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Metamemory Experiments in Neurological Populations: A Review

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Metamemory refers to knowledge about one's memory capabilities and strategies that can aid memory, as well as the processes involved in memory self-monitoring. Although metamemory has been studied in cognitive psychology for several decades, there have been fewer studies investigating the neuropsychology of metamemory. In recent years, a growing number of studies of neurological patient groups have been conducted in order to investigate the neural correlates of metamemory. In this review, we examine the neuropsychological evidence that the frontal lobes are critically involved in monitoring and control processes, which are the central components of metamemory. The following conclusions are drawn from this literature: (1) There is a strong correlation between indices of frontal lobe function or structural integrity and metamemory accuracy (2) The combination of frontal lobe dysfunction and poor memory severely impairs metamemorial processes (3) Metamemory tasks vary in subject performance levels, and quite likely, in the underlying processes these different tasks measure, and (4) Metamemory, as measured by experimental tasks, may dissociate from basic memory retrieval processes and from global judgments of memory.

KEY WORDS: metamemory; memory; monitoring; anosognosia; self-awareness.

INTRODUCTION

Throughout the centuries, philosophers from Descartes to William James have mused about the duality of mind, reflecting upon the ability of a person to be the knower of information in the world, while simultaneously observing oneself in the process of knowing (James, 1890/1981). More recently, this ability to be the concurrent perceiver of phenomena and the observer of this perceiving has been encompassed in the construct of self-awareness. Self-awareness may be defined as the "the capacity to perceive the 'self' in relatively objective terms while maintaining a sense of subjectivity" (Prigatano and Schacter, 1991, p. 13). Moreover, it has been proposed that the capacity to be self-aware is essential to human life, as it facilitates the modification of one's behavior to achieve social goals (Stuss and Benson, 1986).

Neuropsychological methods have provided insight into the properties of self-awareness. For instance, lesion-based studies of patients indicate that unawareness may be domain specific. As one example, Young et al. (1990) report a striking case of a woman who suffered a right middle cerebral artery subarachnoid hemorrhage. This patient was not aware of her deficit in face recognition, but was nevertheless quite aware that she had deficits in other domains such as memory, motor function, and vision.

In the clinical neurological literature, the term "anosognosia" is used to describe the loss of self-awareness of a neurological or cognitive impairment (Kaszniak and Zak, 1996). Joseph Babinski, who coined the term anosognosia in 1914, observed that several patients with right hemisphere damage and resultant left-sided paralysis had no awareness of their paralysis. Subsequent clinical reports extended the concept of anosognosia to include unawareness of neurosensory deficit and memory impairment (McGlynn and Schacter, 1989). Accounts of self-awareness deficits in other domains include anosognosia for linguistic deficits (Rubens and Garrett, 1991), blindsight (Shimamura, 1994), and face recognition (Young et al., 1990). In this paper, we

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discuss the self-awareness of memory, or metamemory. While self-awareness is a broad concept and difficult to comprehensively define, metamemory frameworks allow for operationalization of memory self-awareness, providing theory and predictable hypotheses to work from. Metamemory has been the subject of a significant amount of research primarily due to the central role it appears to play in human learning throughout development. The investigation of metamemory is essential for a comprehensive understanding of how people use memory in day-to-day life, given that metamemory appears essential to strategies used by people to encode and retrieve information, and control memory output. For example, in learning new information, people decide whether they have studied the new information sufficiently for later recall. If the internal feedback they receive indicates they have not sufficiently learned the material, they can engage in further study and employ strategies, such as mnemonics, to learn the material better. There is a growing body of research that is facilitating the merger of metamemory research and basic memory research, investigating cognitive control strategies and their relation to memory.

The goal of the current paper is to critically review the experimental literature concerned with metamemory in neurological populations. Studying metamemory in patient populations can provide insight into the neural correlates of metamemory, and help to understand how people monitor memory and utilize strategies to retrieve memories by observing how such strategies are differentially affected by brain disease and damage. In addition, an understanding of the self-monitoring processes and memory strategies that become impaired with brain insult may ultimately lead to the formulation of targeted rehabilitation efforts. A review of metamemory in neurological patients is particularly important because metamemory results seem to vary widely across studies, and often, clinical descriptions of loss of insight into memory ability in patients do not coincide with results of experimental tasks designed to assess memory monitoring. There are a number of potential reasons that can explain the varying results. One unresolved issue is that the term "metamemory" is not consistently defined across studies. As reviewed by Kaszniak and Zak (1996), metamemory is a broad construct that encompasses several aspects of knowledge about one's memory, including long-term knowledge about task demands, knowledge of strategies that can aid memory, and the processes of memory monitoring. The quest for quantification of the different aspects of metamemory has led to the development of different experimental and self-report measures including: interviews designed to elicit introspective report (Kreutzer et al., 1975), memory self-report questionnaires (Zelinski et al., 1990), task specific predictions of memory performance (Yussen and Levy, 1975), feeling-of-knowing (FOK) judgments or memory confidence ratings after encoding or retrieval (Hart, 1965), judgments of learning (JOL) and ease-of-learning (EOL) (Nelson and Narens, 1990), time allotment and selection of mnemonic strategies during study (Brown and Smiley, 1978), and duration of memory search (Lachman and Lachman, 1980). A related literature focuses on the tip-of-the-tongue (TOT) phenomenon, in which retrieval of target information is deemed to be imminent. The diversity of definitions and the variety of research methods used to measure metamemory likely contributes to inconsistent results across the literature.

The current review paper attempts to identify factors that may explain the diversity of outcomes with respect to metamemory tasks in neurological populations. Experimental metamemory tasks are the primary focus, with less attention to studies utilizing questionnaires and self-report measures. The rationale for this emphasis upon experimental metamemory tasks stems from the multitude of problems that are associated with using questionnaires to assess metamemory. For example, Trosset and Kaszniak (1996) point out that self-report scales that depend on discrepancy scores between patients' self-report and caregivers' report of cognitive functioning cannot discriminate between patient overestimation of abilities and caregivers' underestimation of abilities. Questionnaire-based studies are included in the present review if other metamemory tasks are also employed, or when there is a paucity of studies utilizing the experimental metamemory measures in a particular research domain.

In the following review, a brief description of metacognitive theory and experimental methods of metamemory research is followed by sections reviewing research that focuses upon particular neurological syndromes. The following syndromes will be discussed: amnesia, focal frontal damage, multiple sclerosis (MS), traumatic brain injury (TBI), epilepsy, Alzheimer's disease (AD), Parkinson's disease (PD), Huntington's disease (HD), and HIV infection. The review concludes with a discussion of future research needs and directions.

Theoretical Considerations

A useful framework for understanding the interaction between monitoring and control processes is provided by Nelson and Narens (1990) and depicts the sequence of monitoring and control stages during the acquisition, retention, and retrieval of a given memory content (Fig. 1). As illustrated in this figure, monitoring is hypothesized to occur prior to a learning episode (EOL judgments), during and after acquisition (JOL and FOK judgments), and

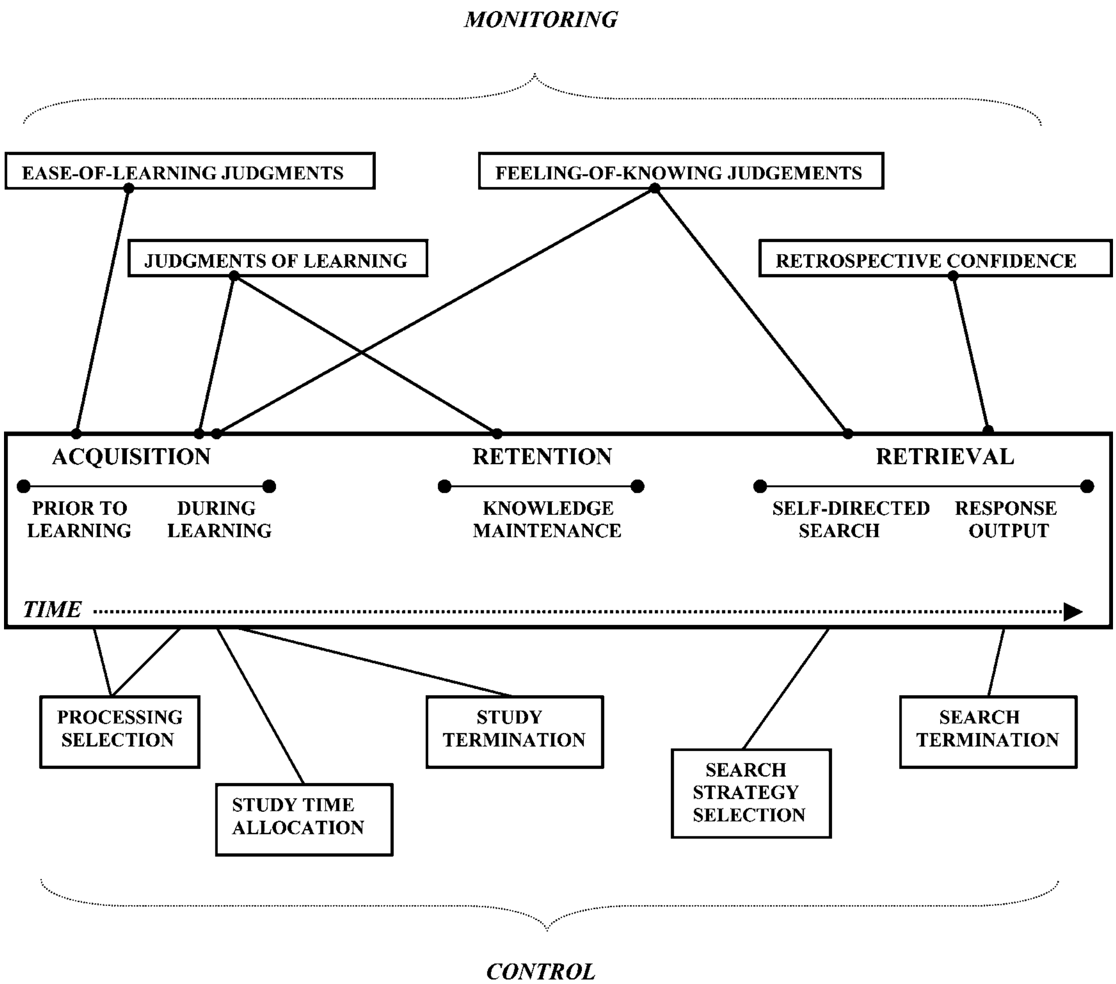

Fig. 1. Illustration of monitoring and control processes in a theoretical framework. Adapted from Nelson and Narens (1990).

following attempted retrieval (retrospective confidence judgments).

The metacognitive framework outlined by Nelson and Narens (1990) shares many similar characteristics with theories of executive function, such as that proposed by Norman and Shallice (1986). Both Nelson and Narens' model and executive function models include a basic level of operation that is made up of schemas and automatic processes, as well as a higher order level that includes processes such as cognitive control and conflict resolution (Fernandez-Duque et al., 2000). Similarly, within Lezak's (1995) model of executive functioning, the hypothesized executive component of *effective performance* is posited to depend upon the ability to monitor and regulate one's own mental activity and behavior.

There is a substantial amount of evidence consistent with the hypothesis that the frontal lobes are critically involved in initiating the higher order processes that are collectively assumed under the term "executive function" (Mega and Cummings, 1994). Because of the similarities between the Nelson and Narens (1990) metacognitive framework (see Fig. 1) and other theories of executive function, it is likely that the frontal lobes are involved in metacognitive tasks as well.

