INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI
Bell & Howell Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600
EPISODIC MEMORY FOR PERSONALLY RELEVANT INFORMATION:
EVIDENCE FROM AGING, DIVIDED ATTENTION AT RETRIEVAL,
AND POSITRON EMISSION TOMOGRAPHY

by

Tara Michelle Moroz

A thesis submitted in conformity with the requirements
for the degree of Doctor of Philosophy
Graduate Department of Psychology
University of Toronto

© Copyright by Tara Michelle Moroz (1999)
The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

L’auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author’s permission.

L’auteur conserve la propriété du droit d’auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.
Three components of episodic memory are retrieval content, retrieval success, and retrieval experience. These components, as they relate to episodic memory for personally relevant information, were investigated in two behavioral experiments and in a positron emission tomography (PET) experiment; the PET study investigated the neural correlates of the three components with particular attention paid to changes in frontal activity. In each experiment retrieval content was investigated by comparing the retrieval of adjectives that were processed in one of four ways: in terms of the self, another person, social desirability, or phonological structure. Retrieval success was investigated by comparing recognition performance across the four conditions and/or between groups. Retrieval experience was investigated by using a “remember/know” (R/K) recognition procedure; R responses index retrieval that is accompanied by a “re-experiencing” of aspects of the
encoding episode whereas K responses index retrieval based on a feeling of familiarity.

The retrieval content results suggest that the retrieval of category specific information engages anterior cortical areas when the category is personally or socially relevant. The retrieval success results support previous suggestions of right frontal involvement. The retrieval experience results suggest that increases in frontal activity are more correlated with K responses than R responses. Additional frontal regions may be recruited for K responses to verify and monitor the output, and to engage additional strategic search processes to try to change K responses to R responses. R responses primarily engaged limbic regions and anatomically related structures that may deliver their output to right frontal regions or be “switched on” by them.

The PET results converge with the results of the two behavioral studies. Relative to young adults under full attention, the R scores of old adults were smaller in only the self-reference and social desirability conditions, and young adults who divided their attention at retrieval performed similarly to old adults; previous studies have suggested that divided attention and aging affect frontal function.

The present series of experiments shed light on the neuro-cognitive system that mediates the retrieval of self-referential information. The experiments revealed different components of episodic memory that contribute to the cognitive processes and patterns of neural activity associated with episodic memory for personally relevant information.
ACKNOWLEDGMENTS

Many people from different facets of my life contributed to the completion of this thesis. First, I would like to thank my supervisor, Morris Moscovitch, who provided an environment that was challenging and rewarding, both intellectually and personally. I am also very grateful for the help that I received from my “number one” committee member, Gus Craik, whose influence was greater than I think he realizes. I feel very fortunate to have had the opportunity to work closely with both Morris and Gus. I also thank the remainder of my stellar committee, Cheryl Grady, Randy McIntosh, Art Shimamura, and Don Stuss for their insightful comments on my thesis.

I could not have had better lab-mates/friends. I am indebted to Jessica Goldberg, Amy Siegenthaler, Margaret McKinnon, and Myra Fernandes for their support through the ups and downs of graduate student life. Thanks are also extended to Nicole Anderson and Stefan Köhler who were superb role models; I shall live an academic career vicariously through them.

Two University of Toronto Open Scholarships, a National Science and Engineering Council of Canada Scholarship, and an Ontario Graduate Studies Scholarship supported me financially throughout my Ph.D. degree.

Special thanks go to three truly special people, my mom, dad, and sister, for their constant encouragement and for always being there for me.

Finally, I thank my best friend and fiancé, Carl Noel, for his unconditional love and support – because of him my life is filled with sunshine and smiles.
TABLE OF CONTENTS

OVERVIEW 1

CHAPTER 1 8

REMEMBERING SELF-REFERENTIAL INFORMATION: THE EFFECTS OF AGING AND DIVIDED ATTENTION AT RETRIEVAL 8

INTRODUCTION 8

METHOD 17

Participants 17

Task Design 18

RESULTS 23

Encoding 24

Reaction Time (RT) 24

Retrieval 25

Recognition 25

Reaction Time (RT) 29

Neuropsychological Tests 34

Correlations Between Test Scores and Remember and Know Scores 35

DISCUSSION 36

EXPERIMENT 2 40

METHOD 45

Participants 45

Task Design 47

RESULTS 48

Encoding 49

Reaction Time (RT) 49

Retrieval 51

Secondary Task Performance 51

Recognition 51

Reaction Time (RT) 57

DISCUSSION 62

GENERAL DISCUSSION 65

Mnemonic Similarities of Self-Reference and Social Desirability 66

Knowing: Unaffected by Aging, Divided Attention, and Level of Processing 71

Retrieval Success and Retrieval Experience can be Differentiated 72

SUMMARY OF CHAPTER 1 78

CHAPTER 2 80

NEURAL CORRELATES OF THE RETRIEVAL OF SELF-REFERENTIAL INFORMATION: I. CATEGORY SPECIFIC RETRIEVAL 80

INTRODUCTION 81

METHODS 86

Participants 86

Cognitive Task Design 86

PET Scanning Techniques 90
LIST OF TABLES

Table 1. Demographics of the participants in Experiment 1 .............................................. 17

Table 2. Average overall recognition of words and average recognition of words classified as remembering or knowing by young and old adults in Experiment 1 for four levels of processing. .......................................................... 26

Table 3. Average reaction time (ms) for hits and hits classified as remember responses and know responses by young and old adults in Experiment 1 for four levels of processing ................................................................. 31

Table 4. Average neuropsychological test scores for young and old adults (standard errors in parentheses). * ................................................................. 35

Table 5. Demographics of the participants in Experiment 2 .............................................. 47

Table 6. Average overall recognition of words and average recognition of words classified as remembering or knowing by young adults under full attention (Y-FA), young adults who divided attention at retrieval (Y-DA), and old adults in Experiment 2 for four levels of processing. .................. 52

Table 7. Average reaction time (ms) for hits and hits classified as remember responses and know responses by young adults under full attention (Y-FA), young adults who divided attention at retrieval (Y-DA), and old adults in Experiment 2 for four levels of processing .............................................. 59

Table 8. Peaks of brain regions with stable positive and negative saliences from LV1 (Self) ................................................................................................................ 97

Table 9. Peaks of brain regions with stable positive and negative saliences from LV2 (Other) ........................................................................................................... 100
Table 10. Peaks of brain regions with stable positive and negative saliences from LV3 (Social Desirability). .............................................................. 103

Table 11. Coordinates (Talairach & Tournoux, 1988) of brain activity observed in the medial aspect of the frontal lobe (Brodmann's area 8/9) in the Self LV in the present experiment and in previous 'theory of mind' PET investigations................................................................. 112

Table 12. Mean proportion of hits/misses, proportion hits minus proportion false alarms (FA), and proportion of hits that were remember/know responses in each condition (standard error in parentheses).......................... 138

Table 13. Mean response time (ms) for correct remember responses and correct know responses in each condition (standard error in parentheses). ............... 141

Table 14. Peaks of brain regions (stable positive saliences) that correlated with increased hits................................................................. 144

Table 15. Peaks of brain regions (stable negative saliences) that correlated with increased misses............................................................. 145

Table 16. Peaks of brain regions (stable positive saliences) that correlated with increases in the retrieval experience of remembering............................ 149

Table 17. Peaks of brain regions (stable negative saliences) that correlated with increases in the retrieval experience of knowing.............................. 150
LIST OF FIGURES

**Figure 1.** Average normalized brain score in each condition in LV1.................................98

**Figure 2.** Singular image of LV1 (Self)..................................................................................99

**Figure 3.** Average normalized brain score in each condition in LV2.................................101

**Figure 4.** Singular image of LV2 (Other).................................................................................102

**Figure 5.** Average normalized brain score in each condition in LV3.................................104

**Figure 6.** Singular image of LV3 (Social Desirability)..........................................................105

**Figure 7.** Correlations between brain score and proportion of hits in each condition.................................143

**Figure 8.** Singular Image of Hits/Misses.................................................................................146

**Figure 9.** Correlations between brain score and proportion of correct remember responses in each condition........................................................................148

**Figure 10.** Singular Image of Remembering/Knowing..........................................................151
Appendices

Appendix A: Participant Screening Questionnaire.................................................................202
Appendix B: Mill Hill Vocabulary Test (Shortened Version).................................................203
Appendix C: Word Lists of Personality Trait Adjectives......................................................204
Appendix D: Test Instructions...............................................................................................209
Appendix E: Frontal Lobe Cytoarchitectonic Designations in Chapter 2:
  Brodmann (Talairach & Tournoux, 1988) and Petrides and Pandya
  (1994)......................................................................................................................................219
Appendix F: Frontal Lobe Cytoarchitectonic Designations in Chapter 3:
  Brodmann (Talairach & Tournoux, 1988) and Petrides and Pandya
  (1994)......................................................................................................................................220
OVERVIEW

A conscious image, then, whether recognition or recollection, is the consequence of complex neurophysiological interactions; in it the person's past and present experiences are integrated, and the subjective, self-referential quality is of its very essence.

- Israel Rosenfield (1992, p.86)

One aspect of self that has been investigated by cognitive psychologists and neuropsychologists is self-related memory, that is, how personally relevant information is processed and recollected. Self-related memory is interesting for two primary reasons. First, encoding material in terms of the self is mnemonically advantageous in that it produces the self-reference effect (SRE), that is, better memory for material that is processed in terms of the self than for material that is processed in other ways (reviewed by Symons & Johnson, 1997). Second, self-related memories may be accompanied more frequently by a higher level of conscious awareness (i.e., "self-knowing" or autonoetic consciousness; Tulving, 1985) than are other types of memories (Conway & Dewhurst, 1995). The cognitive and neural processes that mediate the SRE and the cognitive and neural processes that mediate autonoetic consciousness, however, remain largely unknown.

The self is not a unitary concept. Several levels of self have been proposed, and the different levels have been associated with the development and evolution of other mental capacities (e.g., Stuss, 1991; Mitchell, 1994; Suddendorf & Corballis, 1997). Self, as it is considered in studies of the SRE, represents a category or domain
of information. Although self as a category of information may be present throughout the human life span and in many non-human animals, the self category is typically accessed in studies of the SRE concomitantly with other higher cognitive capacities (e.g., imagination, mental time travel, language, judgments, and comparisons). Therefore, the presence or absence of other mental capacities will color the representation of self that is recovered when the self category is accessed.

In addition to multiple levels of self, it is well established that memory is not a unitary phenomenon. Memory is composed of several relatively independent systems (e.g., Tulving, 1995). Tulving (1985) proposed that different memory systems are associated with different levels of consciousness. Specifically, he proposed that procedural, semantic, and episodic memory systems correspond to anoetic (non-knowing), noetic (knowing), and autonoetic (self-knowing) consciousness, respectively. Procedural memory is memory for how things are done (e.g., riding a bike), and is associated with anoetic consciousness which is a level of consciousness that is bound to action and to the perception of the here and now. Semantic memory is memory for facts (e.g., knowing that the capital of Canada is Ottawa), and is associated with noetic consciousness which is a level of consciousness that allows the organism to operate on objects and events in their absence. Episodic memory is memory for specific, personally experienced events (e.g., remembering that you got wet walking to work yesterday because you forgot your umbrella), and is associated with autonoetic consciousness which is the highest level of consciousness. It allows the organism to remember a personally experienced event as a veridical part of himself or herself, as well as the personal
feel associated with remembering a personally experienced event. Autonoetic or “self-knowing” consciousness is intimately linked to the self.

