), explained these distortions as resulting from autochthonous cortical forces that transform perceptual traces into more regular, symmetrical, and simple memory forms (*Prägnanz*). Wulf (1922), who had subjects draw geometrical figures from memory, identified two opposite types of changes: ''sharpening,'' which involves the exaggeration of selected characteristics of the original figure, and ''leveling,'' which entails a weakening of one or more features. These changes were assumed to be progressive, such that later reproductions tend to exaggerate the deviations of the previous ones. Based on these results, Wulf postulated three causal factors underlying both leveling and sharpening: ''normalizing,'' which refers to changes toward a well-known or conventional figure, ''pointing,'' which refers to changes that emphasize a feature of the stimulus, and ''autonomous changes,'' which reflect systematic self-governed modifications of the memory trace toward simpler and more regular patterns (''good form''). It is the postulation of autonomous, intrinsic changes operating on the memory trace that is unique to Wulf's Gestalt perspective. According to this perspective, the memory engram ''cannot be regarded as an immutable impression which can only become blurred with time, similar to a drawing carved on a brick. Rather this engram undergoes changes by virtue of gestalt laws'' (Wulf 1922:370).

Goldmeier's stress model (1982) specifies the conditions under which distortions in the direction of ''good figure'' will occur, conceptualizing *Prägnanz* in terms of the notion of ''singularity.'' Singular features (e.g. a full circle) contain no stress and should remain stable and accurate over time. By contrast, nonsingular features, such as ambiguous or poorly integrated material, produce unstable and imprecise traces that gradually lose information. It is the nearly singular features (e.g. an almost closed circle), those having the strongest stress, that

elicit the tendency to shift toward singularity and therefore should exhibit progressive distortions over time. The nearly singular traces originally have the structure of schema-plus-correction, and the gradual distortion in memory eliminates the correction but retains the schema. This change toward increased self-consistency is adaptive, because it achieves maximal compactness within the trace system while suffering only a minimal loss of information.

Rhodes' (1996) more recent work on distortions in face recognition can also be seen as an example of the operation of sharpening. Using a computer-implemented caricature generator to manipulate the distinctiveness of facial features, line drawings of faces were distorted by either exaggerating the metric differences between each target face and a norm (i.e. sharpening), thus creating a caricature of the original face, or, conversely, by reducing these differences (i.e. leveling), creating anticaricatures. Several studies (see Rhodes 1996 for a review) indicated that when subjects learned to associate a name with a face, naming the caricature version of the face was faster than naming its anticaricature version, suggesting that sharpening is less disruptive to recognition than leveling (Rhodes et al 1987, 1997). Furthermore, the recognition of the caricature versions was as good or even better than that of the original face (Benson & Perrett 1994, Rhodes et al 1987). Rhodes concluded, ''In some cases caricatures are even *superportraits*, with the paradoxical quality of being more like the face than the face itself.'' (Rhodes 1996:1). She proposed that the effectiveness of caricatures in recognition may derive from the fact that the representations stored in long term memory are ''schematized so as to emphasize the distinctive properties of what is being represented.'' (Rhodes et al 1987:474).

The Gestalt idea of distortion toward ''better form'' has also been very influential in social cognition, primarily in cognitive consistency theory and cognitive balance theory, following from the work of Fritz Heider (1958; see Gilbert et al 1998). This research too illustrates the continuity between memory and perception, and in fact in this type of research, the distinction between memory (i.e. person memory) and perception (i.e. person perception) is generally blurred.

Spatial Memory and Distortion

The study of spatial memory also brings to the fore various features of the correspondence metaphor. First, it discloses an explicit interest in the nature and basis of the correspondence between memory representations and their spatial referents. Second, it invites the application of assessment procedures that depart greatly from those that follow from the storehouse metaphor. Third, it highlights some inherent similarities between the study of memory and of perception, allowing both to be analyzed in terms of the same theoretical constructs.

Early studies were primarily concerned with demonstrating an isomorphic mapping between spatial layouts and their memory representations. Kosslyn et al (1978), for example, found that the time it took to scan between two points on a mental image of a memorized map increased with the actual distance between the

points. A similar isomorphism was demonstrated in studies comparing performance in the presence and in the absence of spatial maps (e.g. Kerst & Howard 1978, Thorndyke 1981). These studies laid the groundwork for exploring various aspects of miscorrespondence.

Memory psychophysics (see Algom 1992) embodies the view of memory as the perception of the past, bringing perceptual issues and techniques to bear on the study of memory. For example, Kerst & Howard (1978) found that perceptual and memorial estimates of distance were related to the actual distances by similar power functions, but the exponent of the memorial function was equal to the square of the exponent of the perceptual function. They proposed a ''re-perceptual hypothesis'': The same psychophysical transformation that operates on the sensory input to produce a perceptual representation is reapplied to the perceptual representation to produce the memorial estimates (but see Radvansky et al 1995 for alternative accounts). Thus, memorial judgments are performed via ''internal psychophysics'' (Moyer 1973), causing a magnification of perceptual distortions.

Thorndyke (1981) found that for perceptual as well as memorial tasks, estimated distances increased as a linear function of the number of intervening points (i.e. ''clutter'') along the route. Thus, although distance estimations made from memory were not entirely faithful to the actual distances in the external environment, they were faithful to the information that perception delivered to memory. In fact, Thorndyke, as well as others, implied that such memory distortions as the clutter effect actually stemmed from misperception: perceptual biases or illusions.

However, accumulating evidence of systematic distortions in spatial memory has motivated alternative accounts, attributing spatial distortion to error-prone reconstructive heuristics. For example, Byrne (1979) found an overestimation of distance for routes containing bends as opposed to linear routes, and for routes within the town center as opposed to peripheral routes, as well as a tendency to normalize the angles between urban roads to 90^{o}. Byrne proposed that spatial representations do not preserve the exact metrics of the spatial environment (e.g. veridical distances or angles); rather, subjects base their estimates on heuristics (e.g. ''the more locations that are remembered along a route, the longer the route must be'') that are generally adequate, but are sometimes prone to bias or inaccuracy.

Additional types of errors in distance estimation also challenge the assumption that internal representations preserve metric spatial information. For example, the finding that landmarks produce asymmetric distance estimates—nonlandmarks judged as closer to landmarks than vice versa (e.g. McNamara & Diwadkar 1997)—clearly violates the symmetry of Euclidean distances. This bias too has been explained in terms of the reconstructive view, which suggests that spatial properties ''are not retrieved from long-term memory and reported in pure form, but rather, are interpreted and scaled by the context in which the retrieval takes place.'' (McNamara & Diwadkar 1997:188). This approach can also account for the ''perspective effect'': Subjects who imagined themselves in New York judged the distance between New York and Pittsburgh to be longer than those who imag-

ined themselves in San Francisco, whereas the opposite was found for judgments of the distance between San Francisco and Salt Lake City (Holyoak & Mah 1982). Distance estimates have also been found to be under- or overestimated depending on whether the judged locations are in the same or different spatial regions or units (e.g. McNamara 1986). The latter phenomenon is reminiscent of Stevens & Coupe's (1978) finding of an inferential process underlying memory for direction relations, in which subjects' reproductions were distorted in the direction of the superordinate relationships (e.g. Reno remembered as east of San Diego because Nevada is generally east of California).

Tversky (1981) reported distortions of alignment and rotation (e.g. toward canonical axes) that she interpreted as reflecting simplifying heuristics (compared to leveling, normalizing, or assimilation to a schema) that facilitate both the encoding and reconstruction of complex spatial information. More generally, she also demonstrated that various spatial distortions were analogous to biases and errors in other cognitive domains, suggesting that they are a ''result of general cognitive processes and not restricted to spatial thinking'' (Tversky 1998:267).

In virtually none of these studies, then, is spatial memory treated as the mere retrieval of stored items of spatial information, nor is it evaluated in terms of the mere amount of information that can be recovered. Instead, these studies illustrate a concern with the qualitative aspects of accuracy and distortion, and attempt to explain these phenomena in terms of perceptual biases and reconstructive processes.

Memory for Gist versus Detail

The idea that people can often remember the gist of an event without being able to remember its details is difficult to accommodate within the traditional quantity-oriented approach to memory. Work on this topic raises two issues that are unique to the correspondence metaphor. First, the correspondence between an event and its subsequent memory can be assessed at different levels of generality. For example, in his analysis of John Dean's memory for conversations with the president, Neisser (1981) identified three levels at which correspondence could be achieved: (*a*) accurately reproducing the details of a conversation, (*b*) distorting the details but retaining the gist or overall meaning, or (*c*) distorting both details and gist, but remaining faithful to the overall theme or ''narrative truth'' of the events. This can severely complicate the assessment of memory correspondence (see later discussion). Second, the choice of level of achieved correspondence is generally under the strategic control of the rememberer. For example, Goldsmith et al (1998; see also Goldsmith & Koriat 1999), showed that subjects strategically adjust the grain-size of their report (e.g. reporting ''he was in his 20's'' rather than ''he was 23 years old''), often trading precision for accuracy. Similarly, Neisser observed that in answering open-ended questions, subjects tend to choose ''a level of generality at which they [are] not mistaken'' (1988:553). While such control can

complicate memory assessment, it is in fact an important topic of study in its own right (see Metacognitive Processes and Accuracy).

Most research on the topic of gist has focused on the relative memorability of gist versus verbatim information. Many studies have shown that the general representation or semantic content of studied material (gist) is better retained over time than memory for surface details or verbatim wording of that material (see Brainerd & Reyna 1993). Kintsch et al (1990), for example, found differential decay rates for three different levels of information, with surface information (i.e. verbatim memory) becoming inaccessible within four days, memory for the semantic content (i.e. gist) declining at a slower rate, and judgments based on situational memory (i.e. inferences from a relevant knowledge schema) remaining highly stable over time.

Schema-based interpretations of such findings generally hold that as a result of abstraction and integration processes, verbatim traces of the original information are either lost or become integrated with schematic-gist information (Alba & Hasher 1983; but see Brewer & Nakamura 1984). Subsequent memory performance is then based on reconstructive processing of gist. By contrast, Brainerd & Reyna's fuzzy-trace theory (Brainerd & Reyna 1992, Reyna & Brainerd 1995) contends that during encoding, verbatim and gist traces are formed in parallel, creating a hierarchy of independent representations at varying levels of precision. In accessing these representations, because of the superior memorability and accessibility of gist, especially over time, rememberers tend to choose the highest possible level that complies with task demands. In support of the verbatim-gist independence, Reyna & Kiernan (1994) showed that subjects sometimes falsely recognize gist representations despite having accurate verbatim memories. Using tests of stochastic dependence, they found that correct recognition of verbatim information and misrecognition of gist were independent.