Within the domain of memory, it is hypothesized that monitoring and control processes work together to guide successful retrieval from memory. According to the model proposed by Koriat and Goldsmith (1996), subjects 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. When monitoring effectiveness is poor, the selective screening of answers does not enhance accuracy. Koriat and Goldsmith (1998) have theorized four different processes that occur when a subject is retrieving information within a free recall memory task. The four components are:

1. Overall retention—the amount of correct information available to be retrieved
2. Monitoring effectiveness—extent to which assessed probabilities successfully differentiate correct from incorrect answers:
   a. Resolution: extent to which the subject is able to distinguish between answers that are more likely or less likely to be correct
   b. Calibration: absolute correspondence between subject's confidence in his/her answers and actual likelihood they are correct
3. Control sensitivity—extent to which volunteering or withholding answers is based on monitoring output
4. Response criterion setting—a probability threshold set in accordance with incentive to be accurate

Metamemory tasks can assess overall retention, monitoring effectiveness, and whether subjects engage in control processes. Monitoring resolution is typically measured by the Goodman–Kruskal gamma correlation (recommended by Nelson, 1984) and calibration is often assessed by plotting calibration curves that provide a visual representation of the relationship between a subject's confidence in their performance and their actual performance. The types of metamemory tasks typically used in patient studies are reviewed in the following section.

Types of Experimental Tasks

The most common types of experimental metamemory tasks that are utilized in patient studies involve FOK judgments, JOL, recall readiness, EOL judgments, global predictions, retrospective confidence judgments, and TOT judgments.

Feeling-of-Knowing Judgments

The FOK paradigm requires the subject to indicate whether an item is currently recallable, and if not, specify whether the answer will be remembered at a later time (Nelson and Narens, 1990). Hart (1965) was one of the first researchers to develop an empirical method for the investigation of FOK. He employed the recall-judgment-recognition (RJR) paradigm, in which subjects learn word pairs, make judgments of whether or not they would be able to remember those pairs in the future, followed by a recognition task to test their memory for the word pairs. Results from Hart's study indicated that subjects were better than chance in their judgments; the average percentage of agreement between FOK judgments and subsequent recognition across subjects was 66%.

There are two hypotheses that have been proposed to explain how FOK judgments are made. The cue familiarity hypothesis states that the cue that is present when the metamemory judgment is made is processed for familiarity or novelty (Metcalfe et al., 1993). This sense of familiarity or novelty is accessible to control processes which then allow for the metamemory judgment. A second hypothesis is the accessibility account, which states that metamemory judgments are based upon all information that is present at the time the judgment is made, including but not limited to cue familiarity (Koriat, 1993). Other information that can influence metamemory judgments includes whether letters or sounds associated with the to-be-retrieved word are available. The two hypotheses concerning FOK judgments are not incompatible (Koriat and Levy-Sadot, 2001), and empirical studies of FOK support both views.

In metamemory studies of neurological populations, FOK tasks usually take the form of a general knowledge test in a semantic memory format (Nelson and Narens, 1980) or an episodic memory task in which the subject learns new material during a study phase. A typical episodic task requires subjects to learn new sentences and then reproduce the last word of the sentence at test. If subjects fail to recall the word, they then make a FOK judgment, assessing their confidence that they will correctly recognize the word at a later time.

Judgments of Learning

In a JOL paradigm, subjects make predictions regarding their ability to later remember items that are currently available (Nelson and Narens, 1990). A typical JOL task requires the subject to study an individual item, such as a word, for a limited amount of time, and then rate how likely they will be to recall the word at a later time. Subject performance is measured by comparing JOLs to objective performance on the recall task. JOLs can be made immediately after the learning session, or after a delay. Studies have found that delayed JOLs tend to be more accurate than immediate JOLs in healthy subjects (Nelson and Dunlosky, 1991). One explanation for this could be that subjects are monitoring from working memory during an immediate judgment, and this information may not be available to retrieve at a later time. Delayed JOLs, however, may be based upon information from long-term memory, and therefore will tend to be more accurate reflections of what the subject will be able to later retrieve.

Recall Readiness Tasks

Some experiments require subjects to study verbal stimuli and declare their "recall readiness" for those stimuli. For example, a subject will study one word at a time, self-paced, from a list of words. The next word is presented only when the subject indicates the previous word had been adequately studied for future recall (see Moulin et al., 2000a). Following the recall readiness trial, the subject is asked to recall the studied words, in order to determine accuracy of the prior recall readiness judgments.

Ease-of-Learning Judgments

EOL judgments do not require the subject to recall or recognize any material at the time the judgment is made, and are therefore highly inferential. They are usually global judgments about whether a stimulus will be easy or difficult to learn. For example, the subject is first presented an item and then asked to make a prediction regarding the difficulty of acquisition of that item. The subject can then implement study strategies in order to maximize learning of the item. Typically, healthy subjects study items that are judged difficult for a longer period of time than items they deem easier to learn (Nelson and Leonesio, 1988).

Global Predictions and Postdictions

Global predictions require the subject to predict how many items from a list they will be able to recall (see Moulin et al., 2000b). These predictions are made before study. Postdictions are made after study and ask the subject to judge how many items they will remember, before they are asked to then recall the items.

Retrospective Confidence Judgments

Retrospective confidence judgments are made regarding the most recently retrieved answer. These judgments are typically made following a recall or recognition item, but preceding a FOK judgment. For example, in a general knowledge task, subjects can be asked, "what is the name of the ship on which Charles Darwin made his scientific voyage?" If subjects recall an answer, they make a retrospective confidence judgment on the likelihood that their response is correct. If subjects do not respond with an answer, they make a FOK judgment regarding future recall or recognition of the correct answer. Retrospective confidence and FOK are different types of judgments in that the former is an assessment that follows retrieval and the latter a prospective judgment regarding future retrieval. These judgments may also depend on different brain regions. Schnyer et al. (2004) suggest that the ventromedial prefrontal cortex may be the critical region for accurate FOK judgments, while the lateral prefrontal cortex, which has been postulated to be involved in retrieval monitoring effort (Henson et al., 2000), may be the critical region involved in accurate retrospective confidence judgments.

Tip-of-the-Tongue Judgments

TOT judgments are similar to FOK judgments, as both require the subject to first attempt retrieval of an item, and then judge whether an unsuccessfully retrieved item will be retrieved in the future. Some researchers make a distinction between the two judgments based on a feeling of imminence of retrieval—retrieval of items on the tip-of-one's tongue may be accessed quicker than those on which a FOK judgment is made. TOT judgments have been studied extensively in the context of healthy aging. A growing number of studies demonstrate that older persons experience the TOT phenomenon more frequently than younger persons (Dahlgren, 1998; Heine et al., 1999; Maylor, 1990). In addition, there is some evidence that people with AD experience more TOT states than normal aging adults (Astell and Harley, 1996).

Statistical Methods

Researchers investigating metamemory in patient populations have employed different statistical methods to quantify metamemory deficits. Three such measures are the gamma correlation, the Somer's *d* correlation, and the Hamann index. All three are statistical indices of concordance.

Gamma coefficients measure monitoring resolution (Nelson, 1984). The Goodman–Kruskal gamma is a symmetric measure of association that is based on the difference between concordant pairs and discordant pairs, and is calculated by the equation $(P - Q)/(P + Q)$, where P: concordant pairs and Q: disconcordant pairs. For an example of the computation of gamma, consider the 3×2 table shown below, in which the predictor variable is percent confidence that the subject will be able to recognize a currently nonrecalled item at a later time, and the criterion variable is a 0 or 1 dichotomous variable indicating incorrect versus correct recognition on the subsequent test. Cell "a" represents the number of observations for which the subject rated they were 0% confident that they would be able to recognize a currently nonrecallable item, and when tested on a recognition task subsequent to the recall task, they indeed did not recognize the item correctly. Cells b, c, etc. are representative of the number of observations defined by the subject's rated confidence and whether they subsequently recognized the item correctly. The γ correlation for this subject is computed below:

$$P = a\,(e + f) + bf = 10\,(4 + 10) + 5\,(10) = 190$$

$$Q = c\,(d + e) + bd = 1\,(1 + 4) + 5\,(1) = 10$$

$$\gamma = (P - Q)/(P + Q) = (190 - 10)/(190 + 10) = .9.$$

In this example, the γ correlation (which can range from -1 to $+1$) is .9. This is a high value, indicating the subject's accuracy in his/her predictions of the recognizability of nonrecalled items. One shortcoming of the γ correlation is that it ignores pairs tied on the predictor variable. Thus, the result may give an inflated estimation of monitoring ability. To address this disadvantage, the Somer's d coefficient has been used in the literature, though not frequently. The Somer's d statistic (Somers, 1962) is identical to the γ correlation with one exception; it includes tied pairs in the denominator of the γ equation to control for non-monotonicity of the data. Somer's d is computed by using the equation: $(P - Q)/(P + Q + X_0)$, where P: concordant pairs, Q: disconcordant pairs, and X_0: pairs tied on X. However, if Y is the predictor variable, the equation is $(P - Q)/(P + Q + Y_0)$, where Y_0 equals the pairs tied on Y. This statistic is asymmetric; however, it can become symmetric by averaging the Somer's d for the X and Y variables. Consider the 3×2 table again below (Confidence: X; Correct/Incorrect: Y):

	0% Confident	50% Confident	100% Confident
Incorrect (0)	$a = 10$	$b = 5$	$c = 1$
Correct (1)	$d = 1$	$e = 4$	$f = 10$

$$P = a(e + f) + bf = 10(4 + 10) + 5(10) = 190$$

$$Q = c(d + e) + bd = 1(1 + 4) + 5(1) = 10$$

$$X_0 = ad + be + cf = 10 + 20 + 10 = 40$$

$$Y_0 = a(b + c) + bc + d(e + f) + ef = 10(5 + 1) +5(1) + 1(4 + 10) + 4(10) = 145$$

$$dxy = (P - Q)/(P + Q + X_0) = (190 - 10)/ \times(190 + 10 + 40) = .75$$

$$dyx = (P - Q)/(P + Q + Y_0) = (190 - 10)/ \times(190 + 10 + 145) = .52$$

In comparison to the γ correlation of .9 computed above, the Somer's d correlations are lower. As illustrated in this example, the Somer's d statistic is a more conservative measure of metacognitive accuracy, although preferable when dealing with tied pairs on the predictor variable.

In addition to the γ correlation and Somer's d, the Hamann index has also been used to measure correspondence of confidence judgments and objective performance. Schraw (1995) argues that the Hamann correlation is a better measure than γ. However, two empirical studies have shown that the Hamann index and γ scores were consistent with each other, and are thus interchangeable (Schnyer et al., 2004; Souchay et al., 2000). Consequently, it remains unclear whether the Hamann correlation is preferable to either γ or Somer's d.

An alternative method to quantify metamemory data is to use calibration curves, which measure the relationship between metamemory judgments and actual recognition performance (see Fig. 2). In this illustration, focusing on confidence judgments, subjective confidence refers to the subject's confidence level of a choice the person has made (e.g., the subject is 40% confident in that they chose the correct answer) and is represented on the x-axis of the calibration graph. The subjects' actual memory performance (i.e., proportion correct) is represented along the y-axis as function of subjective confidence level. Perfect correspondence between subjective confidence and actual

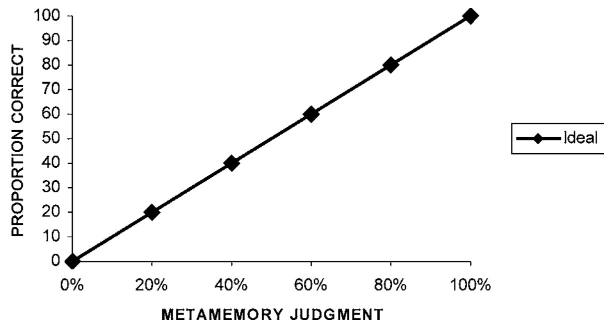

Fig. 2. A calibration curve depicting the ideal straight line representing perfect correspondence between actual memory performance (proportion correct) and subject metamemory judgment.

memory performance results in a straight calibration line, which is shown on the diagram below as the ideal line. Calibration curves provide a visual, graphical representation of monitoring correspondence, showing whether the individual is more or less confident than their actual recognition performance would predict, and whether the relationship between confidence and performance is equivalent throughout the performance range.