Of these three levels of consciousness, autonoetic consciousness has received the most attention. Based on Ingvar’s ideas and observations of a patient (N.N.), Tulving (1985) listed six properties of autonoetic consciousness: it encompasses the personal past, present and future, it appears at a later developmental stage, brain damage can selectively impair it, it is variable, and it is measurable. He also suggested that autonoetic consciousness is necessary for “remembering” events but not “knowing” events. Remembering and knowing are subjective reports of the retrieval experience that accompanies the recovery of stored information, and are indexed by remember or R responses and know or K responses, respectively. The R/K paradigm is based on the idea that some items will be accompanied by details of the prior presentation of the item (e.g., the personal thoughts or associations that accompanied the apprehension of the item), whereas other items only will be accompanied by a feeling of knowing that the item was presented but without the accompaniment of additional details about the item’s presentation. The former type of response, a R response, is accompanied by autonoetic consciousness, whereas the later type of response, a K response, is accompanied only by noetic consciousness.

More recently, Wheeler, Stuss, and Tulving (1997) described the relationship between autonoetic consciousness and episodic memory, and proposed that the frontal lobes provide adult humans with the necessary neural basis for autonoetic consciousness and, therefore, episodic memory. They do not provide a neuroanatomical account of consciousness per se, but they do identify particular
areas of the brain as being necessary for certain types of consciousness. Thus, they proposed that the frontal lobes are necessary for autonoetic consciousness, the medial temporal lobes and hippocampus (MTL/H) for noetic consciousness, and posterior cortical areas for anoetic consciousness.

Relative to other types of processing, material that is processed in terms of the self is associated with more R responses (e.g., Conway & Dewhurst, 1995). The finding that material that is processed in terms of the self in comparison to other types of processing is associated with higher levels of retrieval success (i.e., the SRE) and a different type of retrieval experience (i.e., more R responses) suggests that the processes that are engaged in self-related processing are particularly effective in promoting the successful recovery of contextually rich memories. The specific aspects of the cognitive processes and the neural substrates that mediate self-related memory, however, are poorly understood.

The following series of experiments was designed with two goals in mind. One goal was to shed light on the nature of the neuro-cognitive system that mediates retrieval from the self category. The second goal was to shed light on the neuro-cognitive system that mediates R responses, one aspect of autonoetic consciousness. The two goals are not mutually exclusive because autonoetic consciousness is related to the self, and because some of the processes or capacities that mediate retrieval from the self category also may mediate R responses.

Two of Tulving's (1985) properties of autonoetic consciousness are that it involves mental time travel, in that it encompasses the personal past, present, and future, and that it is necessary for R responses. Suddendorf and Corballis (1997)
proposed that mental time travel requires at least five cognitive capacities including self-awareness, meta-representation, mental attribution, understanding the perception-knowledge relationship, and the ability to dissociate imagined mental states from one's present mental state. They further speculated that these capacities are important for 'theory of mind', which is an individual's ability to use mental states to describe and predict behavior in ourselves and others (Premack & Woodruff, 1978), develop around age 4 in humans, and may be precursors to language. If episodic memory is related to autonoetic consciousness and is dependent upon frontal lobe function (e.g., Wheeler et al., 1997), then the well established decline in episodic memory and frontal lobe function that occur in normal aging (e.g., Moscovitch & Winocur, 1992, 1995) should be associated with declines in autonoetic consciousness. Older adults, therefore, should be impaired on tests that assess mental time travel, or on at least some of the capacities required for mental time travel postulated by Suddendorf and Corballis (1997). Consequently, older adults should provide fewer R responses than young adults.

The following three chapters describe two behavioral experiments and a positron emission tomography (PET) experiment that investigated the hypotheses that frontal system function is related to at least one of the capacities required for mental time travel, self-awareness, and that deficient frontal system function is related to reductions in R responses. Experiment 1 was designed to determine whether old adults, who often have deficient frontal lobe function, are differentially impaired in comparison to young adults in retrieving self-referential information compared to other types of information. According to Suddendorf and Corballis
One of the capacities for mental time travel is self-awareness which also has been related to frontal function (Stuss, 1991). To the extent that self-awareness and the retrieval of self-referential information rely on the recovery of information from a self category that is represented primarily in the frontal lobes, it seemed plausible that the retrieval of self-referential information by old adults may be particularly impaired relative to retrieval from other categories of information. A second purpose of Experiment 1 was to determine whether old adults differ from young adults in the type of retrieval experience they report when retrieving self-referential information. The retrieval experience indexed by R responses has been related to frontal lobe function, and the R/K distinction has been previously used to differentiate the retrieval of self-referential information from other types of information. It was predicted that old adults would provide fewer R responses, especially for information that had been encoded in terms of the self. Experiment 2 was designed to determine whether a task that is believed to interfere with frontal lobe function in young adults particularly affects the retrieval of self-referential information and the type of retrieval experience that they report. It was predicted that the pattern of results in these young adults would be similar to that of old adults.

Chapters 2 and 3 describe the results of the PET study. The PET study provided a more direct way of identifying the neuro-cognitive system that mediates the retrieval of self-referential information. The study was designed in such a way that the contributions of three aspects of episodic memory to the overall pattern of
neural activity related to the retrieval of self-referential information could be individually examined.

One aspect of the retrieval of self-referential information is the content of retrieval. That is, the information belongs to a "self" category as opposed to a "best friend" or an "animal" category of information. The design of the study allowed the pattern of neural activity related to the retrieval of information from the "self" category to be differentiated from the pattern of neural activity related to the retrieval of information from other categories of information. A second aspect of the retrieval of self-referential information is the success of retrieval. That is, the memory is either retrieved or not retrieved and there may be a specific pattern of neural activity related to retrieval success that is independent from the content or category of the information that is retrieved. A third aspect of episodic memory is the subjective experience or conscious awareness that accompanies retrieval.

Episodic memory for personally relevant information is often associated with the retrieval experience indexed by R responses. The pattern of neural activity related to retrieval experience also may be differentiated from other aspects of episodic memory such as retrieval content and retrieval success. Chapter 2 discusses the PET findings related to self-referential information as a category of information. Chapter 3 discusses the PET findings related to retrieval success and retrieval experience that contribute to the overall episodic memory for self-referential information.

Together, the following three chapters provide information about the neuro-cognitive system that mediates self, episodic memory, and autonoetic consciousness.
CHAPTER 1

REMEMBERING SELF-REFERENTIAL INFORMATION:
THE EFFECTS OF AGING AND DIVIDED ATTENTION AT RETRIEVAL

INTRODUCTION

One aspect of memory that is of interest to cognitive psychologists and neuropsychologists is how personally relevant information is encoded and retrieved. It is well established that material that is processed semantically is retrieved better than material that is processed in terms of its surface characteristics, such as its shape or color (Craik & Lockhart, 1972; Craik & Tulving, 1975). In a variation of this standard “level of processing” manipulation, Rogers, Kuiper and Kirker (1977) found that words that were related to the self at encoding (e.g., Does shy describe you?) were retrieved even better than words that were processed in terms of their general semantic characteristics (e.g., Does shy mean the same as bashful?). They suggested that the encoding of self-referential information may reflect an even deeper level of processing (i.e., the self-reference effect; SRE) than the encoding of general semantic information. Additionally, Keenan and Baillet (1980) found an inverse relationship between memory for personality trait adjectives and how well the participant knew the person to whom they applied the trait adjectives. A meta-analysis of the SRE was recently conducted by Symons and Johnson (1997). They concluded that relating material to the self is a particularly effective encoding
strategy in comparison to general semantic and other-referent encoding strategies, and that its effectiveness as a strategy appears to be related to the efficient and spontaneous elaboration and organization of the material into an often-used and well-developed construct.

The neural correlates of self-referential, other-referential, and general semantic encoding strategies also have been examined. Craik et al. (in press) found a pattern of brain activity that was common to the three semantic encoding strategies, as well as patterns of brain activity that were specific to the type of encoding strategy. The pattern of brain activity that was common to the three semantic encoding strategies (in comparison to a phonological encoding strategy) involved primarily widespread left prefrontal areas. These left prefrontal areas may mediate cognitive processes that are common to all semantic encoding strategies, including the self-referential encoding strategy (also see Kapur et al., 1994). Craik et al. (in press) also found a pattern of brain activity specific to the self-referential encoding strategy and a pattern specific to the social desirability encoding strategy. The differences in the patterns of brain activity specific to the self-referential and social desirability encoding conditions may reflect the differential utilization of commonly available encoding strategies in the two conditions. Alternatively, they may reflect the utilization of different encoding strategies that are uniquely available to a specific encoding condition. The most theoretically interesting differences in brain activation patterns between the self-reference and social desirability encoding conditions occurred in the frontal lobes. Whereas additional right and left prefrontal areas distinguished the self-referential encoding condition from the other
three conditions [right Brodmann’s areas (BAs) 9, 10, and 45, and left BA 10], only left prefrontal areas (BAs 8 and 6) distinguished the social desirability encoding condition from the other three conditions. The right laterality of self-referential encoding processes observed in the Craik et al. (in press) study was important because it showed that the encoding of material in terms of the self involves right prefrontal cortex even though encoding processes per se are generally left lateralized [see the hemispheric encoding and retrieval asymmetry (HERA) model of episodic memory (Tulving, Kapur, Craik, Moscovitch, & Houle, 1994; Nyberg, Cabeza, & Tulving, 1996)].

It is unknown, however, whether the retrieval of material that is related to the self at encoding can be neuropsychologically differentiated from the retrieval of material that is encoded in terms of another person or in terms of social desirability. The following two experiments were designed to explore this. The retrieval of material that was encoded with reference to the self, another person, social desirability, and phonological structure, was measured both as retrieval success (i.e., recognition) and retrieval experience (i.e., “remembering” vs. “knowing”). The retrieval success and retrieval experience of young and old adults were compared in Experiment 1. The retrieval success and retrieval experience of young adults under full attention (Y-FA), young adults who divided their attention at retrieval (Y-DA), and old adults were compared in Experiment 2. It was hypothesized that in comparison to Y-FA, retrieval success by old adults and Y-DA would be more reduced for material that was processed in reference to the self than for other semantically processed material (i.e., other-reference and social desirability). It also
was hypothesized that in comparison to Y-FA, both old adults and Y-DA would have reductions in the retrieval experience of remembering, especially for material that was processed self-referentially. These reductions were predicted because both aging and divided attention at retrieval have been associated with reductions in the availability of cognitive resources (e.g., Craik & Jennings, 1992; Salthouse, 1991; Moscovitch, 1994). The depletion of cognitive resources may particularly affect strategic, resource demanding processes associated with the frontal system (e.g., Moscovitch, 1992). Both self-reference and the retrieval experience of remembering may involve strategic processes mediated by the frontal system and, therefore, may be particularly affected by cognitive resource reductions (see below).