Fuzzy-trace theory has also gained impetus as a theoretical framework that could explain a variety of memory errors, such as false recognition and recall in list learning and postevent misinformation effects (see below), verbal overshadowing (Schooler 1998), and some complex age-related differences [see e.g. the special issue of *Journal of Experimental Child Psychology* edited by Liben (November 1998)].

Other distinctions have been explored that seem to parallel the verbatim-gist distinction. For example, Posner & Keele (1970) found that memory for the unpresented prototype of classified dot patterns was more stable over time than memory for the individual studied patterns from which it was abstracted. Also, Dorfman & Mandler (1994) examined memory for categorical information in terms of the tendency of false recognition to be made from the same category as the studied target words (e.g. falsely recognizing ''canary'' when ''sparrow'' was actually presented). Retention of categorical information was found to exhibit a milder rate of forgetting than the retention of the studied target itself (see also Koutstaal & Schacter 1997). Coll & Coll (1994), using a three-level hierarchy, found that commission errors shift from those that preserve fine/specific attributes

to those that preserve more coarse/general attributes as retention interval increases. Recently, however, A Pansky & A Koriat (in preparation) found bi-directional shifts in the memory for items presented at either subordinate (e.g. sports car) or superordinate (e.g. vehicle) levels of a hierarchy toward the intermediate basic level (e.g. car). These symmetrical shifts (including the surprising trend toward instantiation) were especially pronounced following a one-week retention interval.

A different realization of the fine-coarse distinction is in terms of remembering the particular item versus remembering attribute information. For example, subjects have been found to correctly identify the emotional-evaluative tone of a word even when verbatim recall of the word failed (Schacter & Worling 1985). A Koriat, E Edry & G de Marcas (submitted for publication) recently found that subjects have equal access to the evaluative, potency, and activity attributes of unrecalled words, both when this access is measured by explicit attribute identification, and when it is inferred from the nature of the commission errors made. Access to partial information was found to decline less steeply with retention interval than the recall of the full word.

The distinction between access to item information and access to attribute information tends to support current views of memory in which the memory representation of an event is seen to consist of a pattern of features that are bound together to different degrees (e.g. Johnson 1997, Schacter et al 1998). Such views permit greater variability in the completeness of memory retrieval than that provided by the verbatim versus gist distinction.

Schema-Based Effects on Memory Accuracy

Schema theory represents perhaps the most general framework for correspondence-oriented memory research. It has been used by both cognitive and social psychologists to explain a wide array of phenomena concerning accuracy and distortion in both perception and memory.

Drawing on the seminal work of Bartlett (1932), schema theory holds that what people remember is the result of an interaction between the input information and pre-existing ''schemas,'' i.e. generic knowledge structures or expectancies that are developed through experience. Schemas have been shown to affect the correspondence between the input and remembered material in a variety of ways at different stages in the memory process. Thus, the research described here (see reviews by Alba & Hasher 1983, Brewer & Nakamura 1984) demonstrates the correspondence-oriented focus on qualitative rather than only quantitative memory changes, and the type of constructive and reconstructive mechanisms assumed to underlie them.

In their well known review, Alba & Hasher (1983) identified the effects of four basic types of schema processes that occur during encoding: selection, abstraction, interpretation, and integration, as well as a fifth process that may

occur during remembering, reconstruction. Most of these effects concern ways in which memory can go wrong.

Selection Strictly speaking, selection effects concern the amount of remembered information rather than its accuracy: Information that can be assimilated into an active schema is more likely to be remembered than schema-irrelevant information. For example, in the absence of a relevant activated schema or background knowledge during encoding, information is encoded less efficiently and is less likely to be recalled (e.g. Bransford & Johnson 1972). Also, information that is more central to an activated schema will be recalled better than information that is less central (e.g. Johnson 1970). However, inconsistent (rather than irrelevant) information is often remembered better than schema-consistent information (e.g. Davidson 1994). Different accounts have been proposed for this seeming anomaly (see e.g. Erdfelder & Bredenkamp 1998, Stangor & McMillan 1992). Note that although schema-based selection would seem to affect memory quantity performance rather than accuracy per se, unlike the traditional view of omission errors under the storehouse view, schema-based omissions are inherently biased in the direction of greater compatibility with the operative schemas.

Abstraction Abstraction effects are similar to selection effects in that specific details of the input event or material are lost as they are encoded into the various ''slots'' of the generic schematic representation (e.g. Mandler 1979). For example, the finding that people tend to remember the semantic content or gist of textual messages rather than their verbatim format has been taken to imply the operation of schema-based abstraction processes, although other types of explanations have also been proposed (see Memory for Gist versus Detail). Abstraction effects, like selection effects, involve a reduction in the amount of encoded and subsequently remembered information. However, they can also play a critical role in memory error and distortion: When asked to remember details that are not available in the schematic representation, people may try to reconstruct the missing details using schema-based inference processes at the time of remembering (Bartlett 1932, Neisser 1967). These reconstructions replace the original input information with generic information from the schema, yielding commission errors or schema-consistent distortions.

Interpretation Unlike selection and abstraction, interpretation effects involve actual changes and additions to the input information during encoding: Activated schematic knowledge is used to make inferences and suppositions that go beyond the actual input event, which then become incorporated as part of the event's memory representation. For example, subjects may falsely remember the presence of a hammer after reading a passage about a person pounding a nail (Johnson et al 1973) or they may falsely remember information that is consistent with their general knowledge about a famous person (Dooling & Cristiaansen 1977). Similar inferences have been observed for nonlinguistic information: For example,

Intraub et al (1998) report a ''boundary extension'' illusion, in which observers remember seeing a greater expanse of the scene than was actually shown. Interestingly, subjects are unable to avoid the illusion even when explicitly instructed to do so (Intraub & Bodamer 1993). Both linguistic and nonlinguistic interpretation effects have been found to increase with retention interval, apparently due to progressive loss of memory for detail (see Brewer & Nakamura 1984).

Integration Integration effects result from the combining of various pieces of information into a unified schematic whole, either during (e.g. Bransford & Franks 1971) or subsequent to (e.g. Loftus et al 1978) the initial encoding. Integration subsequent to initial encoding has attracted a great deal of attention in the context of post-event misinformation effects (see below). It has also been implicated in explaining ''hindsight bias'' or the ''knew-it-all-along'' effect (Fischhoff 1977, Hawkins & Hastie 1990), in which the exposure to new information regarding an event's outcome distorts one's memory for one's initial estimation of its likelihood. Integration effects in general, and misinformation effects in particular, have generated a heated debate concerning the underlying mechanisms (see Ayers & Reder 1998). One basic issue is whether these effects derive from actual changes to the memory representation, or from inferential processes operating at the time of remembering (see Stahlberg & Mass 1998 for an extension of this issue to the hindsight bias).

Reconstruction The schema effects considered so far are assumed to derive from constructive processes operating during the encoding of information. In contrast, reconstructive processes operating at the time of remembering use ''whatever details were selected for representation and are still accessible together with general knowledge to essentially fabricate what might have happened'' (Alba & Hasher 1983:204). In their review, Alba & Hasher noted that ''the consensus is that reconstruction is quite rare, and occurs only under special circumstances'' (1983:204). Since that time, the consensus seems to have changed.

Ross and colleagues (see Ross 1989) have shown in several elegant studies how people's personal memories are biased by their implicit theories of stability and change. For example, people's belief that their attitudes are stable over time tends to bias recall of their earlier attitudes in the direction of greater consistency with their current attitudes (e.g. McFarland & Ross 1987, Ross et al 1981; and see, e.g. Bahrick et al 1996). Furthermore, people's expectancy that an attribute should change over time can also bias recall: Students led to believe in the effectiveness of a study skills course remembered their initial self-evaluated study skills as being lower, and their subsequent test grades as being higher, than did students in a control condition (Conway & Ross 1984; see Hirt 1990 for similar results in a laboratory study).

Many theorists allow the coexistence of both reconstructive and reproductive (i.e. direct retrieval) memory processing (e.g. Bahrick 1984, Brewer 1986, Hall 1990), and some, in fact view the choice between them as being under the control

of the rememberer (e.g. Reder 1987, Ross 1989, Winograd 1994). Hirt et al (1995) found that whereas subjects who encoded the information under comprehension or impression-formation instructions exhibited a substantial expectancy-driven bias in recall, those encoding the information under verbatim recall instructions did not. Furthermore, the degree of this difference increased with retention interval, supporting the view that reconstructive inference is particularly likely when the memory representation is weak (Brewer & Nakamura 1984; see Hirt et al 1998 for other moderators of reconstructive processing).

Accuracy motivation may also moderate constructive and reconstructive processing. Ross, for instance, suggests that ''people can choose to engage in relatively effortless, theory-guided recall or a more effortful and extensive memory search'' (1989:355), and this choice will depend, among other things, on how motivated people are to accurately reproduce the details (see also Winograd 1994). In line with this idea, a wide range of results in social cognition lead to a view of the perceiver/rememberer as ''a motivational tactician, choosing among a number of possible strategies, depending on current goals'' (Fiske 1993:172).

Source Monitoring

We now turn to several bodies of research that have gained prominence in recent years, beginning with work on source monitoring. Memory for the source of information attracted little attention in traditional quantity-oriented research (but see Winograd 1968). In that context, ''experimental work has largely taken the item or event as the unit of analysis rather than attempting to assess the relative availability for complex events of various phenomenal qualities'' (Johnson et al 1996:137). In contrast, the source monitoring framework, developed by Johnson and her associates (see Johnson et al 1993), stresses the processes involved in determining the origin of memories, such as how, when, and where a certain memory was acquired. They argued that virtually all memory distortions (other than omissions) involve source monitoring failures—taking mental experiences to be something they are not (Johnson et al 1996). Indeed, there has been a growing appreciation of the central role that source monitoring plays in memory accuracy, and ideas from the source monitoring framework have been incorporated in explaining various memory distortions, such as false recalls and recognition in list learning, postevent misinformation effects, source amnesia, and confabulations.

Memory For Source According to the source monitoring framework (Johnson 1997), in discriminating the origin of information, subjects take advantage of the fact that mental experiences from different sources (e.g. perception versus imagination) differ on average in their phenomenal qualities (e.g. visual clarity and contextual details). These diagnostic qualities can support a rapid, heuristically-based source monitoring, but sometimes more strategic, deliberative processes

may be needed. Both types of processes require setting criteria for making a judgment, and procedures for comparing activated information to the criteria.