Many of the studies reviewed in this article employ two different measures of concordance or include calibration curves to complement concordance scores (see Schnyer et al., 2004). This approach appears superior, in that the shortcomings of any particular measure may be compensated by examination of the additional index.

Neuroanatomical Correlates

Studies in neurological patients have implicated the prefrontal cortex as an essential anatomical region in metamemory (McGlynn and Schacter, 1989; Kaszniak and Zak, 1996; McGlynn and Kaszniak, 1991a,b, Shimamura, 1994). This is not surprising in light of the conceptual similarities between the hypothetical components of metacognition and those of executive functions thought to be associated with the frontal lobes. Some of the relevant questions that have been asked in studies of metamemory in neurological patients include: Is it possible to have normally accurate awareness of memory functioning despite having a poor memory? What kinds of syndromes and lesion locations are associated with deficits in metamemory? What brain structures are important for metamemory ability? These questions have been investigated in the following studies in neurological populations.

Korsakoff's Syndrome and Amnesia Associated with Medial Temporal Lobe Damage

Profile and Neuropsychological Performance. Korsakoff's syndrome is an amnestic disorder thought to be caused by chronic alcohol abuse and thiamine deficiency (Kolb and Whishaw, 1995), and is characterized by severe anterograde amnesia as well as retrograde memory loss (Shimamura and Squire, 1986). The disorder is associated with damage to the dorsomedial nucleus of the thalamus, the mammillary nuclei, and also with frontal atrophy (Mayes et al., 1988; Victor et al., 1971). Memory impairment is the hallmark of Korsakoff's syndrome. Korsakoff's patients typically cannot recall items on a delayed recall task, nor often even remember the testing session itself (Delis and Kramer, 2000). Korsakoff's syndrome patients are also impaired on a number executive functioning tasks, showing perseveration errors and difficulty with problem solving (Butters, 1985), as well as an impairment on cognitive estimation tasks (Brand et al., 2003). Korsakoff's syndrome is often accompanied by confabulation, which refers to false statements that are made without the intention to be untruthful (Johnson et al., 2000). Moscovitch and Melo (1997) propose that frontal lobe lesions or dysfunction may result in confabulation due to a breakdown in search mechanisms, poor monitoring, and faulty output from memory.

Patients with amnesia associated with medial temporal lobe damage typically show profound deficits on episodic recognition and recall memory tasks, similar to Korsakoff's patients. However, they do not typically show marked executive function deficits of Korsakoff's patients, nor do they typically confabulate (Johnson et al., 2000). Comparing these two types of amnesic patients has provided clues regarding the dissociability between memory function and awareness of memory function.

Metamemory in Amnesia. Studies of amnesic patients have shown that Korsakoff's patients perform particularly poorly on metamemory tasks. In one study of alcoholic Korsakoff's patients, Bauer et al. (1984) found that this patient group was significantly worse in predicting their performance on a free-recall test than a control group. Shimamura and Squire (1986) investigated whether different groups of amnesic patients would perform similarly on metamemory tasks. The amnesic groups consisted of Korsakoff's syndrome patients, patients receiving electroconvulsive therapy, and a mixed etiological group of four additional cases of amnesia due to anoxia, TBI, and hypotension. Subjects participated in a general knowledge FOK test and a sentence memory FOK test. Results from both experiments showed that the only group that performed poorly on metamemory judgments was the Korsakoff's syndrome group. The other amnesic groups, despite having memory deficits in comparison to healthy control subjects, performed just as well as controls in predicting their performance on the episodic sentence memory task. The authors interpreted the findings as evidence for a specific deficit in metamemory for patients with Korsakoff's syndrome.

Summary. Results from metamemory studies in amnesic patients show that those with Korsakoff's syndrome have marked deficits in their judgments of memory, while those with amnesia secondary to other etiologies do not, despite exhibiting equally poor memory performance on episodic memory tasks. This pattern of results could be explained by differences in executive function. Korsakoff's patients perform poorly on measures of executive function while most other amnesic patients typically do not. Poor performance on metamemory tasks in patients with Korsakoff's syndrome is not surprising, given their reduced abilities on tasks of cognitive estimation and propensity for confabulation (Moscovitch and Melo, 1997). Moscovitch and Melo (1997) have proposed that confabulation may arise from poor monitoring and control functions, perhaps the same processes that are important for metamemory judgments.

Given that executive functions may be associated with metamemory, the question naturally arises whether patients with frontal lobe damage show metamemory deficits.

Focal Frontal Lesions

Profile and Neuropsychological Performance. Patients with frontal lobe damage or dysfunction tend to have deficits in memory, but of a different nature than classical amnesic patients. The general finding is that for frontal lobe damaged patients, the memory deficit lies in inadequate organizational and retrieval strategies resulting from faulty control and monitoring mechanisms (Baldo and Shimamura, 2002), whereas impaired retention of information is the main deficit for amnesic patients. An example comes from studies requiring subjects to recall word lists such as contained in the California Verbal Learning Test (CVLT; Delis et al., 1987). Results often show that frontal lobe damaged patients do not spontaneously use organizational strategies such as semantic clustering (Baldo et al., 2002) or subjective organization (Eslinger and Grattan, 1994), and are also more likely to make intrusion errors despite normal recognition of learned material (Baldo et al., 2002). In addition, frontal damaged patients may have difficulty using context for storage or retrieval (Moscovitch and Umilta, 1991), and do poorly on fluency tasks (Janowsky et al., 1989a), and temporal ordering tasks (Butters et al., 1994). Outcomes from such studies indicate that although frontal patients may have normal learning curves, they typically have a diminished capacity to monitor and organize memory. This lack of strategic organization, in addition to perseveration, difficulties in problem solving, and difficulties in planning are collectively termed executive dysfunction and are typically a prominent feature of patients with frontal damage.

Metamemory in Frontal Lobe Damage. To test whether people with focal frontal lesions do poorly on tasks of metamemory, Janowsky et al. (1989b) administered FOK tasks in a semantic domain and in an episodic domain to a group of frontal lobe damage patients, temporal lobe damage patients, and normal controls. In the episodic task, subjects were asked to study 24 sentences. At test, subjects were presented the 24 sentences along with eight new additional sentences, each with the last word missing from the sentence. Subjects were asked to recall the missing word and then to make FOK judgments if they could not recall the last word. Results showed that those with frontal lobe damage did not perform differently from healthy control subjects in this task. However, when asked to make FOK judgments after a 1–3 day delay, patients with frontal lobe damage performed more poorly than the healthy controls. In the semantic task, subjects were asked to make confidence judgments about general knowledge questions. There were no differences between subject groups on this task. To explain these results, the authors suggested that metamemory deficits may become apparent when the memory trace is weakened, and that in addition to frontal lobe damage, other regions (e.g., subcortical areas) may need to be involved in order to produce deficits in metamemory.

Two studies sought to investigate whether frontal lobe damage patients are as accurate as other brain-injured subjects without frontal damage on a JOL task (Vilkki et al., 1998, 1999). The first study (Vilkki et al., 1998) used a list-learning test to elicit JOLs and the second study (Vilkki et al., 1999) employed a spatial prediction task. Results from both studies, one study in the verbal domain and the second study in the visuospatial domain, indicated that right frontal damaged patients were less accurate in their performance predictions than patients with left frontal damage and healthy control subjects.

A more recent study conducted by Schnyer et al. (2004) investigated whether damage to specific areas of the frontal lobes is associated with metamemory impairment. Subjects learned sentences and made FOK and retrospective confidence judgments regarding the last word of each sentence. Results indicated that overall, frontal patients performed poorer than normal control subjects on the FOK task. Lesion analysis (through structural neuroimaging) revealed an overlapping region in the right medial prefrontal cortex in frontal damaged patients who performed the poorest on this task.

A final study investigated FOK and retrospective confidence judgments with respect to face-name retrieval in a group of frontal damaged patients and healthy control subjects (Pannu et al., in press). Results showed that when faces were either extremely familiar (e.g., Lucille Ball or former president Bill Clinton) or extremely unfamiliar (e.g., novel faces), frontal damaged patients performed similarly to healthy control subjects. However, frontal damaged patients monitored more poorly than control subjects when faces were at an intermediate level of familiarity, suggesting that the monitoring mechanism is engaged most critically when decisions are difficult. These results expand previous reports of metamemory deficits in frontal damaged patients to the ecologically representative domain of face-name association.

Summary. Results of metamemory studies in frontal lobe damaged patients suggest that right frontal damage may be necessary for the appearance of metamemory deficits, particularly damage in the right medial frontal area. Additionally, these studies have shown that the memory trace may need to be weakened in order to show significantly more metamemory deficits than healthy control subjects. This combination of frontal damage and weak memory could mimic what occurs in a Korsakoff's syndrome patient. Weakening of memory trace may be related to type of metamemory task employed. General knowledge, semantic memory tasks, or tasks involving easy items (e.g., naming very famous persons) may not be sufficiently sensitive to elicit metamemory deficits. In contrast, episodic JOL and FOK tasks may require more effortful memory processes that frontal patients may not spontaneously engage, and therefore metamemory performance is negatively impacted.

Multiple Sclerosis

Profile and Neuropsychological Performance. MS is a disease in which the immune system attacks the white matter of the central nervous system and causes focal areas of demyelination. This disease has negative impacts on physical, emotional, and cognitive functioning (Collins, 1997). MS is typically diagnosed between the ages of 20 and 40, with initial symptoms of weakness, numbness, ataxia or diplopia, and in some cases paresthesias around the face and extremities.

Studies of the neuropathology of MS often show demyelination in subcortical paraventricular white matter. Not surprisingly, the results of neuropsychological testing with MS patients have revealed profiles similar to those of patients with subcortical dementia (Rao, 1986). These deficits include principal impairments in processing speed and problem solving (Beatty, 1992). Memory testing in MS patients reveals an impairment in memory recall, but not recognition. MS patients may also have deficits in tasks sensitive to frontal function, such as the Wisconsin Card Sorting Test (WCST; Heaton, 1981) and fluency tasks. However, Beatty (1992) points out that very few MS patients actually show the full syndrome of subcortical dementia and that most patients perform within normal limits on cognitive tasks, or show impairment in only one domain.