It is well known that the cognitive processing and retrieval of information by old adults often differs from the processing and retrieval of the same information by young adults (reviewed by Light, 1991; Verhaeghen, Marcoen, & Goossens, 1993; Craik, Anderson, Kerr, & Li, 1995). Moreover, many of these differences have been correlated with neuropsychological changes that occur with aging (e.g., Huppert, 1991; Gabrieli, 1991). The frontal lobes and the medial temporal lobes (including the hippocampi; MTL/H) are especially susceptible to the effects of normal aging, and the performance of old adults on tasks that are mediated by the frontal lobes and/or the MTL/H is often impaired (e.g., Moscovitch & Winocur, 1992, 1995; West, 1996). In light of the difference between young and old adults in their processing and retrieval of many types of information, one objective of the first experiment was to determine whether old adults retrieve self-referential information similarly to young adults. Some experiments by Mueller and his colleagues suggest that young
and old adults similarly recall material that was related to the self at encoding. Their experiments, however, were designed to examine trait distinctiveness and age specificity (reviewed by Mueller, Johnson, Dandoy, & Keller, 1992) rather than the age-related effects that self-reference compared to other types of semantic processing may have on episodic memory retrieval per se. It remains uncertain, therefore, whether there are age-related differences in the retrieval of self-referential information in comparison to other categories of information.

Although older adults may have poorer episodic memory for semantically processed information than do younger adults, their recognition of material that was encoded in terms of the self may be especially susceptible to the neuropsychological effects of aging. Imaging studies have confirmed the involvement of the frontal lobes in semantic retrieval/episodic encoding and episodic retrieval processes for various types of information under a variety of conditions (for a review see Nyberg et al., 1996), and have demonstrated reduced frontal activity in old adults in comparison to young adults during encoding and retrieval which may contribute to recognition deficits in older adults (e.g., Grady et al., 1995; Cabeza et al., 1997). Similar reductions in frontal lobe activation also have

---

1 In the experiments by Mueller and his colleagues, young and old adults rated adjectives twice (once for self-descriptiveness and once for other-descriptiveness), and then their memory for the adjectives was examined by having participants recall as many adjectives as possible. In each experiment overall recall was very low (< 30% in each experiment), and did not differ between the young and old adults. Mueller and Ross (1984) found that old adults recalled more adjectives that were descriptive of self or self and other (best friend) than adjectives that were descriptive of other or neither self nor other, whereas young adults showed the opposite pattern. Mueller, Wonderlich, and Dugan (1986) found that self-reference led to higher recall than other-reference (Describes most people?) by both groups. Mueller and Johnson (1990) found that traits that were endorsed as self-descriptive and traits that were endorsed as both self-descriptive and other-descriptive (Describes most people?) were similarly recalled by both young and old adults.
been observed in young adults under divided attention, thereby supporting the conjecture that reductions in cognitive resources affect the frontal lobes which in turn can lead to memory deficits (e.g., D'Esposito et al., 1995; Fletcher, Shallice, & Dolan, 1998; Shallice et al., 1994; Fletcher et al., 1995). Frontal lobe damage also has been associated with disturbances of self-awareness (e.g., Stuss & Benson, 1986; Stuss, 1991). Since both self-awareness and self-reference involve the self, they may engage similar processes. Self-reference, therefore, also may be related to frontal function which is deficient in older adults. Worse memory for self-referential information than for other types of information in old adults in comparison to young adults would provide evidence to support the suggestion that the retrieval of self-referential information depends on processes that are compromised in older adults, and that the compromised processes may be resource demanding strategic processes that are dependent on the integrity of the frontal system.

A second objective of Experiment 1 was to determine whether old adults differ from young adults in the type of retrieval experience they report when recollecting self-referential information. Conway and Dewhurst (1995, Experiment 3) found that even when retrieval success (i.e., overall recognition) was similar for self-referential information and general semantic information, the type of retrieval experience that accompanied recognition distinguished memory for self-referential information from memory for other types of information. They found that their participants (who were young) gave significantly more “remember” or R responses to self-related items than to general semantic items and other-related items. Their participants also gave significantly fewer “know” or K responses to the self-related
items than to the general semantic items. R responses involve the retrieval of some aspect of the encoding experience for the item (e.g., how the item looked on the computer screen), whereas K responses involve the feeling of familiarity that the item was presented (e.g., Tulving, 1985; for reviews of experiments that have used the R/K paradigm see Gardiner & Java, 1993; Donaldson, 1996; Rajaram & Roediger, 1997). It is possible, therefore, that retrieval differences between young and old adults may be more related to the type of retrieval experience than to retrieval success per se, especially since the reconstruction of the encoded event necessary for R responses requires greater cognitive resources than the feeling of familiarity associated with K responses.

Sixteen experiments in 10 reports have compared the retrieval experiences of young and old adults using the R/K procedure (Parkin & Walter, 1992; Mantyla, 1993; Perfect, Williams, & Anderton-Brown, 1995; Fell, 1992 cited in Perfect et al., 1995; Maylor, 1995; Java, 1996; Schacter, Koutstaal, Johnson, Gross, & Angell 1997; Norman & Schacter, 1997; Perfect & Dasgupta, 1997; Mark & Rugg, 1997). In all but three of the experiments aging reduced R responses more than K responses, the latter being either unaffected by age or showing only a small increase or decrease. In the remaining three experiments (Perfect et al., 1995, Experiment 2A; Norman & Schacter, 1997; Mark & Rugg, 1997) age-related reductions in R responses did not occur. The old adults provided more R response false positives than young adults in the Norman and Schacter (1997) study, however, and the encoding task in the Mark and Rugg (1997) and Perfect et al. (1995, Experiment 2A) studies was highly
specific and elaborative which may have minimized age-related differences (see Perfect et al., 1995; Perfect & Dasgupta, 1997).

Deteriorating frontal lobe function with age is a likely cause of age-related declines in R responses. Parkin and Walter (1992) found a significant relationship between the performance of very old adults (M age ≥ 80 years) on the Wisconsin Card Sorting Test (WCST), and their probability of giving a R response; poorer performance on the WCST test was associated with fewer R responses. The WCST is sensitive to frontal system dysfunction, though other brain regions mediate performance on this test (Milner, 1963; Lezak, 1995; Berman et al., 1995).

Consistent with Parkin and Walter (1992), evidence from other studies also associates frontal system function with R responses. Düzel, Yonelinas, Mangun, Heinze, and Tulving (1997) found that words that were given R responses elicited more positive event-related potentials in the 600 - 1000 ms post-stimulus onset time window than words that were given K responses. This positivity was found primarily in widespread bifrontal and left parietotemporal areas. Two patients with right prefrontal damage have been tested using the R/K procedure, and both patients provided an abnormal pattern of R responses relative to control participants. The patient reported by Levine et al. (1998) provided significantly fewer R responses than control participants, and Curran, Schacter, Norman, and Galluccio (1997) found that their patient had an extraordinarily high R response false alarm rate. Curran et al. interpreted their patient's high false alarm rate as reflecting an impairment in his ability to utilize specific information to discriminate study items from new items at test (i.e., he may have relied on general information that was
common to both study items and new items at test which would lead to a high false alarm rate). In contrast, damage to the MTL/H or diencephalon reduces both R and K responses as would be expected if the memory for the material were lost (Knowlton & Squire, 1995; Schacter, Verfaellie, & Pradere, 1996; Schacter, Verfaellie, & Anes, 1997; these three studies are reviewed and reanalyzed in Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998; also see Knowlton, 1998).

On the basis this previous research, the main hypothesis was that old adults would provide fewer R responses than young adults, especially for material that was processed in terms of the self. To assess the relation between R responses and frontal system function, the young and old adults in Experiment 1 also completed two standard neuropsychological tests that are sensitive to frontal system function. The test scores then could be correlated with the number of R responses to attain an estimate of the relationship between the retrieval experience of remembering and frontal system function. Although Parkin and Walter (1992) found reductions in R responses by their old-old group of adults (M age = 81.6 years) and by their middle-old group of adults (M age = 67.7 years) in comparison to young adults (M age = 21.5 years), R responses were related to scores on one of their frontal-sensitive tests in their old-old group but not their middle-old group or young group. Because a significant correlation was found in their group of old-old adults but not in their group of middle-old adults, even though both groups provided fewer R responses than young adults, it could not confidently be predicted whether a significant correlation would be found in the group of old adults in the present experiment.
METHOD

Participants

Thirty-two right-handed people divided equally into young and old groups participated in the experiment. The young volunteers were 19 - 24 year-old undergraduates at the University of Toronto at Mississauga. The old adults were between the ages of 64 and 76, and were recruited from a pool of senior volunteers. All participants were screened for a prior history and for current evidence of any serious medical, neurological, or psychological disorder (Appendix A). English was the primary language of all participants. Although the two groups had a similar number of years of education, the old adults outperformed the young adults on a shortened version of the Mill Hill Vocabulary Scale (Raven, 1938; Appendix B). Informed consent was obtained prior to participation from all volunteers. The demographics of the two groups are summarized in Table 1.

Table 1. Demographics of the participants in Experiment 1.

<table>
<thead>
<tr>
<th>Group</th>
<th>Males:</th>
<th>Age</th>
<th>Education</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Females</td>
<td>M years (SE)</td>
<td>M years (SE)</td>
<td>M score (SE)</td>
</tr>
<tr>
<td>Young</td>
<td>7:9</td>
<td>20.1 (0.4) a</td>
<td>14.0 (0.2)</td>
<td>13.4 (0.6)</td>
</tr>
<tr>
<td>Old</td>
<td>4:12</td>
<td>69.9 (1.0)</td>
<td>14.9 (0.5)</td>
<td>16.1 (0.6)</td>
</tr>
</tbody>
</table>

aN = 15

bYoung = Old [t(30)2-tailed = 1.54, p > .05]

cYoung < Old [t(30)2-tailed = 3.39, p < .01]

dmaximum possible score = 20
**Task Design**

In outline, participants were asked to make one of four judgments about personality trait adjectives, then their memory for the adjectives was tested using a R/K recognition procedure.

The same 16 lists of 32 personality trait adjectives used by Craik et al. (in press) were used in the present experiment. Each adjective occurs in only one list. Within each list, half of the trait adjectives represent positive characteristics and half represent negative characteristics. Eight additional lists of 4 personality trait adjectives were constructed for practice trials. The lists are presented in Appendix C.

Eight of the 32-word lists were shown during encoding (the words within each list were randomly presented), and 8 served as distractors on the recognition test subsequent to encoding. Half of the participants made judgments on the first 8 lists; the remaining half made judgments on the other 8 lists. The lists were presented in a pseudo-random order, counterbalanced across subjects. Each word was presented in the center of a computer screen positioned a comfortable viewing distance from the participant.

Reaction time (RT) was measured while participants judged words in one of four encoding conditions; each condition occurred twice for a total of eight measurements. The four conditions were presented in an ABCDDCBA design (counterbalanced across participants) to minimize fatigue effects. Each condition involved making judgments about personality trait adjectives on a four point scale.