Several results suggest that source memory may be independent of item (or occurrence) memory (e.g. Lindsay 1990). Glisky et al (1995), who tested elderly adults, demonstrated a double dissociation between item memory (found to be sensitive to medial temporal lobe functioning) and source memory (found to be sensitive to frontal lobe functioning). Koriat et al (1991) found that self-performed actions yielded better occurrence memory (old-new recognition) but inferior context memory (in which room had the task been performed) than other-performed actions, suggesting that memories for self-performed actions are less contextualized than memories for other-performed actions, and may be more susceptible to source confusions. Johnson et al (1996) found that having subjects focus on how they felt when hearing a person make certain statements yielded better old-new recognition but lower source-accuracy scores than having them focus on how the speaker felt.

The source monitoring framework emphasizes the importance of binding—the integration of the various features of an event into a coherent whole (see also Schacter et al 1998). Deficient binding may result in source confusions, as when words said by one speaker are attributed to a different speaker (Ferguson et al 1992). It may also lead to memory conjunction errors (e.g. Reinitz et al 1996), as when the components of different stimuli (e.g. ''instruct'' and ''consult'') are recombined and result in false recognition (''insult'').

Factors Contributing to Source Confusions According to Johnson (1992, 1997), source confusions may arise because the activated information during retrieval is incomplete or ambiguous, and/or because the processes responsible for attributing information to sources are imperfect. For example, divided attention or emotional self focus during encoding have been found to impair source monitoring (Craik & Byrd 1982, Johnson et al 1996), presumably because they disrupt binding. High perceptual similarity between two sources, as well as similarity in the encoding processes engaged may also result in source confusions (Dodson & Johnson 1996, Ferguson et al 1992). Although thinking about a perceived event after it has happened helps maintain its visual details, thinking about imagined events also increases their vividness, and may therefore result in impaired reality monitoring for these events (Suengas & Johnson 1988). Goff & Roediger (1998) found that the more times subjects imagined an unperformed action, the more likely they were to recollect having performed it.

During testing, conditions that interfere with reviving an episode (e.g. discrepancy between study and test contexts) or with decision and inference processes (e.g. time pressure, divided attention) also tend to impair source monitoring. This is also true for conditions that encourage lax criteria (Dodson & Johnson 1993).

Reducing or Escaping Source Confusions The fact that people know at one time that a certain piece of information was imagined, dreamt, or fictional does not prevent them from later attributing it to reality (Durso & Johnson 1980, Finke et al 1988, Johnson et al 1984). In general, however, manipulations that facilitate or encourage the encoding of distinctive, item-specific features help reduce source confusion (e.g. Johnson et al 1995). During testing, source monitoring can be improved by having subjects make source discriminations, which presumably encourage more stringent decision criteria (Dodson & Johnson 1993; see also Jacoby et al 1989c). Multhaup (1995) found this manipulation to be particularly effective with the elderly.

Age Differences Several studies indicate that young children are particularly deficient in distinguishing between memories of real and imagined events (see Ceci 1995). Elderly adults too have particular difficulty in remembering contextual information. Spencer & Raz's (1995) meta-analysis indicates a stronger age decline in memory for context than in memory for content. This pattern results in a greater rate of ''decontextualized'' memories in old age, which can lead to deficient source monitoring.

Illusions Stemming from Fluency Misattributions

Closely related to the source-monitoring framework is the attributional view of Jacoby, Kelley, and their associates (see Jacoby et al 1989b, Kelley & Jacoby 1998), which has been used to examine a variety of memory illusions and misattributions. Their work demonstrates the intimate link between perceiving and remembering, and particularly between perceptual illusions and memory illusions, thus bringing to the fore some of the unique aspects of the correspondence metaphor of memory.

Illusions of Memory According to the attributional view of memory, the subjective experience of familiarity does not derive directly from the retrieval of a memory trace, but results from the unconscious attribution of fluent processing to the past (Jacoby & Dallas 1981, Johnston et al 1985). Fluent processing of a stimulus is enhanced by its previous presentation, and when fluency is attributed to the past, it gives rise to a veridical recognition. However, fluent processing can also be produced by other factors. In that case, an illusion of familiarity may ensue if fluency is misattributed to the past. Whittlesea (1993) manipulated fluency by priming the target words before they appeared in the recognition test. Primed words were more likely to be falsely recognized than nonprimed words. Fluency can also be enhanced by perceptual manipulations: Showing a brief preview of a test word immediately prior to presenting the word in full view for a recognition memory test increased the likelihood that new (as well as old) words would be judged ''old'' (Jacoby & Whitehouse 1989). Similarly, when the visual

clarity of words at test was varied, new words were more likely to be judged as old when they were visually clear (Whittlesea et al 1990).

Whittelsea & Williams (1998) refined Jacoby's view of familiarity, arguing that it is not fluency per se but rather fluent processing occurring under unexpected circumstances that gives rise to feelings of familiarity. Although unstudied pseudohomophones (e.g. PHRAWG) were processed less fluently than unstudied words, they yielded more false recognitions (when read aloud by the subject), presumably because the unexpected fluency produced by their meaning was attributed to past experience.

Fluency emanating from the characteristics of the task can also be misattributed to stable characteristics of one's memory. Winkielman et al (1998) found that subjects asked to recall 12 childhood events gave poorer judgments of their memory than subjects asked to recall 4 childhood events. Although the former subjects recalled three times more events than the latter, retrieval fluency was the critical factor affecting metamemory judgments.

Misattributions of Memory Memory misattributions are essentially the converse of the memory illusions just described. These occur when fluency emanating from the prior presentation of the stimulus is incorrectly attributed to a current characteristic of the stimulus, resulting in perceptual illusions. For example, when previously heard and new sentences were presented at test under white noise, the noise was judged to be lower for old than for new sentences (Jacoby et al 1988). Also, when subjects judged the duration of presented words, previously read or generated words were judged as occurring for longer durations than new words (Masson & Caldwell 1998).

Memory can also be misattributed to nonphysical qualities of the stimulus: Anagrams were judged to be easier for others to solve when their solution words had been presented earlier than when they had not (Kelley & Jacoby 1996; see also Kelley 1999). Also, in the ''mere exposure effect,'' previous exposure to a stimulus leads to more positive attitudes regarding that stimulus (e.g. Bornstein & D'Agostino 1994). Similarly, in the ''illusory truth effect'' (see Begg et al 1996), sentences are more likely to be judged as true when they have been presented previously than when they are new. In the ''false fame effect'' (Jacoby et al 1989a), nonfamous names tend to be judged more often as famous when they have been presented earlier than when they are new.

Escaping Illusions and Misattributions of Memory Illusions of memory can be avoided when subjects become aware of the manipulations of the physical characteristics of the stimulus. For example, visual clarity does not affect judgments of oldness when subjects know that clarity is being manipulated (Whittlesea et al 1990). Also, when subjects are fully aware of the preview of the test word (Jacoby & Whitehouse 1989), the tendency to judge that word as old is eliminated. Similarly, when subjects in the Winkielman et al (1998) study mentioned earlier were informed that most people find it difficult to recall 12 childhood events,

their memory judgments did not differ from those of subjects who were asked to recall 4 events (but see Lindsay & Kelley 1996).

Misattributions of memory, i.e. falsely attributing fluency to a current characteristic of the stimulus, are more difficult to escape. For example, warning people about the influence of a prior presentation of a sentence on the experienced intensity of a background noise did not eliminate the effects of misattribution (Jacoby et al 1992; see also Whittelsea et al 1990). However, such misattributions can be avoided by recollecting the actual source of familiarity: The false fame effect is eliminated when people initially read the list of nonfamous people under full rather than under divided attention, presumably because they can recollect the prior presentation of those names when making fame judgments (Jacoby et al 1989c). Hence, several factors that disrupt recollection (but do not affect the influence of familiarity), such as divided attention, a short deadline for retrieval, or old age, may increase the likelihood of misattributions of memory (Kelley & Jacoby 1998).

False Recall and Recognition

In the past several years there has been a dramatic increase in the study of false memories, spurred in part by real-life controversies. False memory reports can be induced in a variety of ways for a wide range of materials (see Lampinen et al 1998). In this section we focus on laboratory studies examining commission errors in list learning.

An unprecedented wave of studies on spontaneously occurring false recalls was sparked recently by the influential work of Roediger & McDermott (1995). In a paradigm adapted from Deese (1959), a study list is presented, composed of words associated to a critical, nonpresented word. This critical word tends to falsely intrude in a subsequent recall test. The new Deese-Roediger-McDermott (DRM) paradigm has yielded a wealth of findings in studying false recognition and false recall. Variants of this paradigm have also emerged, including the use of words or pictures belonging to the same semantic category (e.g. Brainerd & Reyna 1998b, Koutstaal & Schacter 1997) and the use of visual stimuli representing stereotypical scenes from which typical exemplars have been removed (Miller & Gazzaniga 1998).

What is interesting about the DRM paradigm is that it affords the study of many aspects of memory accuracy and error within a simple, list-learning paradigm. The critical difference from the traditional use of this paradigm lies first, in the focus on the content of the information that is remembered and second, in the focus on commission errors, which have traditionally been treated as a mere nuisance (Roediger 1996). The progress in this area has been primarily empirical, and we summarize the main findings here.

Rate of False Memory Response An interesting finding concerns the high rate of false memories obtained with this paradigm. In immediate testing, rate of false

recalls is either comparable to or slightly lower than that of recalling studied words from the middle of the list (assumed to reflect retrieval from long-term memory; Roediger & McDermott 1995, Schacter et al 1996), whereas in a delayed test, it is actually higher than that of studied items (McDermott 1996).

McDermott & Roediger (1998) included the critical word in half of the presented lists but not in the other half, and for each list, subjects judged whether the critical word had occurred or had not occurred in the list. Although judgments were generally accurate, the false alarm rate for the critical nonpresented words was still substantial (0.38).

Factors Affecting False Memory The rate of false memories varies with a number of factors. Robinson & Roediger (1997) found the occurrence of false recalls and recognitions to increase with the number of associated words presented in the list. In fact, as the number of studied associates increased, the probability of recalling a study item decreased, whereas that of recalling the nonpresented item increased. The inclusion of unrelated items, however, depressed veridical recall, but left false recall unaffected. Tussing & Greene (1999) observed that repetition of list words increased recognition of these words but did not increase false recognition of semantically related lures.

With regard to study and test conditions, rate of false recognition was not affected by either level of processing or repetition, but was found to be lower when learning was incidental (Tussing & Greene 1997). Divided attention either during study or during test was also found to attenuate false recognition (Payne et al 1996b). These results contrast with those obtained in studies indicating stronger illusions of memory under divided attention (e.g. Jacoby et al 1989c).