Metamemory in MS. The first study to investigate metamemory in MS was published by Beatty and Monson (1991). Forty-five patients with MS, grouped in accordance to their performance on memory tasks and the WCST, participated in four metamemory tasks. The first task was a sentence memory task in which subjects studied sentences were asked to retrieve the last word of each sentence, and then make feeling of knowing judgments if their recall attempt failed. In the second metamemory task, subjects were presented with a list of words and asked to predict how many words they would recall. The third metamemory task involved general knowledge questions and FOK judgments. The fourth metamemory task was a memory questionnaire in which subjects had to compare their memory, motor, sensory, attention, and language abilities in reference to a friend without MS. Results indicated that MS patients did not perform equivalently on all metamemory tasks. All MS patient groups performed similarly to healthy control subjects on the general memory knowledge FOK task. On the free recall task, the only group that showed a deficit in metamemory was that which was a priori assigned "low memory, low WCST" based upon their neuropsychological performance. On the sentence memory task, all MS patients' γ correlations on the FOK task were worse than healthy control subjects, with the "normal memory–normal WCST" group performing the best among the MS patient groups. Finally, on the memory questionnaire, no significant differences were noted between the MS groups and healthy control subjects except for the motor scale, on which MS patients reported more difficulties with walking. Although MS patients performed worse on recall and recognition tasks than healthy control subjects, they did not report more difficulties on a cognitive task questionnaire, suggesting a deficit in self-awareness for memory tasks in everyday life.

In a study by Scarrabelotti and Carroll (1999), subjects with MS were given a stem completion task in which they were asked to remember 48 words at study phase. Subjects were then asked to make JOL regarding the degree to which they felt they would be able to later remember an individual word. Subjects made a judgment of learning on a six-point scale ranging from 0 to 100%. After making this judgment, subjects recalled words within two types of conditions, an inclusion condition in which they were instructed to recall the word that was studied when given the first three letters of it, and an exclusion condition in which subjects were instructed to recall a new word that completed the three letters given. After the recall phase, subjects made a retrospective confidence judgment regarding their confidence that they either recalled the word correctly under the two conditions, and on a rating scale similar to the scale used for the judgment of learning task. The procedure was repeated in a year, yielding two years of data (year 1 and year 2).

MS patients did not show a metamemory deficit under the inclusion condition for the JOL or the retrospective confidence judgment task in either years. However, differences between the MS patient group and the control group emerged under the exclusion condition in year 2. MS patients were significantly worse in correctly predicting their memory for words studied prospectively, and showed a trend toward worse retrospective monitoring. MS patients performed significantly worse than control subjects on the CVLT, the Stroop, and the Word Finding Test in both years.

Summary. Both of the studies described above showed MS patients to perform worse than healthy control subjects on various cognitive tasks. However, this was not always accompanied by poorer performance on metamemory tasks. Patients performed similar to control patients under conditions of less difficult tasks, such as the general knowledge task (Beatty and Monson, 1991) and the inclusion condition in the Scarrabelotti and Carroll (1999) study. However, for tasks that make higher monitoring demands, such as an episodic sentence memory task, or list learning and prediction tasks, MS patients show deficits in comparison to control subjects.

The Beatty and Monson paper raises important issues with respect to MS, neuropsychological performance, and metamemory. Separation of MS patients into four groups of Normal Memory/Normal WCST, Low Memory/Normal WCST, Normal Memory/Low WCST, and Low Memory/Low WCST showed that patients with poor memory combined with poor performance on the WCST (a measure sensitive to frontal lobe function) perform the most poorly on metamemory tasks. This paper also makes the point that MS patients, and possibly other neurological populations, may perform variably on cognitive tasks due to differences in progression of illness and specific areas of demyelination. Therefore, future metamemory studies with this population may be advised to categorize subjects with respect to their current level of functioning instead of grouping all MS patients together, which could lead to averaging artifacts and a masking of individual differences. One approach to accounting for individual differences would be to separate groups by course of disease progression. Two courses have been identified: a “chronic progressive” and the “relapsing–remitting” course (Beatty, 1992). Although there remains much variability within these two groups, chronic progressive patients may perform worse on neuropsychological tasks (Beatty et al., 1989). Another, and perhaps a more fruitful approach would be to separate groups by performance on neuropsychological tasks as described in the Beatty and Monson (1991) paper.

Traumatic Brain Injury

Profile and Neuropsychological Performance. Patients who have sustained a TBI vary in their neuropsychological performance, depending on a number of factors such as whether the patient sustained a mild, moderate, or severe head injury (as typically assessed by the Glasgow Coma Scale). Patients with severe head injuries often have executive dysfunction including problems with mental flexibility, conceptual shifting, and perseveration (Lezak, 1995). Memory impairments are characterized by poor retention and retrieval in the verbal domain (Curtiss et al., 2001). These problems in memory are compounded by the use of ineffective encoding and retrieval strategies or the failure to use strategies spontaneously (Levin and Goldstein, 1986; Millis and Ricker, 1994). In addition to cognitive deficits, TBI patients tend to exhibit behavioral problems such as impulsivity, social disinhibition, and irritability. Patients that develop these characteristics post-injury are often not as aware of them as their relatives are, and this can lead to social difficulties in isolation (Prigatano, 1991).

Metamemory in TBI. Lack of awareness of one’s deficits after TBI has been well documented (Prigatano, 1991). One report showed approximately 90% of right hemisphere damaged head trauma patients to be unaware of their cognitive difficulties as assessed by a self-report measure, in comparison to their difficulties manifest on neuropsychological tasks (Anderson and Tranel, 1989). Often, this lack in acknowledgment of cognitive difficulty has a negative impact on rehabilitation strategies due to the corresponding lack of motivation for treatment.

However, clinical reports and the findings of questionnaire-based studies that indicate deficits in awareness of cognitive ability are not always corroborated by results from experimental tasks. There have been four experimental studies investigating metamemory judgments in TBI patients, all from the same research group. The first study examined two subjects with severe TBIs (Kennedy et al., 1995). Subjects made immediate and delayed JOLs on a list of noun pairs, and subsequently completed a cued recall test. JOL ratings were made on a six-point scale (i.e., 0 to 100% sure of future recall). Results from this study were mixed; one TBI patient performed accurately on both immediate and delayed JOLs (γ correlations of 1) while the second TBI patient performed poorly in both conditions. Interestingly, control subjects performed poorly on immediate JOLs, and improved their performance after a delay. The second TBI patient’s immediate JOL data is uninterpretable, given that control subjects also had difficulty with this task. However, it is of note that only the second TBI patient continued to have difficulty on the delayed JOL task.

In another study conducted by Kennedy and Yorkston (2000), TBI patients learned 120 unrelated noun pairs and were asked to make JOL predictions immediately after study and after a delay. In addition, TBI patients and healthy control subjects made JOL predictions in a retrieval condition, in which subjects were instructed to first attempt to retrieve studied items before making the JOL prediction. Results showed that the TBI patients recalled fewer noun pairs than control subjects, despite having more time to study them. There were no differences between groups on immediate or delayed JOL predictions. Both groups had relatively low prediction performance on immediate JOLs, and both groups improved in their predictions after a delay. In addition, performance did not improve in the retrieval condition in either group.

A third study (Kennedy, 2001) involved asking patients with TBI (the same patients as above) to make retrospective confidence judgments after recall of noun pairs. Again, the TBI group recalled fewer noun pairs than healthy control subjects, but the groups did not differ in metamemory accuracy. Both groups had extremely high γ correlations, with no subjects' correlation below .9 (with 1 being a perfect correlation). Analysis of calibration curves revealed that while TBI patients performed similar to control subjects on relative accuracy (as measured by the γ correlation), they generally displayed a pattern of overconfidence in their answers. Control subjects, however, were underconfident in their retrospective confidence judgments.

The fourth study investigated whether patients with acquired brain injury would study longer those items they judged to be more difficult than items they rated to be easier to learn (Kennedy et al., 2003). The task required subjects to learn noun pairs and make immediate and delayed recall predictions, in addition to selecting items to restudy should they choose to. The acquired brain injury patients were just as likely as the healthy control subjects to select items they rated low in their confidence judgments for further study time. In addition, the patient group benefited more from self-selected restudying of items than control subjects.

Summary. The experimental literature indicates that TBI patients perform worse than control subjects on general memory tasks (i.e., total number of noun pairs recalled), but only inconsistently show metamemory deficits. TBI patients are a heterogeneous group, with variations in the structural and neurophysiological consequences of injury corresponding to variability in neuropsychological profile (see Eisenberg and Levin, 1989; Schoenhuber and Gentilini, 1989). Consequently, it is not surprising that the available studies of metamemory in TBI patients have produced inconsistent results. One approach that could help in future studies would be to separate TBI patients with respect to their performance on neuropsychological tasks. It could be that those TBI patients who do poorly on both memory tests and tests sensitive to frontal function also perform poorly on metamemory tasks. Including all TBI patients in one group, given the likely heterogeneity, may lead to averaging artifacts.

Another factor that could influence the results from the TBI studies reviewed above is the time post-injury at which patients were tested. At least one report suggests that TBI patients are more aware of their deficits the longer from the time of their injury they are tested (Allen and Ruff, 1990). In the set of studies reviewed above, Kennedy (2001) and Kennedy and Yorkston (2000) included patients that averaged 16 months post-injury, while Kennedy et al. (2003) reported on patients that averaged 35 months post-injury. It is possible that testing TBI patients earlier than 16 months post-injury may reveal greater deficits on metamemory tasks. This possibility should be subjected to further investigation.

The available TBI patient studies may have implications for rehabilitation strategies. Some investigators have suggested that when subjects who are initially unaware of their memory performance are given feedback, they may improve their monitoring (Giacino and Cicerone, 1998). Within the studies reviewed above, TBI patients were able to improve their recall when allowed to self-select items for further study (Kennedy et al., 2003). Continued research in this area may suggest approaches that could be beneficial for families, health care providers, and patients with respect to memory improvement.

Temporal Lobe Epilepsy

Profile and Neuropsychological Performance. Epilepsy arises from a state of excessive and abnormally synchronous neuronal firing, and is associated with the occurrence of multiple seizures throughout the patient's lifetime. Partial complex seizures are associated with loss of consciousness and typically arise from abnormal electrical activity in focal temporal lobe areas of the cortex, giving this condition the alternative name of temporal lobe epilepsy (TLE).

Patients with TLE are a heterogeneous group with respect to their neuropsychological performance, reflecting differences in age of onset of seizures, etiology of epilepsy, and frequency of seizures (Lezak, 1995). However, patients with focal irritative lesions tend to have deficits in the cognitive areas associated with the region of cortex that is malfunctioning. For example, patients with seizures originating in their left hemisphere typically show deficits on verbal tasks, while patients with seizures originating in the right hemisphere show deficits on visual–perceptual tasks (Lezak, 1995). TLE patients often have attention, memory, and learning difficulties, which again may be lateralized in material-specific ways.

Metamemory in Temporal Lobe Epilepsy. Metamemory in TLE has not been studied extensively. There have been two published studies that the authors are aware of that experimentally investigated metamemory performance. In one study (Prevey et al., 1988), lateralized temporal lobe epileptic patients and normal controls participated in verbal and visual JOL tasks, and a FOK task. The verbal JOL task involved a list of words for study, followed by a yes/no judgment of learning prediction regarding whether the subject would be able to recall the list of words in the order presented. The visual JOL task involved nonmeaningful geometric figures. On this task, subjects made a prediction whether they could remember the correct sequence of the shown figures. The FOK task was a semantic memory task in which subjects made FOK judgments on general knowledge questions. Results showed that TLE patients tended to overestimate their performance, depending on the lateralization of their lesion. Right TLE tended to overestimate their performance on the visual task, while both left and right temporal lobe epileptics overestimated their verbal memory ability in comparison to healthy control subjects. In addition, TLE patients were poorer than healthy control subjects in their performance on the FOK task.

In another study conducted by the same group of researchers, persons with TLE engaged in two different FOK tasks (Prevey et al., 1991). In the first task, Prevey et al. (1991) attempted to replicate their previous observation of TLE patients performing poorly on a general knowledge FOK task. A total of 60 general knowledge questions were presented, followed by a FOK judgment. Although the TLE patients had nominally lower γ correlations than healthy control subjects, this difference did not reach statistical significance. In the second experiment of this study, the FACTRETRIEVAL software program (Shimamura et al., 1981), which employs the same FOK RJR procedure, was utilized. As in the first experiment, TLE patients had nominally lower FOK γ correlations but this difference did not reach statistical significance.