In one condition, representing the encoding of self-referential information (Self), participants judged how well they thought each trait adjective described them.
In a second task, representing encoding of information about another person (Other), participants judged how well they thought each trait adjective described Brian Mulroney (a former Canadian Prime Minister). In a third task, representing encoding of semantic information that is not specific to a person (Social Desirability), participants judged how socially desirable they thought each trait adjective was. In each of these three conditions, the participants pressed the key beneath their index, middle, ring, or pinkie finger, to indicate a judgment of “almost never”, “rarely”, “sometimes”, or “almost always”. In a fourth task, representing the encoding of phonological information (Syllable), participants judged the number of syllables in each trait adjective. They pressed the key beneath their index, middle, ring or pinkie finger, if they thought that the trait adjective had 2, 3, 4 or 5 syllables, respectively.

Each trial consisted of a 500 ms fixation point followed by an adjective for 2500 ms, then another fixation point for 1000 ms. The participant could enter his or her response any time between the onset of the stimulus and the onset of the 500 ms fixation point of the next trial. Participants were told that if they had not made a judgment by the time the fixation point appeared they should do so quickly because it means that the next trait adjective is about to appear. If a judgment had not been made within the 4000 ms window then the next adjective automatically appeared. This strict timing was used to ensure that each participant used a similar amount of time to make each judgment and to make the present experiment comparable to the positron emission tomography (PET) experiment by Craik et al. (in press) which investigated the neural correlates of these four judgments in young adults.
Subsequent to the presentation of the last list, participants were given an unexpected recognition test. The recognition test was divided into 8 blocks, the same 8 blocks and in the same order as the 8 encoding blocks. This division of the recognition test into blocks was made so that variations in the criterion that participants used to recognize the adjectives from a particular judgment type could be determined. Within each block, half of the adjectives were from the list of adjectives that the participant encoded (i.e., 32 adjectives) and half were new (i.e., 32 adjectives). Each block had 3 windows; the first window contained 6 old words and 14 new words, the second window contained 21 old words and 3 new words, and the third window contained 5 old words and 15 new words. This non-random distribution of old and new words during recognition was used only because a PET investigation of the neural correlates of the retrieval of self-referential information, using the same general methodology as the present experiment, was also being conducted (see Chapters 2 and 3); PET studies require that the process of interest (i.e., retrieval of target items) is the primary process being utilized during the scanning (middle) window. Also note that 11 minutes separated the blocks in the young adults but only 5 minutes separated the blocks for the old adults. Again, this methodology was implemented only so that the results of the young participants could be compared to the young participants in a comparable PET investigation (see Chapters 2 and 3); PET scans are 11 minutes apart to allow for adequate decay of the tracer. If the different waiting time between the blocks for the young and old adults had an effect, the effect would have favored the null hypothesis of the present experiment. The increased waiting time for the young adults would presumably
reduce, not enhance, their memory for the adjectives. Therefore, the memory of the young adults would be more similar to that of the old adults and age-related retrieval differences would be reduced.

At retrieval, an adjective appeared on the computer monitor for 3000 ms followed by a 1000 ms interstimulus interval. The participant could enter his or her response at any time during this 4000 ms window. Similar to the rationale for the strict timing during encoding, strict timing during retrieval was implemented so that the participants would use approximately the same amount of time for each retrieval decision. In addition to being a methodological restriction for the aforementioned PET study, this strict timing was also used to minimize speed/accuracy trade-offs. Before each block, the participant was informed from which list the old adjectives would have been presented during the encoding phase.

Rather than have the participants in the retrieval task simply indicate whether each word is old or new, they were requested to indicate for old words whether they "remembered" the word (i.e., whether they "re-experienced" the original encoding of the word and recollected some additional detail from the previous presentation of the word) or simply "knew" the word (i.e., they knew that the word was presented earlier in a list of words that they judged, but they could not retrieve any additional details from the prior presentation of the word). Participants were given examples of R and K responses, and were told that the distinction was not just one of confidence. They were instructed to press the key beneath their index, middle, or ring finger for R, K, and new responses, respectively. The test instructions given to participants are provided in Appendix D.
Since it was hypothesized that self-referential information and/or R responses are related to frontal system function, two standard neuropsychological tests that are sensitive to frontal system dysfunction were administered to each participant (only 11 young participants completed the neuropsychological tests, the remaining 5 participants could not be contacted or refused to return for a second session). One test was the word fluency test (FAS; Spreen & Strauss, 1991). Frontal system dysfunction is often associated with reduced scores on this test. Note, however, that frontal system dysfunction does not always reduce scores on this test, and reductions in scores equivalent to those observed in patients with frontal lesions have been observed in patients with damage to posterior regions (Stuss et al., 1998). The second test was the Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993). Similar to the word fluency test, poor scores on this test are often associated with frontal system dysfunction, though other brain regions are known to mediate performance on this test (e.g., Milner, 1963; Lezak, 1995; Berman et al., 1995). Two additional tests that are sensitive to MTL/H function were administered for comparison. One test was the Warrington Recognition Memory Test (W-RMT; Warrington, 1984). This test measures verbal and nonverbal recognition memory which are sensitive to left and right MTL/H dysfunction, respectively. Damage to other brain regions, however, may reduce performance on this test, and MTL/H damage may spare recognition under some conditions (Aggleton & Shaw, 1996; Reed & Squire, 1997; Baxendale, 1997). The second test was a category fluency task (animals; Spreen & Strauss, 1991). Similar to the W-RMT, the category fluency test is sensitive but not specific to MTL/H
dysfunction (Baldo & Shimamura, 1998). The four tests took approximately 40 minutes to administer, and were given either at the end of the retrieval phase or in a second experimental session. Participants were tested individually, and the experimental session(s) lasted approximately 2.5 hours.

RESULTS

The results are divided into two broad sections: Encoding and Retrieval. The Encoding section describes the latency with which participants made the four judgments. The encoding data are only briefly discussed because the retrieval data are more relevant to the main hypothesis that aging would particularly reduce R scores in the Self condition. In both sections, all comparisons are reported for which a significant effect or a trend emerged. A significant effect was defined as $p < .05$, and a trend was defined as $p < .10$. Note that data were collected from 2 additional young adults and 2 additional old adults to replace the data from participants who made fewer than 10% correct R responses (2 young and 1 old) or more than 90% correct R responses (1 old) in at least 3 of the 4 conditions. Although it is possible that these participants were able to make the distinction between R responses and K responses, and just had a high degree of remembering or knowing, it is also possible that the lack of variability in their responses reflects an inability of the participants to make the R/K distinction; because of the latter possibility their data were replaced with data obtained from demographically similar participants.

The encoding results show that participants judged the adjectives well within the time that they were allotted, and that they judged the adjectives in the Social Desirability condition more quickly than the adjectives in the Self, Other, and
Syllable conditions. The retrieval results show that overall recognition by the young and old adults was similar, but that the retrieval experience that accompanied recognition differed for the two groups. In comparison to young adults, the old adults had smaller R scores in the Self and Social Desirability conditions, but a similar R scores in the Other and Syllable conditions. K scores, on the other hand, were similar for the young and old adults and in each condition.

Encoding

Reaction Time (RT)

Both the young and old adults judged 98% of the adjectives within the 4000 ms window. Although the young adults made their judgments 132 ms faster than the old adults (M = 1746 ms and 1878 ms, respectively), an analysis of variance (ANOVA) revealed that this difference is not significant [F(1,29) = 2.33, MSE = 229150.05; due to an error, the RTs of one young adult were not collected].

The time it took for judgments to be made varied significantly across the levels of processing [F(3,87) = 9.61, MSE = 40236.59]. The mean RTs for the four conditions were ordered Social Desirability (1657 ms), Self (1824 ms), Syllable (1852 ms), then Other (1924 ms). Post hoc tests (least squares means, uncorrected p < .05) revealed that the social desirability judgments were made significantly more quickly than the other 3 judgments, and that there was a trend (p = .06) for judgments about the self to be made more quickly than judgments about Brian Mulroney. There was no interaction between group (young vs. old) and the level of processing [F(3,87) = 1.50, MSE = 40236.59].
Retrieval

Recognition

*Overall (hits minus false alarms).* Overall recognition was the same for the young and old adults, though both groups recognized more adjectives in the **Self** and **Social Desirability** conditions than in the **Other** condition, and more adjectives in the **Other** condition than in the **Syllable** condition. The overall recognition data are summarized in the upper third of Table 2.
Table 2. Average overall recognition of words and average recognition of words classified as remembering or knowing by young and old adults in Experiment 1 for four levels of processing.

<table>
<thead>
<tr>
<th>Group</th>
<th>Level of Processing</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self</td>
<td>Social</td>
</tr>
<tr>
<td></td>
<td>Hits minus False Alarms (Standard Error)</td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>.39 (.04)</td>
<td>.39 (.05)</td>
</tr>
<tr>
<td>Old</td>
<td>.39 (.04)</td>
<td>.34 (.04)</td>
</tr>
<tr>
<td>Average</td>
<td>.39 (.03)</td>
<td>.37 (.03)</td>
</tr>
<tr>
<td></td>
<td>Remembering * (Standard Error)</td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>.35 (.04)</td>
<td>.30 (.04)</td>
</tr>
<tr>
<td>Old</td>
<td>.23 (.04)</td>
<td>.18 (.04)</td>
</tr>
<tr>
<td>Average</td>
<td>.29 (.03)</td>
<td>.24 (.03)</td>
</tr>
<tr>
<td></td>
<td>Knowing * (Standard Error)</td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>.08 (.05)</td>
<td>.13 (.03)</td>
</tr>
<tr>
<td>Old</td>
<td>.17 (.04)</td>
<td>.13 (.03)</td>
</tr>
<tr>
<td>Average</td>
<td>.12 (.03)</td>
<td>.13 (.02)</td>
</tr>
</tbody>
</table>

* corrected for false alarm rate (see text for formula)

The average hit rate minus false alarm rate for the young and old adults was essentially the same \( [F(1,30) = .12, \text{MSE} = .06] \). Overall recognition, however, was significantly influenced by the level of processing \( [F(3,90) = 17.04, \text{MSE} = .01] \). Post hoc tests (least squares means, uncorrected \( p < .05 \)) revealed that adjectives in the
Self and Social Desirability conditions were recognized equally well, and that recognition in these two conditions was significantly better than recognition in the Other condition which, in turn, was significantly better than recognition in the Syllable condition. There was no interaction between group and the level of processing \(F(3,90) = 2.14, \text{MSE} = .01\).

**Remembering.** The retrieval experience of remembering in comparison to knowing was estimated with R scores. R scores were calculated using the following formula: \((\text{Number of R Hits} - \text{Number R False Alarms})/\text{[Total Number of Hits (i.e., R Hits + K Hits) + Total Number of False Alarms (i.e., R False Alarms + K False Alarms)]]\). This formula was used because it considers variations in the false alarm rate between the two groups and across the levels of processing. An analogous formula was used to calculate K scores to estimate the retrieval experience of knowing. Note that the sum of the R and K scores does not equal overall recognition (hits minus false alarms) because the denominator for the R and K scores differ from the denominator for overall recognition. Therefore, significant differences in overall recognition but not in remembering or knowing (or vice versa) are possible.