An intriguing observation is that there are dramatic and reliable differences between different lists in the extent to which they induce false recall and recognition. These differences are correlated only slightly with differences in correct recall and recognition (see Roediger et al 1998).

Persistence Over Time False memories in the DRM paradigm are remarkably persistent: In comparing the results for an immediate test with those for a test given two days later, the proportion of accurate recall declined over time, whereas false recall actually tended to increase (McDermott 1996). A similar pattern was obtained for false recognition (Brainerd & Reyna 1998a, Payne et al 1996a). Toglia et al (1999) observed that the recall of the nonpresented words remained high over a three-week period, whereas that of studied words revealed the typical decrement.

Multiple study and test opportunities caused the level of false recall to decline over trials, but it remained high even after five study-test trials, suggesting that subjects did not completely edit out the erroneous responses (McDermott 1996). On the other hand, when multiple tests followed a single presentation, the proportion of false recalls increased over repeated tests, but there was no increase in

the proportion of veridical recalls (Payne et al 1996a). Once again, false memories appear to be more robust than true memories.

How Can False Memories Be Avoided? Gallo et al (1997) found that warning subjects about the false recognition effect attenuated, but did not eliminate, false recognitions (see also McDermott & Roediger 1998). An interesting finding by Seamon et al (1998) is also relevant: False recognition of the critical word was obtained even under conditions in which subjects were unable to discriminate studied from unrelated nonstudied words, suggesting that false recognition can stem from nonconscious activation of semantic concepts during list presentation.

There is evidence suggesting that distinctive processing of individual items can help reduce false memories. Thus, false recognition rates can be reduced by presenting each word together with a picture representing it (Israel & Schacter 1997, Schacter et al 1999), by visual rather than auditory presentation (Smith & Hunt 1998), by having subjects rate the pleasantness of the words during study (Smith & Hunt 1998), or by instructing them to remember the order of presentation (Read 1996).

Qualitative Characteristics of True and False Memories Do true and false memories differ phenomenologically? When know/remember judgments (Tulving 1985) were solicited, true and false recognitions were equally likely to give rise to remember responses (Payne et al 1996a, Roediger & McDermott 1995, Schacter et al 1996). Also, subjects have been found to be relatively confident in their false recalls, claiming to have detailed and vivid memories of these items (e.g. Payne et al 1996a). From the perspective of the subject, such false memories are as real as their memories for studied words.

In experiments that probed the qualitative characteristics of true and false memories, Norman & Schacter (1997) found that both types of memories were predominantly associated with access to semantic/associative information (see also Mather et al 1997). However, true memories were associated with greater access to perceptual/contextual information than were false memories.

Individual Differences Older adults sometimes exhibit as much or more false recognition of related lures, despite showing lower levels of true recognition (Norman & Schacter 1997; see also Koutstaal & Schacter 1997, Schacter et al 1999, Intons-Peterson et al 1999). This may stem from the tendency of older adults for generic, indistinct encoding (Rabinowitz et al 1982), or from their tendency to rely on gist-based processing during memory testing (Tun et al 1998). Henkel et al (1998) proposed that both aging and damage to medial temporal and frontal brain regions are associated with impairment in binding features into complex memories, and in accessing contextual features of memories.

Theoretical Accounts Several accounts of the DRM phenomena have been considered (see Roediger et al 1998). Unfortunately, however, there is still no con-

sensus even about the proper conceptual framework within which false recognition and recall phenomena can be analyzed. Perhaps the most prominent candidate is fuzzy-trace theory, which assumes that false recall or recognition of the critical lures relies on a gist representation (see Brainerd & Reyna 1998a, Payne et al 1996a). It would seem, though, that elements from different frameworks may be needed because some of these (e.g. implicit associative response activation; see Nelson et al 1998) can explain the activation of false memories, whereas others (e.g. source monitoring or memory attributions) are needed to explain their confusion with studied items as well as their phenomenological characteristics.

Misleading Postevent Information

The seminal work of Loftus and her associates (Loftus 1979a) on the contaminating effects of misleading postevent information (MPI) was instrumental in stirring up interest in memory accuracy and distortion in general, and in reconstructive aspects of memory in particular. This work coalesced with the move toward the investigation of real-life memory phenomena (Neisser 1978), and with the increased interest in societal and legal issues concerning false memory (see Ayers & Reder 1998, Belli & Loftus 1996). Whereas some of the early studies were primarily designed to document the memory impairment that ensues from misinformation, later investigations were more concerned with the underlying mechanisms, and led to important theoretical distinctions.

In the prototypical MPI paradigm, participants are exposed to an event, are later misinformed about some detail, and are finally given a forced recognition test requiring a choice between the original and suggested detail. This manipulation has been shown to result in an apparently impaired memory for the original detail, testifying for the malleability of memory (Loftus 1979a). Variations of this procedure have been used that differ either in the format of the memory test or in the order in which the target information and suggested information are presented (see Ayers & Reder 1998, Wright & Loftus 1998).

Conditions that Affect the Magnitude of the Misinformation Effect The MPI effect is stronger (*a*) with peripheral than with central details (Cassel & Bjorklund 1995, Heath & Erickson 1998), (*b*) when retention interval is longer (Belli et al 1992, Higham 1998; but see Windschitl 1996), (*c*) when the misleading information is presented in the context of a question (possibly encouraging imagination of the original event) than when presented in the context of a statement (Zaragoza & Lane 1994), and (*d*) particularly when the question is presented in a presupposition format (''what was the color of the . . . ''; Fiedler et al 1996) rather than in an open format.

Zaragoza & Mitchell (1996) found that repeated exposure to postevent suggestions augmented the MPI effect, particularly when contextual variability between the repeated exposures was increased. Presumably, the variability

impaired subjects' ability to discriminate the precise source of the suggestion (Mitchell & Zaragoza 1996). Zaragoza & Lane (1994) found a stronger MPI effect when subjects were encouraged to engage in active mental reconstruction of the original series of events before testing. Ayers & Reder (1998) suggest that the conditions most conducive to the misinformation effects are those in which processing the misleading information requires retrieval of the originally presented information, thus encouraging integration of the original and interpolated misinformation.

Quality of Memories Loftus et al (1989) found that falsely recognized suggested items were as quickly accessed and as confidently held as items that were actually presented. Studies by Zaragoza and her colleagues (e.g. Zaragoza & Mitchell 1996) also indicate that false reports of the misleading detail are often endorsed with strong confidence. Weingardt et al (1994) found that subjects were willing to bet nearly as much money on the authenticity of postevent items as they were on event items. Complementing these findings, memory for the suggested information is often accompanied by ''remember'' rather than ''know'' responses (Roediger et al 1996, Wright & Stroud 1998).

Escaping Misinformation Effects The effects of misinformation are difficult to escape. Subjects continue to report misinformation despite warnings that some or even all of the details suggested to them were wrong or misleading (Belli et al 1994, Lindsay 1990). Furthermore, they exhibit MPI effects even when they are able to correctly identify the misleading items as originating from the postevent narrative in a separate source-monitoring test (Dodson & Johnson 1993, Lindsay & Johnson 1989). Fiedler et al (1996) observed that even propositions that are initially rejected as false can intrude into memory. Ackil & Zaragoza (1998) further found that after one week, subjects reported false memories for details that they were coerced to fabricate immediately after viewing the original videotape. Apparently, these results are not due simply to subjects being forced to provide a response. Higham (1998), using a source-monitoring test, found that subjects misattributed misleading information to the original event even when given the option of reporting that they could not remember the source.

Nevertheless, the size of the MPI effect can sometimes be reduced by encouraging subjects to make fine-grained source discriminations rather than yes/no recognition responses, the latter apparently inducing familiarity-based responding (e.g. Dodson & Johnson 1993; see Source Monitoring).

Age Differences Children have been found to be particularly prone to misleading information (for reviews, see Bruck & Ceci 1999, Ceci & Bruck 1993). They also seem to be particularly sensitive to characteristics of the misinformer, such as age and credibility (Ceci et al 1987, Lampinen & Smith 1995). In addition, Cohen & Faulkner (1989) found that elderly participants were more often misled

by misleading information and were also more confident in their erroneous responses than were younger participants.

Theoretical Accounts of the Misinformation Effect Despite the wealth of research on the misinformation effect, there is still debate concerning its explanation. Several accounts have been proposed (see Ayers & Reder 1998), attributing the misinformation effects to trace alteration (Loftus 1975, 1979b), task demands/strategic effects (McCloskey & Zaragoza 1985), blocked memory access (Bekerian & Bowers 1983), source confusion (Lindsay & Johnson 1989), activation-based effects (Ayers & Reder 1998), and reliance on gist (Brainerd & Reyna 1998a). The attempt to discriminate between these accounts has led to important insights that go beyond the specific phenomena of the MPI paradigm.

Real-Life False Memories and Their Creation

False Memory in Real-Life Situations Clearly, the issue of memory accuracy stands at the heart of the recent debate over the authenticity of recovered memories, particularly memories of childhood sexual abuse (see e.g. Brown et al 1998, Conway 1997, Loftus 1993). Clinical psychologists typically attribute recovered memories to a specialized mechanism of repression that maintains memories of traumatic events outside consciousness, and assume that repressed memories can be recovered even after many years, usually in the course of therapy (see e.g. Courtois 1997, Loftus 1993). Many cognitive psychologists, however, doubt these assertions (Lindsay 1998, Loftus et al 1994), pointing instead to evidence suggesting that false memories may arise from normal reconstructive memory processes.

A survey of the issue of recovered memory is beyond the scope of this review. What is clear, though, is that the social and legal implications of this issue have been a significant driving force behind the recent interest in memory accuracy. Furthermore, this issue has helped crystallize two specific questions that have won experimental attention. The first concerns the processes that are likely to give rise to false memories. For example, many discussions share the belief that ''ironically, the techniques that are effective in aiding recall are the very ones that can distort memory'' (Pennebaker & Memon 1996:383). The second is whether some diagnostic cues exist that can help evaluators differentiate true memories from false memories (Loftus 1997, Schooler et al 1997). We shall briefly mention some pertinent findings.

Memory Implantation Although several anecdotal reports as well as more systematic investigations of false memories occurring in real-life situations have appeared in the scientific literature (e.g. Crombag et al 1996), studies that attempted to experimentally implant memories for events that did not happen are of greater theoretical significance. In one study (Loftus & Pickrell 1995), young adults were asked to try to remember childhood events that had been reported by

a relative. Among these were three events that had actually occurred and one that had not (e.g. being lost in a shopping mall). About 25% of the subjects recalled the false event in two follow-up interviews. Using a similar procedure, Hyman et al (1995) succeeded in implanting some rather unusual childhood memories in college students. While none of the subjects recalled the false event in the first interview, in the second and third interviews 18% and 25% of the subjects, respectively, said that the event had occurred.