Finally, Rapcsak et al. (2005) have investigated metamemory in a patient with prosopagnosia, with the etiology most likely due to right temporal epilepsy. Results indicated that the patient, SV, was quite aware that she could not recognize faces that were presented to her. Her FOK γ correlation was .9, indicating a high degree of correspondence between her subjective FOK ratings and her performance on a face recognition task.

Summary. There is evidence to suggest that TLE patients perform poorly on JOL tasks, but the results from FOK tasks are mixed. The studies reviewed above indicate that TLE patients perform poorly on JOL tasks that are in the same modality as their primary area of cognitive difficulty related to their hemispheric location of epileptic foci (i.e., left TLE patients perform poorly on verbal materials while right TLE perform relatively more poorly on visual material). This finding is not entirely consistent with the proposal that frontal lobe involvement is necessary to produce metamemory deficits, given that the areas that are most affected in TLE are the temporal lobes. However, some TLE patients have been shown to perform poorly on tasks sensitive to frontal lobe function, such as the WCST (Hermann et al., 1988). In addition, some patients with the diagnosis of TLE actually have epileptic foci originating elsewhere, such as in the frontal lobes. The inclusion of frontal lobe epilepsy patients into TLE groups may occur due to the difficulty in differential diagnosis; frontal lobe seizures are often difficult to diagnose because they resemble TLE (Lishman, 1987). It would be useful to compare reliably identified frontal lobe epileptics to true TLE patients to determine whether differences emerge with respect to metamemory judgments.

Although TLE patients performed poorly on JOL tasks in comparison to control subjects, the results from FOK studies are inconsistent. While all of the FOK studies reviewed above showed that there is a trend toward TLE patients performing more poorly on FOK tasks, the fact that differences between TLE and control subjects for two of the three FOK studies were not significant indicates that the effect is weak. In addition, a patient with prosopagnosia thought to be due to TLE was reported to have intact metamemory regarding her area of recognition weakness. One possibility that could explain the different results in TLE patient performance of metamemory tasks concerns whether the task was in an episodic or semantic memory format. The FOK tasks were concerned with general knowledge, and in semantic format, while the JOL tasks were in the episodic memory domain. As mentioned earlier in this paper, patients tend to perform more poorly on episodic FOK tasks, which may require more retrieval effort than semantic tasks, which reflect well-established memory networks.

Alzheimer's Disease

Profile and Neuropsychological Performance. Patients with AD generally show deficits on a number of cognitive tasks including those of memory, language, visuospatial construction, and executive function (Green, 2000). A characteristic of the disease is a marked deficit in memory storage (Welsh et al., 1992). Accordingly, AD patients may perform poorly on the WMS-III Logical Memory II subtest, as well as the CVLT. Impairments in language, and particularly naming ability, are evident on tasks such as the Boston Naming test (Kaplan et al., 1983). AD patients typically do not benefit from phonemic cues and tend to make paraphasic errors on this task (Green, 2000).

Although memory and language deficits are the hallmarks of AD, there is substantial evidence that executive function is often impaired as well (Duke and Kaszniak, 2000). This deficit is inferred from performance on verbal fluency tasks (Monsch et al., 1994), Trail-Making and Stroop tasks (Lafleche and Albert, 1995), and the WCST (Binetti et al., 1996). Because these patients perform poorly on tasks sensitive to the integrity of frontal lobe structures, a prediction is that these patients may also do poorly on metamemory tasks, if indeed the frontal lobes are important for metamemorial abilities.

Metamemory in AD. Underawareness of memory deficit in dementia patients has been well-documented (Kaszniak and Zak, 1996; McGlynn and Kaszniak, 1991a). There are a number of studies utilizing questionnaire data that show patients with AD and/or Pick's disease overpredict their memory abilities and exhibit poor awareness of their memory loss (Danielczyk, 1983; Gustafson and Nilsson, 1982; McGlynn and Kaszniak, 1991a). However, metamemory deficits on empirical tasks and questionnaires are often not observed in these patients until later in the progression of the disease (McGlynn and Kaszniak, 1991a). It has been hypothesized that memory ability is impaired early in the course of AD, while metamemorial abilities may be spared early in the disease.

Consistent with this hypothesis, a few studies have shown that monitoring abilities are intact early in the course of AD. In one study (Bäckman and Lipinska, 1993) mildly demented patients with AD and normal older adults made FOK judgments on a general knowledge test. On both tests of recall and recognition, no significant differences of monitoring ability were observed between the groups. However, as expected, the AD patients recalled and recognized less material than the control subjects. In a follow-up study, the authors varied the datedness of general knowledge questions (Lipinska and Bäckman, 1993). They had hypothesized that the AD patients may show better monitoring for older material than newer material. However, the patient group and the control group again did not differ in their metamemory judgments, regardless of the time of the material. Based on the results of these two studies, the authors suggest that monitoring is relatively intact during the early stages of AD.

In a series of studies investigating metamemory in AD patients on FOK tasks, JOLs, and global predictions memory, no differences were found between groups with respect to monitoring ability (Moulin et al., 2000a,b, 2003). In one experiment, subjects made JOLs regarding future recall (Moulin et al., 2000a). Gamma correlation differences between the AD group and control subjects were not significant. However, this statistic was based on only 10 of the 16 AD patients due to zero recall in 6 of the patients. The authors conclude that there is no metamemory deficit in AD patients at encoding. Another study by the same group investigated whether monitoring accuracy improves as a function of exposure to the task (Moulin et al., 2000b). In this study, AD patients were instructed to make predictions regarding their ability to remember words from a list. Results from the prediction data revealed that AD patients tended to overestimate their recall ability. However, the AD patients made a significant improvement with respect to their postdictions, after study, suggesting that they display some evidence of monitoring from memory. The authors state that AD patients

> . . . realize that they will not recall as many items as they initially thought. Such a shift in predictions must reflect attitudes of memory performance. If AD patients are monitoring memory, even in some gross manner, it is reasonable to try to improve their control of memory with behavioral interventions (p. 241).

Although there is thus experimental evidence of intact monitoring early in the progression of AD, several experimental studies have also shown the opposite. In one of the first experimental studies investigating metamemory in neurological populations, researchers found that patients in the early stages of AD were impaired in metamemory (Schacter et al., 1986). In this study, patients with memory problems caused by a closed-head injury, ruptured anterior communicating artery aneurysm, and AD made predictions of recall from a list of words. While each group of patients recalled fewer words than normal controls, only the AD patients were impaired with respect to metamemory.

Souchay et al. (2002) utilized an episodic memory task to investigate whether FOK deficits occur in early AD. In their study, subjects studied 20 cue–target pairs. Results indicated that their AD patients performed significantly worse than their control counterparts on FOK accuracy as measured by γ correlations and the Hamann score.

In a study by Duke (2000), mildly-to moderately-demented patients with AD engaged in an episodic sentence FOK task. In addition, subjects made predictions and postdictions for their learning on the CVLT. Results showed that patients with AD were less accurate in their predictions on these tasks than their caregivers, who served as control subjects.

Finally, Pappas et al. (1992) conducted in a study in which 12 AD patients with moderate cognitive decline made retrospective confidence and FOK judgments for general knowledge questions and newly learned sentences. Results showed that patients performed similar to normal control subjects on the retrospective confidence judgment task, yet were significantly worse than control subjects on the FOK task. AD patients had severe deficits in recall on the newly learned sentences task. The authors suggest that AD patients perform more poorly on predictions of future recognition than on recall judgments.

Summary. In summary, there are inconsistencies in the published literature with respect to metamemory impairments in Alzheimer's patients. However, a number of factors can be identified that may provide an explanation for the diversity of results.

One such factor is the type of monitoring task in which subjects participated. Some tasks were primarily in the semantic memory domain, such as the general knowledge task, whereas newly learned sentences form an episodic memory task. Episodic memory tasks may be more difficult for subjects to perform because they make greater cognitive demands than semantic memory tasks. A more difficult task may further require a greater degree of monitoring. In fact, each of the FOK studies that have shown differences in metamemory performance between AD patients and healthy control subjects utilized an episodic memory task, while the two FOK studies which utilized a semantic memory task (Bäckman and Lipinska, 1993; Lipinska and Bäckman, 1993) did not show differences between the groups.

Another factor that may influence results is how rating scales are used. In the Souchay et al. (2002) study, FOK judgments were limited to a yes/no forced choice, unlike most of the other studies, which include scales corresponding to a degree of FOK. Although having a forced-choice yes/no task can reduce the problem of restricted range that is common in studies examining patient populations, it also precludes the subject's ability to differentiate between degree of confidence. A related problem is that of variability in the number of metamemory judgments made between patients and healthy controls. This problem may be especially apparent on JOL tasks in which judgments are based on currently recallable items. Since AD patients have marked difficultly in recall, they may not be able to perform the JOL task.

A third factor that may influence results is task format. Studies in normal individuals show that people are generally more accurate on recall tasks than recognition tasks (Koriat and Goldsmith, 1998). However, recognition tasks may require more monitoring than recall tasks (Cabeza et al., 2003). In the semantic memory domain, it is possible that no differences were found between AD patients and control groups because all of the tasks were in recall format, which required subjects to first recall the answers to the questions posed to them. The one exception was the Bäckman and Lipinska (1993) study, in which subjects first made recall judgments on general knowledge questions and then recognition judgments on the same questions. Although there were no differences between groups on the two tasks, it is possible that subjects were able to adjust their monitoring by the time they participated in the recognition portion of the task. As Moulin et al. (2000b) show, mildly impaired AD patients are able to adjust their judgments to reflect better monitoring on postdiction tasks compared to their predictions. This suggests that future studies should be counterbalanced in administration to rule out the possibility that task placement will have an effect on the results.

Agnew and Morris (1998) have noted the inconsistencies in the AD anosognosia literature and have proposed a model to account for these inconsistencies. Specifically, they propose that there are subgroups of patients whose main metamemory impairments they classify as characterized by mnemonic anosognosia, executive anosognosia, or primary anosognosia. In mnemonic anosognosia, there is posited to be a failure in updating the personal knowledge contents of semantic memory, with the result being that the patient believes their memory to be functioning as it always has. In executive anosognosia, it is hypothesized that memory errors are perceived but that this does not result in a comparison with existing knowledge concerning the state of the individuals' memory functioning, due to dysfunction of central executive systems in which comparator mechanisms are posited to reside. In primary anosognosia, the signal from the hypothetical comparator mechanism, indicating a mnemonic error, is not registered in awareness.

In addition to such potential sources of heterogeneity in the metamemory impairments of AD, consideration must be given to whether depression exists as a comorbid condition. Depression occurs more frequently among persons with AD than is true for non-demented individuals of comparable age (Wragg and Jeste, 1989). As noted by Agnew and Morris (1998), despite the intuitive appeal of a hypothesized negative correlation between depression and dementia severity in AD (viewing depression as a psychological reaction to experienced cognitive loss, which then decreases as the capacity for self-monitoring deteriorates), empirical evidence in support of this hypothesis has been equivocal. Some studies have found depression to be more prevalent in mild as opposed to more severely demented AD patients while others have not (see Agnew and Morris, 1998 for a review). However, Smith et al. (2000) found the presence of depression in AD to be a moderating variable in the relationship between dementia severity and anosognosia for impaired functioning (as assessed by discrepancy between patient questionnaire self-report and caregiver observations).