The results for remembering show that the average R score was similar for the young and old adults, but varied across the four levels of processing and was dependent on both the group and the level of processing, that is, there was a group by level of processing interaction. In comparison to young adults, the R score for the old adults was smaller in the Self and Social Desirability conditions but similar in
the Other and Syllable conditions. The R score data are summarized in the middle third of Table 2.

The average R score was similar for young and old adults [F(1,30) = 1.08, $\text{MSE} = .06$]. The R score significantly varied, however, as a function of levels of processing [F(3,90) = 15.75, $\text{MSE} = .01$]. Post hoc tests (least squares means, uncorrected $p < .05$) revealed a trend ($p = .06$) toward a higher R score in the Self condition than in the Social Desirability condition. The R score in the Social Desirability condition was higher than the R score in the Other condition, and the R score in the Other condition was higher than the R score in the Syllable condition.

Importantly, however, the ANOVA also revealed that in contrast to the absence of a group by level of processing interaction for the overall recognition scores, the main effect of the level of processing was significantly modified by group for the R scores [F(3,90) = 5.71, $\text{MSE} = .01$]. Subsequent ANOVAs were performed to unravel the interaction. Subsequent ANOVAs for each group (the mean square error terms were corrected; for each ANOVA the $\text{MSE} = .01$) revealed that R scores significantly varied across the levels of processing in young adults but not in old adults [F(3,45) = 19.08 and 1.50, respectively]. Post hoc tests (least squares means, uncorrected $p < .05$) revealed that the R score for the young adults was highest in the Self and Social Desirability conditions, which were not significantly different. The R score was significantly higher in these two conditions than in the Other condition, and in the Other condition than in the Syllable condition.

Subsequent ANOVAs for each level of processing (the mean square error terms were corrected; for each ANOVA the $\text{MSE} = .02$) revealed that the R score for
young adults was higher than the R score for old adults in the **Self** \[F(1,30) = 5.20\] and **Social Desirability** conditions \[F(1,30) = 4.75\], but that the R score for the young and old adults was similar in the **Other** \[F(1,30) = .001\] and **Syllable** conditions \[F(1,30) = 1.52\].

**Knowing.** The retrieval experience of knowing was estimated with K scores. It was found that in contrast to remembering, the retrieval experience of knowing was similar for the young and old adults and in each condition. The K score data are summarized in the lower third of Table 2. K scores were calculated using the analogous formula to the one that was used to calculate R scores. The formula that was used to calculate K scores is: \[(\text{Number of K Hits} - \text{Number of K False Alarms})/(\text{Total Number of Hits} (i.e., R Hits + K Hits) + \text{Total Number of False Alarms} (i.e., R False Alarms + K False Alarms)).\] K scores varied only slightly between the young and old adults and across the four levels of processing. An ANOVA confirmed that the small variations were not significant \[\text{Group} F(1,30) = .19, \text{MSE} = .05; \text{Level of Processing} F(3,90) = .15, \text{MSE} = .01\], and the absence of an interaction \[F(3,90) = 1.95, \text{MSE} = .01\].

**Reaction Time (RT)**

The average RT was calculated for young and old adults in each condition for their hits, false alarms, R responses, R false alarms, K responses, K false alarms, and new responses. An ANOVA for each of the seven response types was then used to determine whether there were significant differences in average RT between the young and old adults and/or across the levels of processing. These ANOVAs revealed that the young adults were generally faster than the old adults to decide
whether the adjectives were remembered, known, or new, and that the participants were faster to respond with a hit or R response in the Self and Social Desirability conditions than in the Other and Syllable conditions. The results for R response RTs also revealed that the young adults were faster than the older adults to make R responses in the Self, Social Desirability, and Other conditions, but did not differ from older adults in the Syllable condition. The RT to make a K response did not differ across the levels of processing and was not significantly modified by group. The RT data for hits, R responses, and K responses are summarized in the upper, middle and lower third of Table 3, respectively.
Table 3. Average reaction time (ms) for hits and hits classified as remember responses and know responses by young and old adults in Experiment 1 for four levels of processing.

<table>
<thead>
<tr>
<th>Group</th>
<th>Level of Processing</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self</td>
<td>Social</td>
</tr>
<tr>
<td></td>
<td>Desirability</td>
<td></td>
</tr>
<tr>
<td>Hits (Standard Error)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>1694 (70)</td>
<td>1718 (87)</td>
</tr>
<tr>
<td>Old</td>
<td>1916 (83)</td>
<td>1948 (85)</td>
</tr>
<tr>
<td>Average</td>
<td>1805 (57)</td>
<td>1833 (63)</td>
</tr>
<tr>
<td>Remember Responses (Standard Error)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>1642 (62)</td>
<td>1673 (75)</td>
</tr>
<tr>
<td>Old</td>
<td>1890 (96)</td>
<td>1948 (98)</td>
</tr>
<tr>
<td>Average</td>
<td>1765 (60)</td>
<td>1810 (66)</td>
</tr>
<tr>
<td>Know Responses (Standard Error)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>1818 (102)</td>
<td>1835 (114)</td>
</tr>
<tr>
<td>Old</td>
<td>2029 (88)</td>
<td>2059 (90)</td>
</tr>
<tr>
<td>Average</td>
<td>1924 (69)</td>
<td>1947 (74)</td>
</tr>
</tbody>
</table>

**Group.** An inspection of the main effect of group in each of the ANOVAs revealed that the young adults were significantly faster ($p < .05$) than the old adults for hits and for false alarms, that there was a trend ($p < .10$) for them to be faster than old adults for four response types ($R$, $K$, and new responses, and $K$ false alarms), and that the speed with which they made $R$ false alarms did not differ from that of the
old adults (p > .10). Although the young and old adults did not differ in their average overall recognition score or in their average R score, the young adults were faster to respond than the old adults. Differences in RT across the levels of processing and, especially, interactions between group and the level of processing are of more theoretical interest to the present experiment.

**Level of Processing.** Only two of the seven ANOVAs, hits and R responses, revealed a significant effect of the levels of processing on the speed with which participants made their responses [F(3,90) = 4.83 and 6.46, respectively; MSE = 19153.97 and 33260.30, respectively]. The average time it took participants to respond with a hit was ordered **Self, Social Desirability, Syllable**, then **Other**. Post hoc tests (least squares means, uncorrected p < .05) revealed that the average RT was significantly faster in the **Self** condition than in the **Syllable** and **Other** conditions, and in the **Social Desirability** condition than in the **Other** condition. Note that performance measured both in terms of overall recognition and RT to make a hit was best in the **Self** and **Social Desirability** conditions which did not significantly differ from each other.

The average time it took participants to make a R response was ordered **Self, Social Desirability, Syllable**, then **Other**. Post hoc tests (least squares means, uncorrected p < .05) revealed that the average RT was significantly faster in the **Self** condition than in the **Syllable** and **Other** conditions, and in the **Social Desirability** condition than in the **Syllable** and **Other** conditions. Note that this ordering is similar to the ordering of the R scores; that is, both R scores and the RT to make R
responses were best in the Self and Social Desirability conditions which, in turn, were significantly better than in the Other and Syllable conditions.

**Group by Level of Processing.** Out of the seven ANOVAs only one, R responses, revealed a significant interaction between group and the level of processing \([F(3,90) = 3.59, \text{MSE} = 33260.30]\). Subsequent ANOVAs were performed to unravel the interaction. Subsequent ANOVAs for each group (the mean square error terms were corrected; for each ANOVA the \text{MSE} = 33260.30) revealed a significant effect of level of processing for both groups \([F(3,45) = 6.44 \text{ and } 3.61 \text{ for the young and old adults, respectively}]\). Post hoc tests (least squares means, uncorrected \(p < .05\)) revealed that young adults were faster to make R responses in the Self condition than in the Other and Syllable conditions, and faster in the Social Desirability condition than in the Syllable condition. There was also a trend \((p = .09)\) for them to be faster in the Other condition than in the Syllable condition. The old adults were faster to make R responses in the Self, Social Desirability, and Syllable conditions (which did not significantly differ) than in the Other condition.

Subsequent ANOVAs for each level of processing (the mean square error terms were corrected; for each ANOVA the \text{MSE} = 124908.68) revealed a trend for young adults to make faster R responses than old adults in the Self condition \([F(1,30) = 3.94, p = .06]\), and significantly faster R responses by the young adults than the old adults in the Social Desirability and Other conditions \([F(1,30) = 4.83 \text{ and } 6.12, \text{ respectively}]\). The young and old adults did not differ in the time it took them to make R responses in the Syllable condition \([F(1,30) = .09]\). This interaction mirrors the interaction found with R scores. The young adults had both higher R scores and
made faster R responses than the old adults in the Self and Social Desirability conditions, but were only faster than the old adults in the Other condition, and performed similarly to the old adults in Syllable condition, both in terms of mean R scores and mean RT to make R responses. The interactions between group and the level of processing for the retrieval experience of remembering, both for R scores and the time participants used to make R responses, is in stark contrast to the absence of a group by level of processing interaction for overall recognition, both in terms of the hit minus false alarm rate and the time participants used to make hits and false alarms.

Also note that the absence of a group by level of processing interaction for K response RTs is consistent with the absence of a group by level of processing interaction for K scores. Both K scores and the time to make K responses are unaffected by the level of processing and are not significantly affected by aging.

**Neuropsychological Tests**

The scores of the young and old groups were compared on two tests sensitive to frontal function (WCST and word fluency) and three tests sensitive to MTL/H function (verbal and nonverbal subtests of the W-RMT and category fluency). An age-related impairment on the frontal-sensitive tests was not found. The scores of the young and old adults on the WCST were similar, and the old adults outperformed the young adults on the word fluency test. One of the neuropsychological tests sensitive to MTL/H function revealed an age-related deficit (verbal score on the W-RMT), but the young and old adults scored similarly on the
other two tests sensitive to MTL/H function. The average scores of the young and old adults on the neuropsychological tests are displayed in Table 4.

Table 4. Average neuropsychological test scores for young and old adults (standard errors in parentheses). *

<table>
<thead>
<tr>
<th></th>
<th>&quot;Frontal&quot; Function</th>
<th>&quot;MTL/H&quot; Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WCST a</td>
<td>WF b</td>
</tr>
<tr>
<td>Young</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25.1</td>
<td>11.3</td>
</tr>
<tr>
<td></td>
<td>(4.6)</td>
<td>(1.6)</td>
</tr>
<tr>
<td>Old</td>
<td>31.7</td>
<td>17.1</td>
</tr>
<tr>
<td></td>
<td>(4.4)</td>
<td>(2.9)</td>
</tr>
</tbody>
</table>

* MTL/H = medial temporal lobe/hippocampal; WCST = Wisconsin Card Sorting Test; 1 = percentage of errors; 2 = percentage of perseverative responses; 3 = percentage of perseverative errors; 4 = percentage of nonperseverative errors; 5 = number of categories achieved; 6 = loss of set maintenance; WF = word fluency (FAS); W-RMT = Warrington Recognition Memory Test; V = verbal subtest; NV = nonverbal subtest; CF = category fluency (animals)

a Young vs. Old: for all comparisons t(25) two-tailed < 1.57, p > .05
b Young vs. Old: t(25) two-tailed = 2.52, p < .05
c Young vs. Old: t(25) two-tailed = 2.93, p < .05
d Young vs. Old: t(25) two-tailed = .24, p > .05
e Young vs. Old: t(25) two-tailed = 1.42, p > .05

**Correlations Between Test Scores and Remember and Know Scores**

The R score and the K score for each young adult and for each old adult in each condition was correlated with his or her neuropsychological test scores, namely 2 scores from the W-RMT, 1 score from the word fluency test, 1 score from the...
category fluency test, and 6 scores from the WCST. No Pearson correlation coefficient was significant for young adults or for old adults. Note that a significance level of $p < .01$ was adopted as the statistical cut-off for a Pearson correlation coefficient to be considered significant. This more conservative cut-off, rather than the more traditional cut-off of $p < .05$, was used because many correlations were computed, and the $p$-values are not corrected for multiple comparisons.