A more extreme demonstration is provided by Spanos and his colleagues (see Spanos 1996:107). Subjects were implanted with a false memory that allegedly occurred one day after their birth (a colored mobile hanging over their crib). They were then administered procedures that they were told would enable them to remember events as far back as birth. A majority of the subjects were susceptible to these memory-planting procedures, reporting infant memories of the target event. Almost half of them insisted that these were real memories, not fantasies.

Pezdek et al (1997) found that false memories are more likely to be implanted if relevant script knowledge exists in memory, and if the memories are plausible. As with the MPI paradigm, children appear to be particularly suggestible (see Bruck & Ceci 1999). For example, Ceci et al (1994a) conducted repeated interviews with 3–6-year-old children about events that had happened and those that had not. Across interviews, about 30%–40% of the children claimed to remember the false events, and provided considerable detail about them.

These studies show that false memories can be implanted. Two procedures that are particularly conducive to the creation of false memories are imagination instructions and repeated testing. Whereas the former procedure is common in psychotherapy as a means of encouraging the recovery of repressed memories, the latter is common in police investigations.

Imagination Inflation Garry et al (1996) demonstrated what they called imagination inflation: Asking subjects to imagine childhood events in detail increased their ratings that the event actually occurred during childhood. One explanation is that imagination enhances familiarity, which is then misattributed to past experience (see also Goff & Roediger 1998). Hyman et al (1995) showed that repeatedly thinking about whether a nonoccurring childhood event had happened increased the likelihood that subjects believed that it actually happened. Subsequent studies (Hyman & Billings 1998, Hyman & Pentland 1996) indicated that instructions to imagine an event, whether true or false, increased the likelihood of its later remembrance. These results suggest that the creation of false childhood memories involves both memory reconstruction and errors in source monitoring.

Repeated Testing Findings with the DRM paradigm indicate that repeated testing can enhance both true and false memories (Roediger et al 1998). Indeed, both true and false memories have been found to be similarly affected by various experimental manipulations (Toglia et al 1999). Shaw (1996) also observed that

postevent questioning increased subjects' confidence in both incorrect and correct responses.

Testing manipulations, however, may also destroy the balance between true and false memories when such testing is applied selectively to the memory of false events. Ackil & Zaragoza (1998) observed that false memories could be created simply by forcing subjects to answer questions about events that clearly never happened. Using the MPI paradigm, Roediger et al (1996) found that the magnitude of the misinformation effect was much greater if the subjects had received a prior test on the misinformation items than if they had not. Prior testing also increased the likelihood that the misinformation items would be classified as remembered rather than as known. Finally, in an eyewitness memory situation, Schooler et al (1988) found that forcing subjects to provide a false response on a first recognition test (e.g. by having them choose between two false lures), impaired performance on a later memory test.

The finding that repeated questioning—particularly when forced—can foster false memories has important implications for police investigations. A similarly important finding is that of Kassin & Kiechel (1996) that corroboration of an event by another person can instill false memories: Innocent subjects who initially denied the charge of damaging a computer, tended to admit that charge, express guilt, and provide confabulatory details when a confederate said that she had seen them perform the action.

Distinguishing True and False Memories Can the authenticity of memory for a past event be diagnosed by external observers? Loftus & Pickrell (1995) found that subjects used more words when describing true memories and expressed more confidence in these memories than in false memories. They also rated the true memories as being somewhat more clear, although the clarity of false memories tended to rise from first to second interview. However, Ceci et al (1994a,b) showed videotapes of children's memory interviews to both clinical and research psychologists, who could not discriminate accounts of real and fictional events. Loftus notes, ''without corroboration, there is little that can be done to help even the most experienced evaluator to differentiate true memories from ones that were suggestively implanted'' (Loftus 1997:55; see also Schooler et al 1997).

In sum, as research on the experimental implantation of false memory continues, we are reminded that ''achieving a better scientific understanding of memory distortion is not merely a matter of theoretical concern, but has significant implications for the day-to-day lives of many members of our society'' Schacter (1995:20).

Eyewitness Memory

Much of the work surveyed in the preceding sections on false or implanted memories and misinformation effects is either inspired by or directly tied to issues concerning the accuracy of eyewitness testimony. As was pointed out, the impact

of that work extends far beyond the arena of eyewitness testimony, into mainstream experimental research and theorizing. Beyond these bodies of research, however, several other topics of investigation have been motivated primarily by practical concerns relating to issues of eyewitness accuracy. We will briefly mention four of these: questioning procedures, lineup identification, children's testimony, and the confidence-accuracy relationship.

Questioning Procedures It has long been known that the form in which a question is put to a witness can have a strong effect on the quality of the answer (e.g. Binet 1905). Building on these early insights and the more recent work on the potential contaminating effects of postevent misinformation, a basic distinction has been drawn between open-ended, free narrative forms of questioning, and more specific, directed, and recognition formats. Open-ended questioning consistently yields more accurate but less complete reports than the more directed forms (see e.g. Hilgard & Loftus 1979; but see Koriat & Goldsmith 1994, 1996b for a somewhat different interpretation of this difference). Particularly harmful to memory accuracy are leading questions, which, either by form or by content, suggest the desired answer to the witness (see Bruck & Ceci 1999). Thus, the general recommendation is that witnesses should first be allowed to tell their story in their own words before being subjected to more directed questioning, and that even then, greater faith should be placed in the accuracy of the former type of testimony (e.g. Fisher & Geiselman 1992).

The lessons of both eyewitness and traditional memory research have been incorporated into the ''cognitive interview'' (CI), developed by Fisher and Geiselman (Fisher 1999, Fisher & Geiselman 1992). The CI procedure includes a variety of memory enhancing mnemonics (e.g. context reinstatement, multiple perspectives) and communication techniques designed to increase the amount of accurate information obtained from witnesses. In a recent meta-analysis of over 50 experiments (Kohnken et al 1999), the CI consistently elicited more correct information than a standard police or other control interview (mean effect size of $d = 0.87$), with a much smaller increase in incorrect information ($d = 0.28$). Thus, more information can be obtained while maintaining equivalent output-bound accuracy rates ($\sim$85%), but the accuracy rates themselves cannot be improved (Fisher 1995; see also Memon & Stevenage 1996 and responses by Fisher 1996, Goldsmith & Koriat 1996 regarding the proper measure of memory accuracy in this context).

Lineup Studies Another central topic in eyewitness research is person identification from police lineups and photospreads (for reviews, see Wells 1993, Wells et al 1998). Here the issue of accuracy is paramount, as false eyewitness identifications appear to be the primary cause of the conviction of innocent people. In a sobering examination of 40 cases of persons convicted of serious crimes (all of whom had served time in prison, several on death row, until recent DNA analyses proved their innocence), Wells et al (1998) observed that fully 36 (90%) involved

false eyewitness identifications. One basic reason for such errors may lie in witnesses' use of a relativistic judgment process, in which they tend to identify the person from the lineup who most resembles their representation of the suspect (Wells 1993, Wells et al 1998). Thus, rates of false identification increase dramatically when only one member of the (culprit-absent) lineup fits the general description of the culprit (e.g. Wells et al 1993), but decrease when witnesses are explicitly warned that the culprit might not be present in the lineup (e.g. Steblay 1997), and when the members of the lineup are presented sequentially rather than simultaneously (e.g. Sporer 1993). In fact, it appears that many witnesses who correctly identify the culprit in a culprit-present lineup, would simply identify another suspect when the culprit's photo is removed (Wells 1993). These and other findings have important implications for actual police procedures (see Wells et al 1998).

Both interrogation and lineup procedures involve system variables (Wells 1978) over which the judicial system and law enforcement agencies have some amount of control. In addition, estimator variables have to do with characteristics of the event, the suspect, or the witness, which could potentially be used to gauge the reliability of testimony or identifications in particular cases (see e.g. Deffenbacher 1991). Of these, the two most researched areas involve developmental differences in memory accuracy (children versus adults) and the diagnosticity of witnesses' confidence for the accuracy of their testimony.

Children's Testimony The increased importance of child testimony in the courtroom, combined with common doubts regarding its reliability, have spurred a large amount of experimental work dealing with various aspects of children's memory and its accuracy relative to that of adults. Without making any attempt to capture the wealth of issues and findings, we note that unlike the fairly consistent findings that children tend to remember less information than adults (Schneider & Bjorklund 1998), it appears that no general statement can be made about the relative accuracy of children's and adults' memory reports (see e.g. Poole & White 1993). Instead, the focus has been on identifying various potential moderator variables. One of these is type of questioning: As noted earlier, children tend to be more suggestible than adults and hence more susceptible to leading questions and other forms of postevent misinformation (see Goodman & Schaaf 1997), though the findings suggest that this is true primarily for children of preschool age (see Bruck & Ceci 1999 for a recent review). Children may be particularly sensitive to other aspects of the questioning as well, implying the need for special interviewing techniques (see e.g. Walker & Hunt 1998).

Confidence-Accuracy Relation Another key issue in eyewitness research concerns the confidence-accuracy (CA) relation. On the one hand, it has been found that the single most important factor affecting jurors' beliefs about the credibility of eyewitnesses is the confidence they express in their identification choices (e.g. Lindsay 1994, Penrod & Cutler 1995). On the other hand, numerous studies and

meta-analyses have indicated that the CA relation for witness identifications is either nonexistent or quite weak, though the findings vary (see Wells 1993). Proposed moderator variables include the optimality of encoding, storage, and retrieval conditions (Deffenbacher 1980), methodology, realism, and experience in self-evaluation (Wells 1993, Wells & Murray 1984), choosers (witnesses making a positive identification) versus non-choosers (Sporer et al 1995, Read et al 1998), response options (e.g. the option to respond ''don't know''), retention interval, and variability in encoding conditions (Lindsay et al 1998, Read et al 1998). Thus, under some conditions, the CA correlations can be fairly high (overall $r = 0.41$ for choosers in the meta-analysis by Sporer et al 1995 and as high as $r = 0.72$ in Read et al 1998). Moderate to high CA correlations are also common in studies of memory for witnessed details, particularly using within-subject rather than between-subject designs (e.g. Perfect et al 1993; but see Smith et al 1989) and recall rather than recognition testing (e.g. Robinson & Johnson 1996, Stephenson et al 1986; see also Koriat & Goldsmith 1996c).

More objective and perhaps more reliable markers of accurate testimony have also been sought. Some of the studied candidates are response time (Robinson et al 1997), response consistency (Fisher & Cutler 1995), output order (Schwartz et al 1998), and the processes leading to an identification (Dunning & Stern 1994).