Parkinson's Disease

Profile and Neuropsychological Performance. PD is a degenerative illness characterized by rigidity, bradykinesia, and a resting tremor. In addition to these prominent motor features, up to 40% of patients develop dementia (Collins, 1997). Cognitive deficits also occur in many non-demented patients. The types of cognitive deficits that occur in patients with PD (who do not manifest evidence of progressive dementia) are typically most apparent on neuropsychological tests sensitive to frontal lobe function (Bondi et al., 1993), hypothetically due to the disruption of semi-closed frontal–subcortical loop circuits from the dopaminergic denervation of basal ganglia input from the substantia nigra. In a study by Mortimer et al. (1990), 93% of a group of patients with PD had impaired performance on cognitive tests including those measuring processing speed, memory, abstract reasoning, and shifting between sets. PD patients may also have word production anomia, which may lead to the patient being in a "TOT" state more frequently than normal control subjects (Matison et al., 1982). Memory impairment in this disease is evidenced by poor recall of word lists, although patients can often benefit from cueing and recognition tasks (Breen, 1993). Patients with PD do not commonly have deficits in delayed recognition memory (Green, 2000). Poor recall but intact recognition suggests a deficit in retrieval strategies rather than in storage for these patients.

Metamemory in PD. There have been a few empirical studies evaluating metamemory deficits in PD. In a study conducted by Ivory et al. (1999), no differences were found in the accuracy of metamemory judgments between a non-demented PD group and a control group of age matched adults with non-neurological illnesses such as arthritis or osteoporosis. The task employed was a general knowledge test sampled from the task created by Nelson and Narens (1980). In addition, PD patients did not perform differently than matched controls on a test of verbal fluency, which is sensitive to frontal dysfunction, nor on tests of verbal memory.

PD patients often suffer from depression. It has been hypothesized that depression has an impact on monitoring the contents of memory. In a study conducted to assess this hypothesis (Coulter, 1989), depressed PD patients, nondepressed PD patients, and nondepressed control subjects participated in an FOK task. No differences were observed across groups; subjects performed equivalently on a recall from remote memory task.

In accordance with the results of experimental studies of metamemory in PD patients, research utilizing questionnaires and rating scales (Danielczyk, 1983; Seltzer et al., 2001) indicate that non-demented patients with PD do not show deficits in metamemory in comparison to healthy control subjects.

Given that PD patients generally have movement difficulty, are these patients aware of their deficits in the motor domain? In a study investigating metamemory and awareness of motor speed and motor dexterity in PD, patients performed similar to control subjects on a FOK metamemory task, but overestimated their motor dexterity abilities (Dellapietra, 1995). This study is intriguing because it raises the possibility that PD patients may generally perform well on metacognitive tasks, but may be underaware in the domain of their primary deficit, which is in the realm of motor function. However, other researchers have found that awareness of other motor problems (i.e., dyskinesias) is intact in PD patients (Vitale et al., 2001). Further study of anosognosia in PD is needed to clarify the relationship between PD and awareness of deficit.

Summary. There have been fewer studies examining metamemory deficits in PD patients than in AD patients. However, the studies that have been conducted with PD patients show there are no differences between these patients and healthy control subjects or non-neurologically ill groups. In addition, the results from studies utilizing experimental tasks are consistent with the results from questionnaire and rating scale studies in their indication that PD patients do not have deficits in metamemory.

However, it must be noted that the tasks employed in the studies described above were in the semantic, general knowledge domain. As is clear from the AD metamemory literature, patients may perform more poorly when the task is in the episodic memory domain. It remains to be seen whether PD patients will perform poorly on episodic FOK tasks.

In consideration of the possibility that the results of the above mentioned studies are not specific to the type of task (i.e., semantic memory) employed, there are reasons why PD patients may not show metamemory deficits. One possibility is that PD patients with normal performance on neuropsychological tests sensitive to frontal function may perform normally on metamemory tasks. It is indeed the case that not all patients with PD show deficits on neuropsychological tests (Green, 2000). As was seen in the Ivory et al. (1999) paper, no differences between PD patients and a group of medical control patients were found on metamemory or verbal memory tasks. It is not known whether PD patients who do have deficits in tasks sensitive to frontal function are also impaired in metamemory. This is a question that should be addressed in future studies.

Another possibility is that the type of damage that occurs in PD, mainly subcortical in nature, is not sufficient to produce a deficit in *monitoring* processes. PD patients may instead have deficits in control processes that were not measured in the metamemory paradigms used in published studies. An example of a control task would be one that investigates whether PD patients allocate sufficient amounts of study time to words they cannot recall, or whether they engage in rehearsal processes that would facilitate later recall. As is clear from performance on memory tasks such as the CVLT, PD patients do not often utilize fruitful strategies to enhance their memory performance (Buytenhuijs et al., 1994). It is possible that while PD patients monitor their memory accurately, their control processes are dysfunctional.

Huntington's Disease

Profile and Neuropsychological Performance. HD is an inherited degenerative disorder in which an abnormality occurs on chromosome 4, causing caudate nucleus and other degenerative brain changes that result in chorea, dystonia, and mood problems (Collins, 1997). HD may involve dysfunction in frontal–subcortical circuits (Cummings, 1993). Neuropsychological assessment typically reveals deficits in attention and executive function as evidenced by the Trail-Making Test (Army, 1944), WCST, Digit Span Backwards (Wechsler, 1997), and Mental Arithmetic from the WAIS-III (Butters et al., 1978; Josiassen et al., 1983). Memory deficits may include slow and inefficient retrieval from memory (Brandt, 1985). A meta-analysis of neuropsychological impairment in HD patients revealed that delayed recall was the most deficient in these patients, followed by measures of cognitive flexibility and abstraction (Zakzanis, 1998).

Metamemory in HD. As in PD, HD patients do not tend to show deficits in monitoring tasks. In a study conducted by Brandt (1985), 14 HD patients and 14 control subjects participated in a FOK task. The HD patients, described as "mildly-to-moderately demented," were administered a general information task containing questions developed by Nelson and Narens (1980). The subjects attempted to first recall the answer to the general knowledge question. Following six incorrect or "I don't know" responses, subjects were presented with paired items and asked to judge which item of the pair was associated with a strong FOK. The final task was an eight alternative multiple choice recognition task. A Goodman–Kruskal γ correlation between FOK ranks and recognition scores did not show significant differences between the HD patients and normal controls. However, HD patients did not spend as much time as healthy control subjects searching for items they felt they would be able to recall. This may explain HD patients' poorer recall performance. The author interpreted the finding as being consistent with the evidence that poor memory in HD patients is more likely due to memory search and retrieval deficits in HD, and that while monitoring processes are intact in HD, control processes are not.

In one study observing metamemory deficits in a group of patients with HD, McGlynn and Kaszniak (1991b) showed that patients rated themselves less impaired on everyday tasks than their relatives rated these same patients. However, when these patients engaged in a performance prediction task, they were not impaired in their metamemory judgments.

Summary. As the above two studies indicate, HD patients may be unlike Alzheimer's patients in that they perform as well as controls on experimental metamemory tasks. However, the tasks employed may not have been sufficiently sensitive to metamemory impairment. Future research with Huntington's patients should utilize FOK tasks in an episodic memory domain to study whether these patients suffer from prospective metamemory deficits. It was also found that while HD patients did not show deficits in monitoring processes, they may be impaired in control processes such as allocating time to search from memory.

Clinical reports of anosognosia in HD are contradictory. There are some reports that suggest HD patients do not retain insight into their illness. Meggendorfer in 1923 (cited in Bruyn, 1968) noted that a prominent feature of patients with HD type dementia is loss of insight. HD patients have been shown to be unaware of their dyskinesias, while Parkinson's patients are aware of these motor problems (Vitale et al., 2001). However, other clinical reports indicate that HD patients retain insight into their deficits until they become demented (Cummings and Benson, 1992). Differences in reports may depend on progression and severity of illness of the patients studied, whether the patients are clearly demented, and whether their cognitive deficits include frontal dysfunction.

HIV Infection

Profile and Neuropsychological Performance. Epidemiology reports of the Center for Disease Control (CDC) indicate that about 886,575 people had an acquired immune deficiency syndrome (AIDS) diagnosis between the years of 1998–2002 in the United States (CDC, 2002). While the number of new cases of AIDS diagnoses has remained relatively steady, the number of patients dying from AIDS has decreased in the past few years. This decrease in mortality is most likely due to the widespread availability and use of effective antiretroviral medications. As a result, more patients are living with human immunodeficiency virus (HIV) and AIDS in the United States. Consequently, any cognitive symptoms associated with the disease are important to document in order to provide the growing number of surviving patients with adequate care.

Studies have shown that a large percentage of patients with HIV infection suffer from cognitive decline, which can range from mild deficits to full dementia (Grant et al., 1987). About a third of asymptomatic patients infected with the HIV virus, but not meeting criteria for a diagnosis of AIDS, and 55% of patients meeting AIDS diagnostic criteria have been shown to have cognitive impairments, including deficits in attention, processing speed, and learning. In some patients, the constellation of cognitive impairments such as executive dysfunction, motor impairment, and processing speed are consistent with the pattern seen in subcortical dementias (Reger et al., 2002) such as HD (Navia et al., 1986).

Metamemory in HIV. A few studies have been conducted investigating metamemory deficits in patients with HIV infection, demonstrating discrepancies between subjective cognitive complaints and actual performance on neuropsychological measures. To the authors' knowledge, there have been no studies using a population of HIV infected patients that have employed metamemory experimental paradigms. Thus, the existing questionnaire-based metamemory literature in patients with HIV/AIDS will be reviewed with the hope that areas of further study can be identified for future online metamemory experiments in HIV patients.

In one study by Hinkin et al. (1996), subjects with advanced HIV infection rated their perception of cognitive decline on the Cognitive Failures Questionnaire (CFQ), and were then tested on the Wechsler Memory Scale-R (WMS-R), and the CVLT. Subjects were divided into two groups for analysis of data: one group was made up of HIV+ patients who had low scores on the CFQ, meaning that they denied cognitive problems in everyday life, and a second group made up of patients who had high scores on the CFQ, meaning they reported a lot of cognitive symptoms. Results showed that the low scoring patient group, on the whole, did worse on the memory measures than the high CFQ scoring group, suggesting the presence of metamemory deficits in a subset of an HIV+ population. These subjects also tended to be in more advanced stages of the disease process than other groups of subjects. To explain these results, the authors point out that HIV infection could disrupt frontal–subcortical pathways, resulting in impaired awareness of memory deficit.

Other studies have shown that HIV+ subjects' self-reports do not correspond well to their neuropsychological profiles (Moore et al., 1997; van Gorp et al., 1991). However, in most of these studies, HIV+ patients had a tendency to overreport symptoms of decline despite showing normal performance on neuropsychological tests. In addition, these studies show a correlation between psychiatric symptoms and cognitive complaints, suggesting that symptoms of depression may mediate the association between self-report and performance on neuropsychological tasks.

There are a number of studies that show a correlation between asymptomatic HIV+ subjects' self-report of cognitive decline and their performance on neuropsychological measures (Beason-Hazen et al., 1994; Mapou et al., 1993). In a more recent study conducted by Rourke et al. (1999), asymptomatic HIV+ subjects completed the Patient's Assessment of Own Functioning Inventory (PAOF) as a measure of subjective memory complaints, and then were administered a variety of neuropsychological tasks. In this study, 54% of HIV+ subjects' subjective complaints matched with their neuropsychological profiles, while 18% of subjects underreported cognitive decline. Those who underreported cognitive decline tended to do poorly on the CVLT and the WCST. No relationship was found between awareness of cognitive symptoms and estimated progression of disease in this study.