**Discussion**

Experiment 1 revealed that although young and old adults did not differ in overall recognition of trait adjectives that were encoded in terms of the self, another person, social desirability, or number of syllables, their retrieval experience across the four conditions differed. The retrieval experience of remembering and knowing was estimated with R scores and K scores, respectively. The R score for old adults was smaller than the R score for young adults in the Self and Social Desirability conditions, but the two groups had similar R scores in the Other and Syllable conditions. K scores were similar for the young and old adults in each condition and did not differ across the four levels of processing.

These results lead to three main conclusions. First, age-related differences in the experience of retrieval, estimated by R scores and K scores, can occur in the absence of age-related differences in the success of retrieval as measured by overall recognition. Although robust age-related reductions in retrieval success are found on recall tests, the magnitude of the reduction is attenuated on cued-recall tests, and is even more attenuated on recognition tests (e.g., Craik, 1986). Significant age-related deficits in recognition are not always found in the aging literature, so similar
overall recognition by the young and old adults in the present experiment was not unexpected. The recognition data of the present experiment are similar to data collected by White (reported in Craik, 1982). White found no difference in recognition performance between young and old adults, but recognition increased for both groups across three levels of processing with better recognition as the depth of processing increased (capital letters, to rhyme, to category decision; also see Craik & Byrd, 1982). Note, however, that in a meta-analysis by Spencer and Raz (1995) a very small, but nonetheless reliable, age-related deficit in recognition was found for material that was incidentally encoded.

Second, remembering but not knowing appears to be affected by aging and by the level of processing. This result is consistent with several other studies that have found significant age-related reductions in remembering but not knowing (e.g., Mantyla, 1993; Java, 1996; Schacter et al., 1997; Maylor, 1995; Perfect & Dasgupta, 1997). It is also consistent with other research that has found reductions in remembering but not knowing for shallowly versus deeply processed material (e.g., Gardiner, Java, & Richardson-Klavehn, 1996).

Third, as predicted, the results suggest that material that is encoded in terms of the self is especially susceptible to age-related deficits in remembering in comparison to knowing. An equally large age-related deficit in remembering also was found, however, for traits that were encoded in terms of their social desirability. Because a similar age-related reduction in remembering in the Self and Social Desirability conditions was not predicted, it seemed prudent to test the reliability of
the reduction in the **Social Desirability** condition in Experiment 2 prior to discussing its theoretical implications.

All of these conclusions are consistent with the hypothesis that memory loss in aging is associated with age-related declines in cognitive resources. In general, those aspects of memory that are most dependent on reconstructions of the encoding episode and therefore require the most resources, are the ones that were most impaired in the older adults; remembering was more affected than knowing, and the retrieval of material that was processed self-referentially and for social desirability was more affected than material that was processed in terms of another person and for phonological structure. Note that age-related reductions in cognitive resources also may have affected encoding processes, especially those processes that mediate the encoding of contextual details of the episode. The encoding of contextual details is necessary for the retrieval experience of remembering, whereas the encoding of the content of the episode may be sufficient for the retrieval experience of knowing.

A significant correlation between R scores and scores on neuropsychological tests sensitive to frontal function was not found. This finding was not unexpected for two reasons. First, a significant age-related performance reduction on the tests sensitive to frontal function was not found. Second, other investigators also have failed to observe a significant correlation in old adults who were similar in age to the old adults in the present experiment (\textit{M} age = 69.9 years). Neither Parkin and Walter (1992) nor Perfect et al. (1995, Experiment 1) found a significant correlation between scores on tests sensitive to frontal function and R responses in their
“middle-old” adults (M age = 67.7 and 67.1 years, respectively). The absence of a correlation, however, does not rule out the possibility of age-related impairments in frontal system function. The two neuropsychological tests sensitive to frontal function that were used may not have been sensitive enough to reveal age-related impairments or correlations with remembering. The fact that the old adults in the present experiment were high-functioning, well-educated, and in good health may have contributed to their relatively high scores on the neuropsychological tests. Reductions in frontal activity in demographically similar groups of old adults in comparison to young adults, however, have been observed in imaging studies (e.g., Grady et al., 1995; Cabeza et al., 1997). Therefore, it is still possible that age-related reductions in remembering are related to age-related reductions in frontal system function.

The results are consistent with the hypothesis that age-related reductions in cognitive resources reduce the retrieval experience of remembering but not of knowing, and that material that is processed in terms of the self may be especially susceptible to age-related reductions in remembering. To extend the support for this hypothesis, a second experiment was conducted to determine whether reducing the availability of cognitive resources in young adults affects their retrieval of self-referential information more than that of other information, and whether the type of retrieval experience that they report is altered, particularly R responses in the self-referential condition. It was predicted that the pattern of retrieval provided by young adults whose cognitive resources are reduced by dividing their attention at
retrieval will be similar to the pattern provided by old adults who have age-related reductions in cognitive resources (see below).

**Experiment 2**

One interpretation of the results of Experiment 1 is that age-related reductions in the retrieval experience of remembering, especially for information that has been encoded in terms of the self, are a consequence of age-related reductions in cognitive resources. If this interpretation is correct, then normal young adults whose cognitive resources are reduced by having them simultaneously perform two tasks should perform similarly to old adults. Two assumptions are embedded in this prediction. One assumption is that the retrieval experience of remembering requires more cognitive resources than knowing. The second assumption is that the retrieval of self-referential information requires more cognitive resources than the retrieval of other types of information.

The component process model of memory developed by Moscovitch and Umilta (1990, 1991; Moscovitch, 1992, 1995) provides a neuropsychological framework for considering these two assumptions. This model is based on the idea that explicit memory retrieval involves two main types of cognitive processes. One type is strategic, places large demands on cognitive resources, and primarily involves the frontal lobes. A second type is relatively automatic, places few demands on cognitive resources, and primarily involves the MTL/H. Two predictions arise from this model that are particularly relevant to the hypothesis of the present experiment. One prediction is that reductions in cognitive resources should affect strategic retrieval processes but not automatic associative retrieval
processes. Put in the context of the present experiment, R responses may involve more strategic processes whereas K responses may involve more automatic processes, and retrieving self-referential information may involve more strategic processes than retrieving other types of information. A second prediction is that reductions in cognitive resources should affect performance on explicit memory tests that involve the frontal lobes to a much greater degree than tests that primarily involve other brain structures. Thus, in the present experiment, R responses may involve the frontal lobes more than K responses, and retrieving self-referential information may recruit the frontal lobes more than retrieving other types of information.

These two predictions were tested by Moscovitch (1994) in a dual task interference paradigm. He found that simultaneously performing a resource demanding task (sequential finger tapping), with retrieval tasks that were thought to place large demands on strategic retrieval processes mediated by the frontal lobes (letter fluency, recall of a categorized list of words, release from proactive inhibition), was associated with large reductions in performance. The simultaneous performance of the sequential finger tapping task with retrieval tests that were mediated by the MTL/H and believed to place relatively few demands on cognitive resources (rate of learning, words recalled during the build-up of proactive interference), on the other hand, was associated with small reductions in performance. He also found that interference affected letter fluency more than category fluency consistent with clinical data that the letter fluency task is more
sensitive frontal lobe damage than temporal lobe damage (also see Martin, Wiggs, Lalonde, & Mack, 1994; Baldo & Shimamura, 1998).

Moscovitch (1994) discussed his results as being consistent with the idea that strategic retrieval processes are resource demanding and primarily are mediated by the frontal lobes whereas automatic associative retrieval processes place few demands on cognitive resources and primarily are mediated by the MTL/H. There are several other lines of research that are consistent with this idea. First, frontal lobe deficits have been simulated in other neurologically intact adults by having them simultaneously perform two tasks that are thought to recruit frontal mediated cognitive processes (e.g., Dunbar & Sussman, 1995). Second, it has been well established that the frontal lobes of healthy adults, especially the right prefrontal lobe, are recruited during the retrieval of various types of episodic information and under a variety of conditions (for a review of imaging studies in healthy young adults see Nyberg et al., 1996). Third, there is neuroimaging evidence that suggests that frontal lobe activity is related to interference effects (e.g., D'Esposito et al., 1995; Fletcher et al., 1998; Shallice et al., 1994; Fletcher et al., 1995). Together, these studies support the conjecture that because episodic retrieval recruits processes that are mediated by the frontal lobes, performing a secondary task that also recruits processes mediated by the frontal lobes will be related to reductions in performance because the two tasks will compete for the same limited pool of cognitive resources.

Although Experiment 2 focuses on the effects of divided attention and the reduction of cognitive resources at retrieval, it is important to note that there is evidence that reduced cognitive resources at encoding always affects subsequent
recognition and recall. For example, it has been well established that when young adults divide their attention at encoding, their performance is reduced on subsequent memory tests relative to young adults under full attention (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996), and resembles that of old adults under full attention (e.g., Craik & Byrd, 1982; Anderson, Craik, & Naveh-Benjamin, 1998). In this study, therefore, as far as older adults are concerned, cognitive resources are effectively reduced at both encoding and retrieval in comparison to young adults. A study by Gardiner and Parkin (1990) using a R/K procedure showed that a reduction of cognitive resources at encoding (divided attention in young adults) diminishes the retrieval experience of remembering but does not affect knowing. Reduced cognitive resources at encoding may disrupt strategic processes mediated by the frontal lobes, but have little effect on automatic associative processes mediated by the MTL/H. Strategic processes may be required for the encoding of contextual information necessary for the retrieval experience of remembering. Automatic associative processes, on the other hand, may be required for the encoding of the content of material but not the contextual details of the material. Reduced strategic but not automatic associative processes, therefore, would lead to poor encoding of contextual details and thus reduce the likelihood of remembering. The encoding of content information, however, would be spared and thus feelings of familiarity/knowing would not be affected.

Larger reductions in performance on free-recall and cued-recall tests than on recognition following reductions in cognitive resources at encoding is consistent with this idea (e.g., Craik et al., 1996; Whiting & Smith, 1997; also see Craik, 1986).
Feelings of familiarity may be sufficient for success on tests of recognition (and for K responses), whereas the retrieval of contextual cues may be necessary for success on tests of free-recall and cued-recall (and for R responses). Reductions in cognitive resources at encoding have larger effects on memory than reductions in cognitive resources at retrieval (e.g., Craik et al., 1996), though substantial effects of divided attention at retrieval have been found (e.g., Fernandes & Moscovitch, 1998), especially on tests sensitive to frontal lobe damage (e.g., Moscovitch, 1994).