Autobiographical Memory

Autobiographical memory concerns memory for one's past life events and experiences. Although Tulving (1983) suggested that the terms 'autobiographical memory' and 'episodic memory' be treated as equivalent, students of autobiographical memory generally disagree (e.g. Brewer 1986, 1996; Conway 1990, 1996). One of the reasons for this disagreement is that ''the term 'episodic memory' has come to refer to a particular way of studying memory'' (Conway 1990:4), that is, the quantity-based, list-learning paradigm in which discrete and unconnected stimuli that have little personal significance for the subject are used. Autobiographical memory, in contrast, is ''specific, personal, long-lasting, and (usually) of significance to the self-system. Phenomenally it forms one's personal life history'' (Nelson 1993:8). Thus, meaning, self-reference, temporal-spatial context, and the various phenomenological correlates of ''recollective experience'' (Brewer 1996) are of fundamental interest in autobiographical memory research.

Diary Studies The issue of accuracy has been a driving force in the study of autobiographical memory, but a major hurdle is how to determine the veridicality of the memory reports. One technique is the diary method, in which subjects (sometimes the researchers themselves) keep a diary of daily events and are later tested for their memory of these events. Barclay & Wellman (1986), for example, had subjects keep diaries during a 4-month period, followed by old-new recognition tests up to 2½ years later. Although hit rates were quite high (decreasing

from an average of 95% after a 3-month interval to 79% after 31 months), false recognition of altered records averaged about 40% after 3 months, and reached rates of over 50% by the end of one year. False recognition of completely fabricated items was relatively stable over time, averaging 22% over the retention intervals. The high false-recognition rates were shown to depend on the semantic similarity between the foil and original entries (Barclay 1986). Subsequent findings (see Barclay 1993) indicated that people tend to falsely identify foils that are congruent with their general self perceptions, and that mood congruency between foil and actual events leads to higher rates of false recognitions. These and similar results were taken to support a strong reconstructive view of autobiographical memory, in which ''acquired autobiographical self-knowledge drives the reconstruction of plausible, but often inaccurate, elaborations of previous experiences. Memories for most everyday life events are therefore transformed, distorted, or forgotten'' (Barclay 1986:89). This view has also been put forward forcefully by Neisser (1981, 1984).

Brewer (1986, 1996), in contrast, has proposed a ''partially'' reconstructive view, in which ''recent personal memories retain a relatively large amount of specific information . . . but that with time, or under strong schema-based processes, the original experience can be reconstructed to produce a new nonveridical personal memory'' (1986:44; see also Bahrick 1998, Thompson et al 1996). A qualitative analysis of the recall errors for recorded events in his ''beeper'' study led Brewer (1988a,b) to argue against Barclay's strong reconstructive view: Although over 50% of the provided recall responses (excluding omissions) were in error, 90% of these were more likely to be retrieval errors than reconstruction errors. In fact, only 1.5% of the wrong responses were ''true errors'' containing information that was in conflict with the original recorded information.

Phenomenological Data Work on autobiographical memory also illustrates a heightened concern with the phenomenal correlates of accurate and inaccurate remembering (see Brewer 1992). For example, Brewer (1988a,b) found that the strength of imagery differed markedly for seven different types of correct and erroneous recall responses. Interestingly, memory binding errors in which subjects mistakenly combined aspects of events that occurred at slightly different times yielded levels of visual imagery comparable to those of correct recall responses, indicating that from the rememberer's point of view, these items are much like correct recalls. In contrast, recall statements classified as ''correct inferences'' tended to be associated with moderate to weak imagery, suggesting that these responses are based on generic self-schema representations (but see Holmes et al 1998 for evidence of strong visual imagery associated with schema-based processing). In another diary study, Conway et al (1996) also reported phenomenological differentiation for true and false recognitions of recorded events and thoughts.

Flashbulb Memories Studies of ''flashbulb memories'' (e.g. Conway 1995, Winograd & Neisser 1992) have also focused on memory accuracy and its phenomenological correlates. People report unusually vivid and detailed memories of the circumstances in which they heard about an extraordinary event. The idea that such flashbulb memories, with their live quality, are unique, representing a biological ''now print'' mechanism (Brown & Kulik 1977) has generated an intense debate (e.g. McCloskey et al 1988). A major point of contention is their presumed accuracy (Neisser 1982). Thus, for example, on the morning after the *Challenger* shuttle explosion, Neisser & Harsch (1992), had subjects record how they first heard the news of it. When the subjects were tested over 2 and a half years later, most described their memories as visually vivid; yet none was entirely correct, and fully half of them were substantially wrong in their memory reports. Moreover, neither vividness nor confidence ratings, which were both quite high, correlated significantly with accuracy. Using a similar methodology, McCloskey et al (1988) found somewhat higher, but still imperfect, accuracy for memories of hearing about the *Challenger* explosion.

Despite the growing number of flashbulb memory studies, the issue of whether flashbulb memories are inherently more accurate than other types of autobiographical memories is still under debate. Some researchers have maintained that there is good reason to distinguish flashbulb memories from other types of autobiographical memory, as long as several preconditions, such as personal importance, consequentiality, emotion, and surprise are met (Brown & Kulik 1977, Conway 1995, Pillemer 1990). Others have pointed out that ordinary memories can also be accurate and long lasting if they are highly distinctive, personally significant (McCloskey et al 1988, Weaver 1993), or repeatedly rehearsed (Neisser 1982).

Memory for Temporal Context It is taken as self-evident that autobiographical memories are bound together by extensive contextual information—who, what, where, and when (e.g. Conway 1996, Thompson et al 1996). Temporal information, however, appears to have a special status and to be represented and processed differently than other aspects of past events. According to the emerging consensus (see e.g. Friedman 1993, Larsen et al 1996), people do not store and retrieve temporal information directly. Rather, they reconstruct the temporal location of past events on the basis of fragments of information remembered about the content of the event (temporal cues) and general knowledge about time patterns (temporal schemata).

The data regarding the accuracy of people's memory for temporal information are intriguing. Although temporal memory is unbiased, in that the average dating error is close to zero (Larsen et al 1996, Rubin & Baddeley 1989), the absolute magnitude of dating errors increases as a linear function of elapsed time, by a constant error (0.10–0.22 days) per elapsed day (see Rubin & Baddeley 1989), similar to what has been found for simple perceptual properties (Larsen et al 1996; cf. memory psychophysics).

Error patterns, however, reveal the reconstructive nature of temporal memory. ''Scale effects'' occur when temporal accuracy is higher at a more finely grained scale (e.g. the hour of day) than at a more coarsely grained scale (e.g. the week it took place) (e.g. Bruce & van Pelt 1989, Friedman 1987, White 1982), suggesting the use of independent temporal schemata at each level. Independent schemata are also implicated in the ''day-of-the-week effect,'' in which people are often able to localize an event with respect to the day of the week (using a temporal ''week schema''), although they are wrong about the absolute date. Hence, dating errors that are multiples of seven days are heavily overrepresented (Thompson et al 1996). ''Telescoping effects'' involve date estimates that are moved forward from the actual dates toward the present, so that time seems to be compressed (e.g. Bradburn et al 1987, Loftus & Marburger 1983). Such effects occur when the interval from which the events are drawn is known by the rememberer to have distinct boundaries at the end (e.g. last semester), allowing the selective screening of errors beyond the interval (Huttenlocher et al 1990, Rubin & Baddeley 1989).

In sum, many features of correspondence-oriented memory research find clear expression in the study of autobiographical memory: concern with issues of veridicality and error, the propositional, relational, and (self-) referential nature of memory, the active role of the rememberer in constructing the memory report, and the output-bound, qualitative approach to memory assessment.

METACOGNITIVE PROCESSES AND ACCURACY

Discussions of memory errors have brought to the fore a variety of metacognitive operations that mediate memory accuracy. Complementing the reconstructive view, these discussions imply an active rememberer who engages in a variety of inferential and decisional processes that are characteristic of problem solving and decision making (see Burgess & Shallice 1996, Goldsmith & Koriat 1999, Koriat 2000, Koriat & Goldsmith 1998b, Nelson & Narens 1994). Hence, the accuracy of one's memory report is seen to depend heavily on the effectiveness of these processes.

Decisional processes underlying remembering have of course received attention in more traditional approaches to memory, notably in the context of signal-detection theory. Rather than focusing on a single hypothetical dimension of ''trace strength,'' however, current discussions emphasize the multidimensional qualities of phenomenal experience on which the rememberer must operate, such as the know-remember distinction, vividness and clarity, amount of contextual details, and the like. The rememberer is conceived as facing the challenge of interpreting an ambiguous mental record, applying heuristics that are of limited validity, and engaging in a variety of fallible inferential processes (see Johnson 1997). Inferential processes are assumed to operate not only in making decisions

on the basis of phenomenal experience, but also in affecting subjective experience itself (Kelley & Jacoby 1998).

Metacognitive processes are implicated at various stages of learning and remembering (Barnes et al 1999, Koriat & Levy-Sadot 1999). However, those operating during remembering are particularly crucial in determining memory accuracy and error. The functions of these processes include specifying the origin of mental experience (Johnson 1997), avoiding the influence of contaminating factors by attributing them to their proper source (Förster & Strack 1998, Whittlesea & Williams 1998), formulating a focused, well circumscribed description of the sought for past event (Koriat 1999, Schacter et al 1998), monitoring the correctness of information that comes to mind (Kelley & Lindsay 1993, Koriat 1993), choosing the proper remembering strategy for the task at hand (Nhouyvanisvong & Reder 1998), regulating the reporting of information according to the incentive for accuracy (Koriat & Goldsmith 1996c), and so forth. Some of these processes were mentioned in the earlier review of accuracy-oriented research. Indeed, Norman & Schacter (1996) have argued that monitoring and retrieval processes are so intertwined that they should not even be distinguished.

In this section we focus somewhat narrowly on monitoring the correctness of information that comes to mind, and the ensuing decision regarding how and whether to report the information. Evidence collected thus far indicates that people can generally monitor the correctness of their memories and that this ability is critical for the strategic regulation of memory accuracy.

Monitoring the Correctness of One's Own Knowledge: Metamemory Illusions

While metamemory judgments have been shown to be moderately accurate in predicting memory performance (Schwartz 1994), recent work on the bases of metacognitive judgments has disclosed several conditions that produce a dissociation between memory and metamemory (Bjork 1999). These appear to stem from the fact that metacognitive judgments rely on error-prone heuristics (Benjamin & Bjork 1996, Koriat & Levy-Sadot 1999). Benjamin et al (1998), for instance, had subjects answer general-information questions and make judgments of learning (JOL) about the likelihood of recalling the answer at a later time. Whereas the probability of eventual recall increased with the time spent retrieving the answer, JOLs in fact decreased with retrieval latency. Benjamin et al proposed that JOLs are generally based on retrieval fluency, which may sometimes be misleading.