Summary. Research with HIV+ patients indicate that this group is heterogeneous with respect to measures of cognitive decline, awareness of cognition decline, and psychiatric symptoms. This is not surprising given that there is great variability in clinical presentation of the illness within HIV+ patients. Questionnaire-based metamemory studies have found subgroups of patients that vary in the awareness of their memory deficits. One subgroup consists of patients who are symptomatic and are acutely aware of their cognitive decline. Other symptomatic patients are not fully aware of their cognitive deficits, and at least one study has found that unawareness is related to disease severity. Another subgroup consists of patients who do not suffer from cognitive decline as assessed by standard neuropsychological testing, yet overreport cognitive deficits. An important likely mediator in these findings is psychiatric symptoms, which are associated with overreporting of cognitive decline symptoms.

A significant research opportunity in studying metamemory in HIV patients relates to the heterogeneity of the population with respect to cognitive decline and executive dysfunction. Future studies could address whether the patients who are most unaware of their cognitive deficits have a pattern of impaired performance on neuropsychological tests sensitive to frontal dysfunction. In addition, studying this population could shed light on the neural and psychiatric correlates of "overreporting" memory decline and cognitive symptoms. This line of research could have implications for psychotherapeutic approaches in this population, as well as for the further understanding of processes contributing to accurate self-awareness.

CONCLUSIONS AND FUTURE DIRECTIONS

A summary of the results across neurological groups are presented in Table 1. In addition, we summarize below some conclusions that can be drawn from the reviewed metamemory literature.

What Have We Learned About the Neural Correlates of Metamemory?

Results across metamemory studies in neurological populations are consistent with the conclusion that the frontal lobes play a central role in the production of accurate metamemory judgments. This conclusion is strongly supported by studies with frontal damaged patients (Janowsky et al., 1989a,b; Schnyer et al., 2004; Vilkki et al., 1999), in addition to studies that have shown patients who perform poorly on neuropsychological tasks sensitive to frontal lobe function have deficits in metamemory (Beatty and Monson, 1991).

Furthermore, results from the studies reviewed above indicate that patients with memory loss in addition to frontal lobe dysfunction, typical of the syndromes that occur in dementia and Korsakoff's syndrome, perform the most poorly on metamemory tasks. One possible explanation is that metamemory is inextricably linked to memory retrieval processes and is therefore always associated with severe memory loss. However, this explanation cannot account for the amnesia associated with temporal lobe damage literature, which has shown that restricted damage to temporal lobe structures (and therefore deficits in memory) is not accompanied by poor metamemory. It can be concluded from such results that metamemory and memory are dissociable processes.

Studies conducted with frontal lobe damaged subjects support the claim that frontal lobe dysfunction, in conjunction with poor memory, is the condition under which metamemory deficits are the greatest. The poorest metamemory performance in frontal damaged patients was observed when the metamemory task required an effortful episodic memory task (Schnyer et al., 2004), or the memory trace was weakened after adding a delay between study and test periods (Janowsky et al., 1989a,b). In addition, deficits within a particular domain of memory may lead to relatively greater metamemory deficits in that domain. For instance, Prevey et al. (1988) showed that patients with left TLE had more deficits on a verbal metamemory task than right TLE patients. This suggests that metamemory deficits are greatest in areas in which memory performance is weak to begin with. Taken together, these results are consistent with other data (such as that from the false memory literature, see Rapcsak et al., 1999) that suggest frontal lobe dysfunction to be associated with poor mnemonic, retrieval, search, and monitoring of memory processes.

Are Different Metamemory Judgment Tasks Related?

Metamemory tasks differ in many respects, but purport to measure the same underlying constructs of monitoring and control processes. Metamemory judgments can be made prior to the study of new information (EOL), after a study period (JOL), following retrieval of information (retrospective confidence), or regarding future retrieval of currently unrecalled information (FOK). Given the differences in metamemory tasks, it is crucial to investigate whether these tasks are in fact measuring the same underlying constructs and whether changes in task protocol will significantly change the outcome of results. Although we have evidence from the literature on healthy younger and older adults regarding similarities and differences between the different tasks, there is no way to distinguish between the underlying mechanisms unless it is investigated in patients who may have an impairment in some of the processes. In this way, research involving patients can shed light on the processes that may be similar in all metamemory tasks, and determine whether some metamemory tasks are not as affected by disease.

A number of the metamemory studies reviewed above utilized more than one metamemory task, as well as varied the memory domain in which their task was presented (episodic vs. semantic memory), providing the opportunity to compare subject performance between two or more different tasks. Results typically showed that patients did not perform uniformly on the various

Table 1. Summary of Published Metamemory Studies

Neurological group	Reference	Method	Results
Korsakoff's and amnesia	Bauer et al. (1984)	Global predictions	Korsakoff's < Control
	Shimamura and Squire (1986)	FOK	Korsakoff's < Control
Focal frontal patients	Janowsky et al. (1989b)	FOK	Frontal < Control on delayed FOK
			Frontal = Control on semantic FOK
	Pannu et al. (under review)	FOK	Frontal = Control on FOK task
		RCJ	Frontal < Control on RCJ
	Schnyer et al. (2004)	FOK	Frontal < Control on FOK task
		RCJ	Frontal = Control on RCJ
	Vilkki et al. (1998)	JOL	Right frontals < Control
	Vilkki et al. (1999)	JOL	Right frontals < Control
Multiple sclerosis	Beatty and Monson (1991)	FOK, global predictions	Subset of MS patients < Control
	Scarrabelotti and Carroll (1999)	JOL	MS patients < Control on exclusion task
Traumatic brain injury	Kennedy (2001)	RCJ	TBI = Control
	Kennedy and Yorkston (2000)	JOL	TBI = Control
	Kennedy et al. (1995)	JOL	Mixed results
	Kennedy et al. (2003)	JOL	TBI = Control
Temporal lobe epilepsy	Prevey et al. (1988)	JOL, FOK	TLE < Control
	Prevey et al. (1991)	FOK	TLE = Control
	Rapcsak et al. (in preparation)	FOK, RCJ	TLE = Control
Alzheimer's disease	Bäckman and Lipinska (1993)	FOK	AD = Control
	Duke (2000)	FOK	AD < Control
	Moulin et al. (2000a)	JOL	AD = Control
	Moulin et al. (2000b)	Global predictions	AD < Control
		Postdictions	AD = Control
	Moulin et al. (2003)	RCJ	AD = Control
	Lipinska and Bäckman (1993)	FOK	AD = Control
	Pappas et al. (1992)	FOK	AD < Control on FOK
		RCJ	AD = Control on RCJ
	Schacter et al. (1986)	Global predictions	AD < Control
	Souchay et al. (2002)	FOK	AD < Control
Parkinson's disease	Coulter (1989)	FOK	PD = Control
	Dellapietra (1995)	FOK	PD = Control
	Ivory et al. (1999)	RCJ	PD = Control
Huntington's disease	Brandt (1985)	FOK	HD = Control
	McGlynn and Kaszniak (1991b)	Predictions	HD = Control
HIV	Beason-Hazen et al. (1994)	SIP, HRSD	Positive correlation: subjective complaint and NP
	Hinkin et al. (1996)	CFQ	Subset of HIV+ patients had impaired monitoring
	Mapou et al. (1993)	Structured interview	Positive correlation: subjective complaint and NP
	Moore et al. (1997)	Structured interview	No correlation: subjective compliant and NP
	Rourke et al. (1999)	PAOF	Positive correlation: subjective complaints and NP
	van Gorp et al. (1991)	CFQ	HIV+ patients = Control

Note. FOK—Feeling-of-knowing judgments, JOL—Judgments of learning, RCJ—Retrospective confidence judgments, HIV—Human immunodeficiency virus, SIP—Sickness impact profile, HRSD—Hamilton Rating Scale of Depression, CFQ—Cognitive Failures Questionnaire, PAOF—Patient's assessment of own functioning inventory, NP—Neuropsychological test results.

metamemory tasks, suggesting that different metamemory tasks may not assess the same cognitive processes. A number of factors contribute to these results which have implications for how future studies should be designed. One factor is that different tasks may tap different underlying aspects of the broad construct of metamemory. Some tasks make demands upon prospective memory, such as making judgments about future performance, while other tasks require retrospective memory. These two types of memory may involve different processes, and may tap into different stages of the retrieval and reflective process. Retrospective confidence judgments are based on already retrieved information, so there is not as great of a need for inferential processes as in other metamemory tasks.

There is evidence that various patient groups (i.e., TBI, Alzheimer's, focal frontal damaged patients) perform as well as healthy control subjects on retrospective confidence judgments (Kennedy, 2001; Pappas et al., 1992; Schnyer et al., 2004. For an exception, see Pannu et al., in press). EOL judgments are perhaps the most inferential type of judgment because these are made before study periods and before recall and recognition is elicited. Thus, frontal damaged patients might be expected to perform the most poorly on EOL tasks. This hypothesis has not yet been tested in frontal damaged patients. However, such as study would need to take note that EOL judgments are perhaps the most difficult type of metamemory judgments—it has previously been shown that healthy control subjects' EOL judgments are not as strongly correlated with later recognition as their JOL and FOK judgments (Leonesio and Nelson, 1990). Therefore, such a study would need to equate for difficulty between EOL and FOK or JOL tasks.

Task format may be another variable that affects subjects' performance. Metamemory tasks can vary on whether the initial memory attempt occurs within a recall or a recognition format. For instance, within a retrospective confidence judgment paradigm, a subject may be asked to recall an answer prior to the confidence judgment, or choose an answer from multiple choices. One study provides some evidence that frontal damaged patients perform poorly on a retrospective confidence judgment task that is based on a multiple choice format, than one based on a recall task (Pannu et al., in press). The authors suggest that this finding is due to the possibility that under free recall conditions, a subject already has an indication of whether he or she was able to recall the target word or not, which may lead to a better calibration of the memory attempt. A subject, failing to recall information from memory, may feel less confident that he or she will later recognize the target. However, on a recognition test, the subject is not required to search from memory, but merely pick one answer. Thus, in a recognition metamemory task, the subject is not required to recollect any information at all, but simply required to make a decision based from the options given. The frontal damaged subject, with faulty monitoring processes, may be lured to choose items with high confidence on a recognition task because he or she does not receive negative feedback, thus leading to inaccurate metamemory judgments.

Dissociations Between Metamemory and Other Constructs

As stated above, metamemory has been proposed to consist of monitoring and control mechanisms. These processes may function to facilitate memory retrieval by guiding search. For instance, it may be the case that a FOK drives a person to search their memories longer because they are relatively certain that the information exists in memory. JOL can also facilitate learning. People can judge the time it takes to learn information and can plan accordingly, increasing study time if they perceive learning of that item to be difficult. Therefore, metamemory could be an important adaptation of memory that guides and facilitates encoding and retrieval in memory. Given that metamemorial processes can assist in forming learning strategies, one might assume that there is a close correspondence between the use of semantic clustering on tasks such as the CVLT and performance on metamemory tasks. However, metamemorial processes can be dissociated from memory retrieval strategies such as semantic clustering. This point is highlighted by the literature concerning Parkinson's patients, which has shown that PD patients have poor retrieval strategies on tasks such as the CVLT, with consequent free recall impairment (Bondi and Kaszniak, 1991; Buytenhuijs et al., 1994), and yet these patients seem to perform as well as healthy control subjects on metamemory tasks. This suggests that the enactment of retrieval strategies is not entirely dependent upon feedback from metamemory, and, as is possible in PD patients, metamemory may not necessarily affect the initiation of strategies that will facilitate recall. One way to address this issue further would be to employ a JOL task in a population of PD patients. The hypothesis would be that PD patients do not search longer from memory or study difficult items for longer periods of time, suggesting that the patients do not utilize metamemory cues to enhance memory retrieval.