According to the component process model of memory and its related empirical support, interference should reduce the retrieval experience of remembering but have minimal (or no) effects on knowing if remembering is more frontal-mediated and resource demanding than knowing. Similarly, interference should reduce the explicit retrieval of self-referential information more than other types of information if self-referential information is more frontal-mediated and resource demanding than other types of information. The evidence that has accumulated thus far that suggests that the retrieval experience of remembering is more related to frontal function than the retrieval experience of knowing, and that self-referential information is more related to frontal function than other types of information was reviewed in the Introduction to Experiment 1.

To the extent that older adults have deficient frontal lobe function and to the extent that the processing of self-referential information and R responses are mediated by the frontal lobes and are resource demanding, it should be possible to mimic the performance of old adults in young adults on the self-reference retrieval task by having young adults perform an interfering task concurrently with the
retrieval task. It was predicted, however, that the magnitude of the performance reduction in young adults who divide their attention at retrieval may be smaller than that of old adults. The performance of young adults who divide their attention at retrieval should fall between that of young adults under full attention and old adults because reducing cognitive resources in young adults is expected to affect only frontal-mediated strategic retrieval processes because interference occurs only at retrieval. Reduced cognitive resources in old adults, on the other hand, may affect both encoding and retrieval processes that are strategic and mediated by the frontal lobes. Additionally, although old adults primarily have deficits in frontal functions, they also may have some impairment in MTL/H functions (recall the finding in Experiment 1 that the old adults performed significantly more poorly than the young adults on one of the neuropsychological tests sensitive to MTL/H function). Therefore, reductions in the performance of young adults who divide their attention at retrieval is expected to reflect reductions in frontal mediated strategic retrieval processes. Reductions in the performance of old adults, on the other hand, is expected primarily to reflect reductions in frontal mediated strategic retrieval processes but additional reductions may occur due to MTL/H deficiencies and/or to impaired encoding processes.

METHOD

Participants

Thirty-two right-handed young adults and 16 right-handed old adults participated in the experiment. Similar to the participants in Experiment 1, the
young volunteers were undergraduates at the University of Toronto at Mississauga (age range = 18 - 29 years), and the old adults were recruited from a pool of senior volunteers (age range = 65 - 79 years). All participants met the same criteria as the participants in Experiment 1 (i.e., they were all screened for a prior history and for current evidence of any serious medical, neurological, or psychological disorder, and English was their primary language; see Appendix A). The young adults were randomly divided into two groups of 16 participants: the young full attention (Y-FA) group, and the young divided attention (Y-DA) group. The three groups had a similar male/female ratio. The young adults were slightly more educated than the old adults, but the old adults outperformed the young adults on a shortened version of the Mill Hill Vocabulary Scale (Raven, 1938; Appendix B). Three ANOVAs (one for age, education, and score on the Mill Hill Vocabulary Scale) were performed to confirm these impressions. For all three ANOVAs there was a significant effect of group (for all three $F > 5.29, p < .01$), and subsequent post hoc tests (least squares means, uncorrected $p < .05$) confirmed that the difference was due to the old adults differing from the two groups of young adults who did not significantly differ. Informed consent was obtained prior to participation from all volunteers. None of the volunteers participated in Experiment 1. The demographics of the three groups are summarized in Table 5.
Table 5. Demographics of the participants in Experiment 2.

<table>
<thead>
<tr>
<th>Group</th>
<th>Males:</th>
<th>Females</th>
<th>Age</th>
<th>Education</th>
<th>Vocabulary</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>M years (SE)</td>
<td>M years (SE)</td>
<td>M score (SE)</td>
<td>M score (SE)</td>
</tr>
<tr>
<td>Young</td>
<td>8:8</td>
<td>22.3 (0.7)</td>
<td>15.8 (0.4)</td>
<td>13.6 (0.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young DA</td>
<td>7:9</td>
<td>22.1 (0.6)</td>
<td>15.9 (0.6)</td>
<td>14.4 (0.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td>8:8</td>
<td>71.8 (1.2)</td>
<td>13.8 (0.6)</td>
<td>16.3 (0.6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*maximum possible score = 20

b N = 15

Task Design

The design was identical to that of Experiment 1 with two exceptions. First, the neuropsychological tests were not administered. Second, half of the young participants (i.e., participants in the Y-DA group) performed an interfering task while they performed the retrieval task. That is, while the participants in the Y-DA group decided whether they remembered the adjective, knew the adjective, or thought that it was new, they performed a continuous auditory digit monitoring task (e.g., Griew & Davies, 1962). Since the participants were making manual responses to visually presented adjectives, an auditory digit monitoring task rather than the finger tapping task used by Moscovitch (1994) was chosen as the interfering task so that participants would not have to perform a second manual continuous response interfering task. A series of digits between 0 and 9 were auditorily presented at a rate of 1/1.5 s for the duration of the presentation of the adjectives within each list. In addition to making retrieval decisions, participants were requested to keep a running count in their mind of the number of times 3 odd-digits
occurred in a row (e.g., 1-7-3). This task was hypothesized to involve working memory. Working memory has been related to frontal lobe functions (e.g., Smith & Jonides, 1995), and working memory capacity has been demonstrated to be important for strategic retrieval processes but not automatic retrieval processes (e.g., Conway & Engle, 1994). Within each list, participants heard between 10 and 12 sequences of 3-odd digits; at the end of each list participants were asked to indicate how many sequences they heard. Participants also were informed that the digit monitoring task and their retrieval decisions are equally important and that they should evenly divide their cognitive resources between the two tasks. This final instruction was given because other research has found that performance varies depending on the emphasis that is placed on each task (e.g., Craik et al., 1996; Anderson et al., 1998). The test instructions that were given to the participants are provided in Appendix D.

**Results**

The results of this experiment are divided in the same manner as Experiment 1 (i.e., a brief encoding section and a retrieval section). The same statistical cut-offs that were used in Experiment 1 are used in this experiment. That is, all comparisons are reported for which a significant effect ($p < .05$) or a trend ($p < .10$) emerged. Similar to Experiment 1, data were collected from additional participants to replace the data from participants who made fewer than 10% correct R responses (1 old) or more than 90% correct R responses (4 old) in at least 3 of the 4 conditions. Additionally, the data from 1 young and 1 old adult were replaced because they judged fewer than 90% of the words within the 4000 ms window in at least 2 of the
conditions. It also should be noted that two old adults were unable to complete the experiment (1 could not process the words quickly enough during encoding, and 1 did not understand the encoding task requirements) so two new but demographically similar old adults were recruited to replace them.

The encoding results show that the participants judged the adjectives well within the allotted time even though the older adults were slower than the young adults to make their judgments. The encoding results also show that the social desirability and self-referential judgments were made more quickly than other-referential and syllable judgments. The retrieval results show that the overall recognition of the Y-FA group and the Y-DA group was similar but better than that of old adults. Similar to Experiment 1, young adults under full attention reported the retrieval experience of remembering more often than older adults in the Self and Social Desirability conditions, but equally often in the Other and Syllable conditions. The R scores of the Y-DA group fell in between the R scores of the Y-FA group and the Old group, but significantly differed from neither the Y-FA group nor the Old group. In contrast to overall recognition and the retrieval experience of remembering, the retrieval experience of knowing was unaffected by age, divided attention at retrieval, and the level of processing.

Encoding

Reaction Time (RT)

Participants in all three groups judged 99% of the adjectives within the 4000 ms window. The mean RT for each group was ordered Y-DA (1639 ms), Y-FA (1754
ms), then Old (1887 ms). An ANOVA revealed a significant difference between the three groups \([F(2,45) = 5.35, \text{MSE} = 183918.16]\). Post hoc tests (least squares means, uncorrected \(p < .05\)) confirmed that the two young groups did not significantly differ, and that the Y-DA group was significantly faster than the Old group. The difference between the Y-FA group and the Old group did not quite reach significance \((p = .09)\). These results essentially replicate the RTs of the young and old adults in Experiment 1. Old adults often perform this type of task more slowly than young adults, but the magnitude of the difference between young and old adults has been found to vary (cf. Salthouse, 1996).

The time it took for judgments to be made significantly varied across the levels of processing \([F(3,135) = 27.65, \text{MSE} = 29510.63]\). The mean RTs for the four conditions were ordered **Social Desirability** (1588 ms), **Self** (1732 ms), **Syllable** (1842 ms), then **Other** (1878 ms). This order is the same as was found in Experiment 1. Post hoc tests (least squares means, uncorrected \(p < .05\)) revealed that words were judged in the **Social Desirability** condition significantly more quickly than words in the **Self** condition, which were judged significantly more quickly than words in the **Syllable** and **Other** conditions, which did not differ from each other. As in Experiment 1, the effect of group and the effect of level of processing did not significantly interact \([F(6,135) = 1.49, \text{MSE} = 29510.63]\).
Retrieval

Secondary Task Performance

Performance of the participants in the Y-DA group on the secondary task (digit monitoring) during retrieval was similar across the four levels of processing. Over 2/3 of the 3-digit sequences in each of the four conditions were correctly identified by the participants; the mean proportion of sequences correctly identified in the Self, Social Desirability, Other, and Syllable conditions was .70, .71, .75, and .69, respectively. An ANOVA confirmed that the small variations in the means across the four conditions were not significant [F(3,45) = .81, MSE = .01]. These data suggest that the participants were attending to the secondary task, and that overall recognition, R, K, and RT scores are relatively free from differential trade-offs in secondary task performance across the four conditions.

Recognition

Overall (hits minus false alarms). The two groups of young adults distinguished old from new adjectives equally well but better than the Old group. Overall recognition also differed between each level of processing. These two main effects, however, were modified by a significant group by level of processing interaction; the two young groups recognized more semantically processed adjectives (self, social desirability, and other) than the Old group, but recognition of words that were processed in terms of their phonological structure (syllable) was similar for the three groups. The overall recognition data are summarized in the upper third of Table 6.
Table 6. Average overall recognition of words and average recognition of words classified as remembering or knowing by young adults under full attention (Y-FA), young adults who divided attention at retrieval (Y-DA), and old adults in Experiment 2 for four levels of processing.