Similarly, feeling of knowing judgments (FOK) about the likelihood of recalling or recognizing a solicited piece of information in the future have been assumed to be based on the overall familiarity of the memory question (Schwartz & Metcalfe 1992) or on the extent to which it brings some fragmentary clues to mind (Koriat 1993). Because subjects often fail to specify the source of familiarity or accessibility, irrelevant influences may result in illusions of knowing (Koriat

1998). Thus, for example, advance priming of a recall cue was found to enhance FOK without correspondingly affecting actual recall (Nhouyvanisvong & Reder 1998). In one experimental condition, Koriat (1995) in fact obtained a negative correlation between FOK judgments and actual recognition performance: When subjects failed to provide an answer to a question, they reported inordinately high FOK for specially chosen questions that generally tend to bring a great deal of incorrect information to mind. Similar illusions have been found with confidence judgments that subjects give after reporting an answer: Chandler (1994), for instance, found that when studied pictures were made similar to nontarget foil pictures, they were less likely to be recognized, but the responses were made with stronger confidence than when the target pictures bore no similarity to the nontarget pictures.

These metamemory illusions, however, are the exception rather than the rule. By and large, people are successful in monitoring the correctness of their memory. With respect to confidence judgments, the within-subject correlations are often moderate to high (e.g. Koriat & Goldsmith 1996c). These correlations contrast with the generally low confidence-accuracy relation observed using between-subjects designs in eyewitness research (see above).

The Strategic Regulation of Memory Accuracy

People's ability to monitor their own memories is not just of intrinsic interest; it is also a critical component of the strategic regulation of memory accuracy. Koriat & Goldsmith (1994, 1996c; see also Barnes et al 1999) showed that monitoring and control processes operating during memory reporting can have a substantial effect on the accuracy of the reported information. This work derived from the observation that people generally have much more control over the information they report than is typically allowed in laboratory experiments: They can choose which aspects of the event to relate and which to ignore, what perspective to adopt, how much detail to provide, and so forth.

Koriat & Goldsmith focused on one particular type of control, ''report option,'' that is, the option to volunteer or withhold specific items of information (i.e. to respond ''don't know''). Their results indicate that people utilize the option of free report to enhance the accuracy of the information that they report, by screening out incorrect candidate answers. Moreover, given stronger incentives for accuracy, people enhance their accuracy performance even further. The basic dynamic, however, is a quantity-accuracy trade-off: Accuracy can be enhanced by withholding answers, but because the screening process is not perfect, this generally comes at a cost in quantity performance.

According to Koriat & Goldsmith's (1996c) model, under conditions of free reporting, people utilize a monitoring process to assess the probability that each piece of information that comes to mind is correct, and a control process that volunteers information only if its assessed probability passes a preset threshold. The setting of the threshold is sensitive to competing demands for quantity and

accuracy. Thus, memory performance depends not only on overall retention (memory), but also on two additional metacognitive factors: the setting of the control threshold (response criterion) and monitoring effectiveness, that is, the validity of the assessed probabilities for distinguishing correct and incorrect information. Although the implications of the first factor are well known from signal detection theory, Koriat & Goldsmith's model brings out the critical role of monitoring effectiveness: When monitoring effectiveness is poor, the selective screening of answers does not enhance accuracy much or at all (Koriat & Goldsmith 1996c: Experiment 2). As monitoring effectiveness improves, however, greater increases in memory accuracy can be achieved, and at a lower cost in memory quantity performance. Thus, according to the model, only when monitoring effectiveness is perfect can eyewitnesses tell ''the whole truth'' and also ''nothing but the truth'' as they are often sworn to do in courtroom situations. Based on their theoretical framework, Koriat & Goldsmith (1996b,c) proposed a general assessment procedure (QAP, Quantity Accuracy Profile) that isolates the unique contributions of retention, monitoring, and control to free-report accuracy and quantity performance.

The theoretical framework developed for report option has recently been extended to encompass a further means of subject control, control over ''grain size,'' that is, the level of generality or detail of the information that is reported (Goldsmith & Koriat 1999, Goldsmith et al 1998). Here too, results indicate that people utilize monitoring and control processes to strategically regulate the grain size of the information they report, attempting to achieve a balance between competing demands for accuracy versus informativeness (see also Yaniv & Foster 1997).

In sum, metacognitive processes have gained increasing prominence in correspondence-oriented research, both as a means by which people validate the accuracy of their own memories, and as mediators of memory accuracy performance itself. As such processes become more and more integrated into memory research and theorizing, they may help increase our understanding of memory phenomena in such varied domains as aging (Hasher et al 1999), brain damage (Schacter et al 1998), children's memory (Bruck & Ceci 1999, Koriat et al 1999, Schneider & Bjorklund 1998), scholastic testing (Koriat & Goldsmith 1998b), survey research (Schwarz 1999), and more.

TOWARD A PSYCHOLOGY OF MEMORY ACCURACY: METHODOLOGICAL, THEORETICAL, AND METATHEORETICAL ISSUES

This chapter brought together a broad array of correspondence-oriented memory research. The work reviewed exhibits a great deal of heterogeneity in the kind of phenomena investigated, in the questions asked, and in the experimental para-

digms employed. Nevertheless, it has in common a concern with the faithfulness of memory. This concern is the essential core of the correspondence metaphor outlined in the introduction. Throughout the review we attempted to show how the various ingredients of this metaphor are reflected in accuracy-oriented memory research and theorizing.

In an earlier analysis, Koriat & Goldsmith (1996b) showed how the correspondence metaphor can help bind together the ''what'' (phenomena, questions, theories), ''how'' (experimental paradigms, assessment procedures), and ''where'' (naturalistic versus laboratory research contexts) of accuracy-oriented memory research. In concluding this chapter, we first focus on the ''what'' and ''how'' aspects, ending with a discussion of the place of memory accuracy and error within a broader functional perspective.

Correspondence-Oriented Research: Phenomena, Questions, and Theories

Clearly, the phenomena of interest under the correspondence metaphor differ from those that have occupied traditional memory research. The storehouse metaphor, with its associated quantity-oriented approach, has directed researchers' thinking toward such aspects of memory as storage capacity, the internal architecture of the store, the transfer of units from one department to another, competition between units, and of course, information loss. This metaphor, with its associated list-learning paradigm, has also dictated the type of phenomena investigated, for instance, the effects of list length, retention interval, item spacing, serial order, and so forth.

In contrast, the correspondence-oriented research reviewed here has concentrated on phenomena that pertain to the congruence between what one remembers and the actual input, focusing on the content of what is recalled or recognized, rather than on the mere amount of remembered information. Thus, in addition to omissions, correspondence-oriented research stresses a wealth of other ways in which what is remembered can depart from what actually occurred. These can roughly be classified into five categories: (*a*) falsely recalling or recognizing items or events that never happened (e.g. false recognition and recall, false memory, confabulation, schema- or script-based importation); (*b*) wrongly recombining features or elements that belong to different objects or events (e.g. illusory conjunctions, fluency misattributions, source confusions, misinformation effects); (*c*) distorting remembered information (e.g. leveling, sharpening, increased symmetry or consistency, clutter and perspective effects, telescoping, retrospective bias); (*d*) remembering information at a different level of generality or abstraction than the actual input (e.g. remembering gist versus detail, substituting the actual input with a different exemplar from its category or from a different hierarchical level); and (*e*) metamemory errors (e.g. over- or underconfidence, illusions of knowing or not knowing).

The common preoccupation with issues of accuracy and error cuts across the various research domains reviewed here and is also reflected in the kind of questions that are asked: How faithful is memory and what are the factors that affect its faithfulness? What is the origin of memory errors and what are their underlying mechanisms? To what extent are the same processes responsible for both accuracy and error? To what extent are memory errors escapable or preventable? What are the distinctive phenomenological correlates of true and false memories? What cues can be used to diagnose the authenticity of memories? Are there systematic individual and group differences in memory accuracy and error? And, more generally, what does the occurrence of memory errors and distortions tell us about the functioning of memory in general? Of course, not all of these questions find expression in any one domain. However, it is encouraging to see that the increasing similarity of questions across different domains and paradigms has helped promote cross-talk between them.

Nevertheless, a major challenge for the psychology of memory accuracy lies in the integration of the various threads of memory accuracy research within a general conceptual framework. At present, there is a great deal of diversity in the status of theoretical development across the various domains. Whereas in some domains (e.g. eyewitness research, DRM), theory development has lagged behind data collection, possibly because of the practical importance of the empirical findings as such, in other domains (e.g. MPI, schema theory, spatial memory) research is more theory driven. In addition, many of the theoretical accounts are local and ad hoc, closely tied to the specific phenomena investigated, and the specific paradigms used.

Recently, however, there is increasing awareness of the need for more general conceptual frameworks that can handle several threads of accuracy-oriented research together. This has led to attempts to extend some of the existing frameworks to account for new phenomena. Thus, beyond the schema-reconstructive framework, which is perhaps the most general of the accuracy-oriented frameworks, Brainerd & Reyna's (1998a) fuzzy-trace theory, Johnson's (1997) source monitoring framework, and Jacoby and Kelley's (Jacoby et al 1989b) attributional approach are increasingly applied to explain phenomena for which they were not originally developed. These extensions appear to be paving the way for the emergence of more integrative, correspondence-oriented theories. Importantly, there seems to be a growing consensus about some of the theoretical notions that could serve as basic building blocks for the development of such theories: assimilation and interpretation during encoding, reconstructive inferences and heuristics, top-down processes in recollection, binding, distinctiveness, source monitoring, attribution and misattribution, the phenomenal quality of recollective experience, metacognitive judgments, control processes, and response criteria. These theoretical notions clearly differ from those included in the traditional quantity-oriented memory theories.

One recently proposed integrative framework that incorporates many of these notions is Schacter et al's (1998) constructive memory framework (CMF), which

emphasizes feature binding, pattern separation, pattern completion, retrieval focusing, and criterion setting as mediators of accurate or inaccurate memory. Representations of events are conceptualized as patterns of features, and retrieval involves a process of pattern completion through spreading activation. When a match is produced, a decision must be made whether the information delivered to awareness constitutes an episodic memory of the sought for target. Memory errors can result from deficient binding of the features comprising a specific episode, insufficient source information, or from setting a lax criterion in source monitoring. Errors can also result from inadequate separation of the episodic feature pattern from other similar patterns, or from unfocused retrieval, when people fail to construct a sufficiently focused retrieval cue, thus activating extraneous information.