Another dissociation apparent from the literature is that between global judgments of memory and specific judgments of memory for a particular task. In the neurological literature, there are reports of TBI patients having a profound unawareness of their deficits (Prigatano, 1991), as seen in daily interactions and when patients make general assessments of their cognitive abilities. However, there is little evidence to show that TBI patients perform more poorly than healthy control subjects on metamemory tasks (Kennedy, 2001; Kennedy and Yorkston, 2000; Kennedy et al., 1995, 2003), although there has not yet been sufficient testing of this neurological group on metamemory measures other than JOL and performance prediction tasks. McGlynn and Kaszniak (1991a) suggested that a split between clinical reports and experimental tasks may be due to differential demands on various aspects of the metamemory construct that underlie the two types of reports; patients may not be accurate when asking them to think about their abilities abstractly, while they retain some insight when asked to predict their abilities in specific motor and cognitive domains. Patients may not retain a self-generated, general awareness of their deficits but do have the ability to make introspective, specific judgments of their memory when encouraged to do so on a metamemory task. One possibility for this occurrence is that patients may receive internal feedback from a specific memory test as they are performing the task. Lopez et al. (1994) showed that before engaging in neuropsychological tasks, 44% of AD patients denied memory problems. However, after participating in various tasks, more AD patients agreed that they had cognitive difficulties. Thus, participation in memory tasks could provide feedback for patients and this could contribute to more accurate assessments. However, the cognitive and neural processes that are involved in global assessments of memory and specific judgments needs to be explored further.

What Questions Still Need to Be Addressed?

The lesion-based neuropsychological studies in various patients groups have underscored the involvement of the frontal lobes in accurate metamemory performance. At this point, we can go beyond the question of whether the frontal lobes are involved in metamemory, and ask more fruitful questions regarding the specific components of metamemory and the role of brain circuits that underlie these components to bring about successful retrieval from memory. One question that needs to be addressed is the role that metamemory judgments play in encoding and retrieval process. For instance, how do FOK assist in pointing to the memory trace of the to-be-retrieved information? Are there different brain regions involved in successful retrieval versus unsuccessful retrieval accompanied by a FOK? Are different brain regions involved in retrospective confidence judgments versus prospective confidence judgments? Some of these questions have been, and are in the process of being addressed, by functional neuroimaging methods. Neuroimaging studies can indicate the brain areas that are activated during normal metamemory processes and provide converging evidence to neuropsychological studies. A few studies have investigated whether there are different activations for a FOK experience versus successful retrieval.

Maril et al. (2003) investigated the FOK during encoding and retrieval of episodic memory utilizing event-related fMRI. During retrieval, a graded activation pattern was observed, with activation greatest during successful retrieval, intermediate for the FOK condition, and the lowest for unsuccessful retrieval. This pattern was observed in a number of brain regions, including the anterior cingulate, the inferior frontal gyrus, and in the parietal cortex. The authors suggest that this pattern may reflect the amount of information that is manipulated and maintained in working memory and argue that during successful retrieval, more information is being retrieved and manipulated than during the FOK and unsuccessful retrieval conditions. During encoding, a left posterior parahippocampal region was observed to reflect the overlap of encoding and successful retrieval. This study provides an intriguing look into the neural correlates of the FOK. The results suggest that the brain regions involved in successful retrieval are also those that are involved in the FOK, but are more activated in the successful retrieval condition. However, other fMRI studies have isolated specific areas that are more involved in metamemorial judgments than in successful or unsuccessful retrieval.

One such study investigated the role of cognitive conflict during TOT states in healthy young adults (Maril et al., 2001). The authors suggest that the TOT phenomenon reflects a conflict between confidence of semantic knowledge and the failure to retrieve that knowledge. In this study, young adults attempted to retrieve the answers to general knowledge questions, and then made “know,” “TOT,” and “don’t know” responses. Results showed that the TOT experience was associated with activity in the anterior cingulate (ACC) and right middle frontal cortex, consistent with the literature indicating that the ACC-prefrontal cortex network is typically associated with error detection and other cognitive control processes (Banfield et al., 2004). Thus, the results from the Maril et al. (2001) study support the hypothesis that TOTs arise from inferential processes that are unique from successful retrieval. This result was also found in a similar study utilizing face stimuli (Pannu et al., 2004b). In this study, the FOK was associated with ACC and medial frontal cortex. These studies raise questions regarding the relationship between metamemory, cognitive conflict, and error monitoring. Goldberg and Barr (1991) have proposed that awareness of deficit can result from a lack of “local” error monitoring (e.g., perseveration on a task), and “global” error monitoring (e.g., lack of concern about diminished cognitive capability). The ACC-medial PFC system may be a crucial region in providing the feedback necessary for accurate metamemory judgments. For instance, if a subject cannot successfully recall an item at test, but a FOK is present, he or she may receive feedback that the metamemory judgment needs to reflect that state of unsuccessful retrieval accompanied by a FOK. Disruption of this system may lead to inaccurate metamemory judgments and poor self-awareness of cognitive ability. Thus, it appears that error monitoring and metamemory are closely tied. This hypothesis could be further investigated with a metamemory study combining ERP methods (i.e., error-related negativity) with fMRI. If TOT judgments, for example, were associated with error-related negativity and the ACC-medial PFC region, it would make a compelling argument in support for the role of error monitoring in accurate metamemory.

Although future neuroimaging studies should provide additional knowledge about the neural correlates of metamemory, there are some questions it cannot address. For instance, the FOK responses that were analyzed in the above neuroimaging studies only reflect an unsuccessful retrieval attempt. However, it is possible that FOK drives all of the successful responses as well, but the FOK is ignored in those cases because the response is categorized as a successfully retrieved item. Thus, the activation associated with successful retrieval may include an early FOK component as well. To understand the differences between successful and unsuccessful retrieval, the time course of FOK and subsequent retrieval is necessary to obtain, which may not be possible with current fMRI temporal resolution.

Other questions that should be addressed further relate to the specific components of metamemory and how they are related to executive function processes. Although Nelson and Narens (1990) have proposed a general framework consisting of monitoring and control, the role of these processes are poorly understood. For instance, how are these processes related to source monitoring and the processes, when impaired, that are responsible for confabulation? One way to address this issue may be to include a host of neuropsychological tasks when assessing metamemory in patient groups. Poor metamemory may be related to retrieval deficits, poor attention, and other components of executive function. If neuropsychological measures differentially correlate with metamemory, it may provide clues about the specific components necessary for accurate judgments of memory. Souchay et al. (2000) found that healthy older adults who scored lower on neuropsychological tasks sensitive to frontal lobe function also performed more poorly on metamemory tasks. It may be possible to identify the specific components of frontally sensitive neuropsychological tests through factor analysis. For instance, some tasks may load more heavily on working memory factor, while other neuropsychological tasks load more heavily on a different factor that depends on frontal lobe function. If this approach proved to be tenable, perhaps the specific component processes that are involved in metamemory could be identified.

An additional area that has not been addressed to a great extent is the relationship between underawareness of memory and hyperawareness, which may cause a subject to report a poorer memory than they actually have. It is likely that psychiatric symptoms, particularly those of depression, may play a role in hyperawareness. Some depressed individuals may exhibit excessive worry about their memory despite relatively normal memory performance. Others, however, may underestimate their memory abilities in association with a general hopelessness in regard to self-efficacy. Thus, under certain circumstances, symptoms of depression may be related to apparent better insight of a disorder. In a study of psychiatric symptoms in AD patients, it was found that patients who reported that they experienced hopelessness (as measured by the Hamilton Depression Rating Scale) also were rated as having more insight into their cognitive impairment (Harwood and Sultzer, 2002). As the disease progresses, a patient who recognizes declines in their cognitive ability may experience greater despair and helplessness, while a patient who is unaware to these declines may not. Further investigation of the relationship between deficit awareness and depression could lead to the development of specific therapeutic intervention plans for patients who are coping with the realization that they suffer from AD.

Finally, additional research is needed on the relationship between metamemory inferred from interview or questionnaire responses and performance on experimental tasks. Conclusions concerning the question of whether metamemory is impaired in a particular neuropsychological syndrome may vary as a function of whether relevant evidence is based upon interview, questionnaire, or experimental task data. Variance in the results obtained from these different methods can reflect patient sampling differences (e.g., in terms of severity of memory impairment or presence of additional associated deficits). However, such variance may also reflect fundamental differences in what the methods are actually measuring. When a patient is asked, in interview or via questionnaire items, to assess the extent or severity of their own memory difficulty, answers may be provided that do not necessarily reflect online monitoring of the individual's own memory contents or processes. Thus, when asked such questions, the patient may attempt to recall prior instances of memory failure or difficulty. The presence of episodic memory impairment would be expected to result in a minimization of memory difficulty (in comparison to the reports of others who observe the patient's day-to-day memory abilities or objective memory task performance), since few such instances might be recalled. Similarly, if the patient attempts to access some more general mental representation of their own memory self-efficacy, and (due to anterograde episodic memory impairment) this representation has not been sufficiently updated to reflect their current functioning, answers to interview questions or questionnaire items could be expected to suggest metamemory impairment. In contrast, FOK task performance, requiring the monitoring of present memory contents and processes, might suggest more intact metamemory functioning. Alternatively, it is also possible for the opposite pattern of results to obtain if a patient with a chronic memory impairment has acquired (via intact semantic and procedural memory systems and the repetitive feedback of caregivers and others). In such a case, the patient could provide answers to direct questions that suggest awareness of their memory impairment, while FOK task performance could reveal metamemory impairment (if the hypothesized mechanisms of memory self-monitoring are indeed dysfunctional).

The relationship between metamemory performance, as observed in the laboratory setting, and behavior outside of the laboratory, in everyday life has also not been thoroughly explored. For instance, would a person with poor performance on an experimental metamemory task also fail to use mnemonics to remind themselves of important dates, such as a doctor's appointment? It is conceivable that a person who is not aware of their memory deficit would not see the need to use mnemonics at all. Investigations of such issues may perhaps lead to better diagnostic indicators of the problems that arise in everyday life, allowing for appropriate intervention.

In conclusion, metamemory task performance provides one indicator of self-awareness of memory ability. Metamemory research is important because it allows an empirical approach to the broad construct "self-awareness," and can be extended as a framework to explore the processes and neural underpinnings of other cognitive, social, and sensory domains. Moreover, research on metamemory is important in its own right, because it has implications for wide-ranging issues, such as decision making (Rapcsak et al., 1999), eye-witness testimony (Koriat and Goldsmith, 1996), psychiatric disorders (McGlynn and Kaszniak, 1991b), and neurorehabilitation (Kennedy et al., 2003). The present review of metamemory experiments in neurological populations shows that there is a relationship between indices of frontal lobe function and metamemory accuracy, and that there are many variables that affect metamemory performance such as type of memory task (i.e., semantic or episodic task, prospective or retrospective task), format of memory task (recall or recognition), type of metamemory judgment to be made (FOK, JOL, etc.), and mood. In addition, areas of future study were proposed in order to gain a more comprehensive understanding of the processes and neural correlates of metamemory. Although there remain many unanswered questions, studying neurological populations has facilitated our understanding of the cognitive mechanisms that underlie metamemory.

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