An important feature of the CMF is that it is neuropsychologically informed. In fact, neuropsychological investigation is currently providing a fertile meeting ground for researchers working within different accuracy-oriented paradigms. The data derived from such investigations have been found valuable in organizing the various patterns of memory error and distortion, and may ultimately help researchers home in on a set of core theoretical constructs for accuracy-oriented memory theorizing (see e.g. Moscovitch 1995, Norman & Schacter 1996).

Experimental Paradigms and Assessment Procedures

In discussing the implications of the correspondence metaphor, we noted earlier that one obstacle to the development of a psychology of memory accuracy stems from the difficulty of devising experimental paradigms and assessment procedures that can be applied across a broad spectrum of accuracy-oriented research. This difficulty derives from the fact that the correspondence metaphor admits many ways in which memory for the past can deviate from veridicality. Hence, experimental paradigms and memory measures tend to be tailored to individual facets of correspondence and miscorrespondence.

In the context of the storehouse metaphor, the availability of such all-purpose measures as percent recall and percent recognition provided quantity-oriented research with standard operational definitions that could be used to study the characteristics of ''memory'': to derive forgetting curves and to examine the general effects of such variables as study time, divided attention, level of processing, and so forth. Can we envisage the development of parallel all-purpose measures of memory correspondence that would allow a similar study of factors affecting the overall faithfulness of memory?

In their analysis, Koriat & Goldsmith (1996b) specified two types of assessment procedures that can, with certain limitations, yield global measures of memory correspondence. The first, the wholistic type of correspondence measure, can be illustrated within the domain of visual-spatial memory. Waterman & Gordon (1984) measured the correspondence between a studied and a remembered map by assessing the fit between each memory reproduction and the actual map: They

first applied transformations to neutralize differences in rotation, translation, and scale, and then computed an overall ''distortion index'' in terms of the squared distances between corresponding points on the output map and the criterion map. Also, Siegel (1981) used multidimensional scaling techniques to compare remembered distances between landmarks on a campus route against the actual distances.

Such overall goodness of fit measures, however, are much more difficult to apply to verbal reconstructions of real-life events. Such events can submit to a multitude of different descriptions, each of which may be accurate in some sense (Neisser 1981). Thus, in order to specify the relevant dimensions of correspondence or miscorrespondence, how they are to be measured and integrated and at what level of grain, an assessment model is needed that incorporates functional assumptions regarding both the reasons for remembering and the particular circumstances of the memory report. Furthermore, Neisser (1996) points out that even when such a measure is developed, it may be global but not all-purpose: A ''weighted accuracy score'' developed for use in a flashbulb memory study concerning the *Challenger* explosion (Neisser & Harsch 1992) had to be adapted for use in a different study concerning an earthquake disaster (Neisser et al 1991).

One option that circumvents some of these problems is to rely on subjective global accuracy ratings. In a clever variation on this idea, Wells & Turtle (1988) assessed the faithfulness of memory for faces in terms of the proportion of correct target recognitions that could be achieved by independent judges on the basis of the subjects' memory reports alone.

The second type of global correspondence measure is more similar to the traditional item-based measures. In the context of item-based assessment, overall measures of memory quantity and accuracy can be derived in terms of the input-bound and output-bound proportion correct, respectively: The input-bound quantity measure (e.g. percent recall), traditionally used to tap the amount of studied information that can be recovered, reflects the likelihood that each input item is correctly recalled or recognized. The output-bound accuracy measure (e.g. percent of recalled items that are correct), in contrast, reflects the likelihood that each reported item is in fact correct. Hence, it uniquely evaluates the dependability of memory—the extent to which remembered information can be trusted to be correct. Essentially, whereas the input-bound measure holds the person responsible for what he or she fails to report, the output-bound measure holds the person accountable only for what he or she does report.

The conceptual distinction between these two measures is sometimes missed. To illustrate, consider the issue of the dependability of children's eyewitness testimony. The finding that children remember less information than adults (Schneider & Bjorklund 1998) is relevant if we are concerned that a child witness may not be able to provide as much information from memory as an adult. However, if our concern lies in whether or not we can trust what the child does report to be true, then the proper measure is output-bound accuracy; the quantity measure is in fact irrelevant. Focusing on the output-bound accuracy measure can allow researchers to answer questions such as, Is the testimony provided by children,

or by elderly adults, less dependable? What are the underlying mechanisms (e.g. monitoring and control) that account for such differences? How might dependability be improved? Does the dependability measure change over time in the same way as the quantity measure? An interesting finding in this regard is that whereas quantity performance typically decreases as a decelerating function of retention interval, output-bound accuracy may in fact remain constant (Ebbesen & Rienick 1998). Clearly, in order to get a more complete picture of memory performance, it is necessary to consider both accuracy and quantity in tandem (see e.g. Koriat & Goldsmith 1996b,c; QAP procedure, mentioned earlier; and see the discussion regarding the evaluation of the cognitive interview technique, also mentioned earlier). Unfortunately, not many studies have done this.

In sum, it is possible to derive correspondence measures that reflect the overall faithfulness of a memory report. However, this derivation requires the researcher either to ignore the specific content of the remembered information (output-bound accuracy) or to derive and justify a complex assessment model. Hence, most experimental work on memory accuracy has used dependent measures that are tailored to the task at hand and to the targeted facet of correspondence. Such measures are sometimes narrowly content-specific: for example, the likelihood of recalling a particular critical word in the DRM paradigm, or the likelihood of reporting having seen a ''yield'' sign in a misinformation paradigm.

Beyond the issues just discussed, however, there is still another issue concerning the proper criterion for measuring memory correspondence. Should memory reports be validated against reality or against perception, i.e. the initially encoded representation of reality? Newby & Ross's argument is representative: ''Perhaps researchers should evaluate memory against an individual's initial representation of the event, rather than against the supposed objective stimulus. After all, we cannot ask more of memory than that recollections reflect the person's original reality; otherwise, we confuse differences in memory with differences in perception'' (1996:205). This issue is complex (see Koriat & Goldsmith 1996d, 1998a), and we do not propose to resolve it here. Many theories of course, most notably schema theory, hold that changes that occur during the initial encoding are part and parcel of memory itself. On the other hand, efforts should continue to be made to isolate errors and distortions that are due to the initial perception and encoding from those that occur at later stages (see e.g. Alba & Hasher 1983; and see Spatial Memory and Distortion).

Memory Accuracy and Error Within a Broader Functional Perspective

The work on memory accuracy reviewed in this chapter could leave a pessimistic impression about the general faithfulness of human memory. As Schacter recently noted with regard to some of the deficiencies of memory, these ''could easily lead one to question the wisdom of Mother Nature in building such a seemingly flawed system'' (1999:196). But is the memory system really as flawed as it seems? First,

as Schacter (1999) points out, although some of the memory deficiencies may appear to reflect flaws in the system design, they are in fact by-products of otherwise adaptive features of memory. Thus, for example, remembering the gist rather than the details of stories and events, or inferring information not actually present in the input, is often what is required. Indeed questions about the functional utility of memory cannot be settled in the abstract because the same processes that contribute to adaptive functioning in one case may be detrimental in another.

Second, while memory may in fact be more fallible and malleable than is assumed by the layman, it seems to us that the interest in memory illusions and false memories, spurred perhaps by real life problems, has led researchers to selectively focus on the dark side of memory, resulting in a somewhat biased picture.

In fact, a great deal of the work on memory errors defies the principle of representative design advocated by Brunswik (1955; see also Gibson 1979, Gigerenzer et al 1991). Consider, for example, false recalls in the DRM paradigm. The results indicate that the rate of false recall is roughly equal to that of accurate recall. If this finding were representative of memory performance in general, that is, if information retrieved were as likely to be correct as wrong, then memory would be totally useless. However, this high rate of false memories for particular items was obtained under deliberately contrived conditions. Under more representative conditions, a recalled item is much more likely to be correct than false (Koriat 1993). Thus, the output-bound accuracy of free recall has been found to be remarkably high across many experiments, typically ranging from 0.85 to 0.95. That is, over 85% of the items typically recalled are correct (Fisher 1995; Koriat 1993; Koriat & Goldsmith 1994, 1996c). Fisher reached the conclusion that ''when uninfluenced by external pressure, most of the recollections that we bring to conscious awareness are accurate'' (1995:741).

Interestingly, this conclusion holds true even for the contrived circumstances of the DRM paradigm when the entire recall output is considered. In McDermott's (1996) Experiment 1, for example, in which lists of 15 words were used, rates of correct and false recall were 0.58 and 0.44, respectively, for an immediate test, and 0.50 and 0.46, respectively, for a delayed test. Fortunately, McDermott also reported data on extralist intrusions, which averaged 0.22 and 0.32 words, respectively, for each list (McDermott 1996:216). On the basis of these data, we calculated the output-bound accuracy for each test: It amounted to 0.93 for the immediate test and 0.91 for the delayed test! Thus, recall responses in the DRM paradigm are remarkably dependable overall.

Nevertheless, unrepresentative as they may be, memory errors deserve experimental attention for two reasons: First, even if they are relatively rare, the devastating consequences of some memory errors demand a better understanding of when, how, and why they occur. Second, errors are particularly useful in providing insight about the normal processes underlying memory. This has also been the main motivation behind the study of illusions in perception (Gregory 1980).

Finally, however, memory clearly does not operate in a vacuum, and hence memory accuracy and error may need to be analyzed in the context of the personal and social goals of the rememberer. In fact, several authors have argued that memory should be evaluated in terms of its utility (e.g. Neisser 1996, Winograd 1994). This pragmatic view of memory, which has gained prominence in social psychology (Fiske 1993, Swann 1984), entails the idea that ''accuracy is not absolute, it depends on one's purpose'' (Fiske 1993:156). Thus, Neisser's (1996) proposal that remembering should be seen as a form of purposive doing, resonates well with Fiske's (1992) assertion that ''thinking is for doing'' in social cognition. In general, the issue of accuracy has been examined within a much wider range of perspectives in social psychology than in cognitive memory research (e.g. Kruglanski 1989). This has proven valuable both in evaluating the accuracy of social judgments, and in studying their underlying processes. Perhaps the time has come for memory researchers to devote more attention to the place of accuracy and error within a broader functional framework (Neisser 1997, Schacter 1999, Winograd 1994).

ACKNOWLEDGMENTS

The preparation of this chapter was supported by a research grant from ZEIT Foundation Ebelin and Gerd Bucerius. We wish to thank Ravit Levy-Sadot for her valuable comments.

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