<table>
<thead>
<tr>
<th>Group</th>
<th>Level of Processing</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self</td>
<td>Social</td>
</tr>
<tr>
<td></td>
<td>Desirability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hits minus False Alarms (Standard Error)</td>
<td></td>
</tr>
<tr>
<td>Y-FA</td>
<td>.50 (.04)</td>
<td>.44 (.04)</td>
</tr>
<tr>
<td>Y-DA</td>
<td>.48 (.03)</td>
<td>.37 (.03)</td>
</tr>
<tr>
<td>Old</td>
<td>.32 (.05)</td>
<td>.25 (.05)</td>
</tr>
<tr>
<td>Average</td>
<td>.44 (.03)</td>
<td>.35 (.03)</td>
</tr>
</tbody>
</table>

|       | Remembering * (Standard Error) |         |         |          |
| Y-FA  | .42 (.05)           | .33 (.05) | .25 (.03) | .09 (.02) | .27 (.03) |
| Y-DA  | .31 (.05)           | .23 (.02) | .25 (.03) | .17 (.03) | .24 (.02) |
| Old   | .26 (.04)           | .16 (.03) | .15 (.03) | .10 (.02) | .17 (.02) |
| Average | .33 (.03) | .24 (.02) | .21 (.02) | .12 (.02) |         |

|       | Knowing * (Standard Error) |         |         |          |
| Y-FA  | .05 (.03)           | .10 (.03) | .12 (.03) | .11 (.02) | .10 (.01) |
| Y-DA  | .16 (.06)           | .14 (.04) | .15 (.04) | .10 (.03) | .14 (.02) |
| Old   | .06 (.03)           | .07 (.04) | .11 (.03) | .09 (.03) | .08 (.02) |
| Average | .09 (.03) | .10 (.02) | .13 (.02) | .10 (.02) |         |

* corrected for false alarm rate (see text for formula)
The impression that the two groups of young adults recognized the adjectives equally well but better than old adults was confirmed by an ANOVA \[F(2,45) = 6.66, \text{MSE} = .04\] and post hoc tests (least squares means, uncorrected \(p < .05\)).

The overall recognition of the adjectives also was significantly influenced by the level of processing \[F(3,135) = 40.03, \text{MSE} = .01\]. The average hit rate minus false alarm rate for the four conditions was ordered Self, Social Desirability, Other, then Syllable. This order is the same as was found in Experiment 1. Post hoc tests (least squares means, uncorrected \(p < .05\)) revealed a significant difference between each condition.

In contrast to Experiment 1, the group by level of processing interaction was significant \[F(6,135) = 2.85, \text{MSE} = .01\]. Additional ANOVAs were performed to unravel the interaction. Additional ANOVAs for each group (the mean square error terms were corrected; for each comparison the \(\text{MSE} = .01\)) revealed a significant effect of level of processing for each group \[F(3,45) = 25.09, 15.08, \text{and } 4.25 \text{ for the Y-FA, Y-DA and Old groups, respectively}\]. Post-hoc tests (least squares means, uncorrected \(p < .05\)) revealed that all comparisons, except Self to Social Desirability which showed only a trend toward being different (\(p = .08\)), were significant for the Y-FA group. For the Y-DA group all comparisons except Other to Social Desirability were significant. For the Old group, only the Self vs. Other and Self vs. Syllable comparisons were significant.

Additional ANOVAs for each level of processing (the mean square error terms were corrected; for each comparison the \(\text{MSE} = .02\)) revealed that the young adults, (both groups, which did not differ significantly from each other) differed
from the old adults in all three semantic conditions \[F(2,45) = 8.11, 7.06, \text{ and } 4.24 \text{ in the Self, Social Desirability, and Other conditions, respectively,}] \] but that the three groups did not significantly differ in their overall recognition of adjectives in the Syllable condition \[F(2,45) = .31].

**Remembering.** Remembering was calculated using the same formula as was used in Experiment 1 (recall that overall recognition does not equal the sum of the R and K scores because the R and K scores have a different denominator than overall recognition; therefore, significant differences in overall recognition but not in remembering or knowing, or vice versa, are possible). Although the main effect of group approached significance and the main effect of level of processing was significant, both of these effects were modified by a significant group by level of processing interaction. The R scores of the Y-FA group were higher than the R scores of the Old group in the Self and Social Desirability conditions, but the R scores for the two groups were similar in the Other and Syllable conditions. The R scores of the Y-DA group, however, did not differ from the R scores of the Old group. Although the Y-DA group had numerically smaller R scores than the Y-FA group, the difference was not significant; R scores by the Y-DA group fell between the R scores of the Y-FA group and the Old group but significantly differed from neither the Y-FA group nor the Old group. The remembering data are summarized in the middle third of Table 6.

Similar to overall recognition, it appeared that the participants in the Y-FA group had a higher R score than the participants in the Old group, and that the R score of the young adults was not influenced by divided attention at retrieval. An
ANOVA essentially confirmed these impressions. The main effect of group approach approached significance \([F(2,45) = 3.15, \text{MSE} = .06, p = .05]\).

Remembering was significantly influenced by the level of processing \([F(3,135) = 38.08, \text{MSE} = .01]\). Mean R scores for the four conditions were ordered Self, Social Desirability, Other, then Syllable. This order is the same as was found in Experiment 1. Post hoc tests (least squares means, uncorrected \(p < .05\)) revealed that the average R score was significantly higher in the Self condition than in the Social Desirability and Other conditions, which did not differ from each other, but were significantly higher than the average R score in the Syllable condition.

The ANOVA also revealed a significant group by level of processing interaction \([F(6,135) = 4.12, \text{MSE} = .01]\). Additional ANOVAs were performed to unravel the interaction. Additional ANOVAs for each group (the mean square error terms were corrected; for each ANOVA the MSE = .01) revealed a significant effect of the level of processing for all three groups \([F(3,45) = 34.67, 5.90, \text{and } 8.00\) for the Y-FA, Y-DA, and Old groups, respectively]. Post hoc tests (least squares means, uncorrected \(p < .05\)) revealed that all comparisons were significant for the Y-FA group. Although the order was the same as in Experiment 1 (Self > Social Desirability > Other > Syllable) the difference between the Self and Social Desirability conditions was not significant in Experiment 1. For the Y-DA group, the Self condition differed from the three other conditions, the Other condition differed from the Syllable condition, and there was a trend \((p = .07)\) for the Social Desirability condition to differ from the Syllable condition. For the Old group, the Self condition differed from the other three conditions, and there was a trend \((p = .07)\)
for the Social Desirability condition to differ from the Syllable condition. Although the order was the same for the old adults in the present experiment as in Experiment 1 (Self > Social Desirability > Other > Syllable), none of the comparisons was significant in Experiment 1.

Additional ANOVAs for each level of processing (the mean square error terms were corrected; for each ANOVA the MSE = .02) revealed a significant effect of group in the Self and Social Desirability conditions [F(2,45) = 4.89 and 5.35, respectively], but not in the Other and Syllable conditions [F(2,45) = 2.31 and 1.34, respectively]. Post hoc tests (least squares means, uncorrected p < .05) revealed that in both the Self and Social Desirability conditions R scores were significantly higher for the Y-FA group than for the Old group, and that the Y-DA group did not significantly differ from the Old group. The R scores of the Y-DA group fell between those of the Y-FA group and the Old group in both conditions. The R scores of the Y-DA group did not differ significantly from those of Y-FA group in the Self condition, but there was a trend (p < .08) for the Y-DA group to have lower R scores than the Y-FA group in the Social Desirability condition.

Note the difference in the interactions found with the overall recognition data and the remembering data in this experiment. The overall recognition data suggest that young adults under full attention and young adults under divided attention are similar and that they outperform old adults on the three semantic tasks but not the phonological task. The remembering data, on the other hand, suggest that in comparison to young adults under full attention, aging reduces remembering in the Self and Social Desirability conditions, but not in the Other or
Syllable conditions. It also suggests that remembering by young adults who divide their attention at retrieval is between that of young adults under full attention and old adults, rather than the same as young adults under full attention and different from old adults as was the case for overall recognition.

**Knowing.** Knowing was unaffected by aging, level of processing, and divided attention. The knowing data are summarized in the lower third of Table 6. Knowing was calculated using the same formula as was used in Experiment 1. Similar to the results of Experiment 1, K scores varied only slightly between the young participants (both the Y-FA group and the Y-DA group) and the old participants. K scores also varied only slightly across the four levels of processing. An ANOVA confirmed that these small variations were not significant [Group F(2,45) = .99, \textit{MSE} = .05; Level of Processing F(3,135) = 1.12, \textit{MSE} = .01]; it also confirmed the absence of an interaction [F(6,135) = 1.02, \textit{MSE} = .01].

**Reaction Time (RT)**

As in Experiment 1, the average RT was calculated for hits, false alarms, R responses, R false alarms, K responses, K false alarms, and new responses. An ANOVA for each of the seven response types was then used to determine whether there were significant differences in average RT between the three groups and across the levels of processing. The results show that both groups of young adults were faster than older adults to decide whether a word was remembered, known, or new, and that the speed with which participants made hits, R responses, R false alarms, and new responses varied as a function of the level of processing. The results also show that both groups of young adults were faster than old adults to make R
responses in the three semantic conditions, but that response latency in the Syllable condition was similar for all three groups. Finally, aging, divided attention at retrieval in young adults, and the level of processing did not affect the latency to make K responses. The hit, R, and K response latency data are summarized in the upper, middle, and lower third of Table 7, respectively.
Table 7. Average reaction time (ms) for hits and hits classified as remember responses and know responses by young adults under full attention (Y-FA), young adults who divided attention at retrieval (Y-DA), and old adults in Experiment 2 for four levels of processing.

<table>
<thead>
<tr>
<th>Group</th>
<th>Self (Desirability)</th>
<th>Social (Desirability)</th>
<th>Other (Desirability)</th>
<th>Syllable (Desirability)</th>
<th>Average (Desirability)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits (Standard Error)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y-FA</td>
<td>1674 (68)</td>
<td>1697 (69)</td>
<td>1859 (72)</td>
<td>1872 (69)</td>
<td>1776 (36)</td>
</tr>
<tr>
<td>Y-DA</td>
<td>1704 (81)</td>
<td>1742 (71)</td>
<td>1787 (72)</td>
<td>1770 (71)</td>
<td>1751 (36)</td>
</tr>
<tr>
<td>Old</td>
<td>2045 (95)</td>
<td>2066 (91)</td>
<td>2119 (87)</td>
<td>2087 (86)</td>
<td>2079 (44)</td>
</tr>
<tr>
<td>Average</td>
<td>1808 (53)</td>
<td>1835 (50)</td>
<td>1922 (48)</td>
<td>1910 (47)</td>
<td></td>
</tr>
<tr>
<td>Remember Responses (Standard Error)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y-FA</td>
<td>1557 (68)</td>
<td>1546 (59)</td>
<td>1713 (63)</td>
<td>1885 (97)</td>
<td>1675 (40)</td>
</tr>
<tr>
<td>Y-DA</td>
<td>1618 (57)</td>
<td>1746 (84)</td>
<td>1801 (87)</td>
<td>1735 (86)</td>
<td>1725 (40)</td>
</tr>
<tr>
<td>Old</td>
<td>1926 (104)</td>
<td>1986 (108)</td>
<td>2059 (102)</td>
<td>1994 (100)</td>
<td>1991 (51)</td>
</tr>
<tr>
<td>Average</td>
<td>1700 (51)</td>
<td>1760 (56)</td>
<td>1858 (53)</td>
<td>1871 (56)</td>
<td></td>
</tr>
<tr>
<td>Know Responses (Standard Error)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y-FA</td>
<td>1948 (88)</td>
<td>2082 (83)</td>
<td>2000 (80)</td>
<td>1933 (76)</td>
<td>1991 (41)</td>
</tr>
<tr>
<td>Y-DA</td>
<td>1848 (111)</td>
<td>1792 (76)</td>
<td>1807 (89)</td>
<td>1825 (88)</td>
<td>1818 (45)</td>
</tr>
<tr>
<td>Old</td>
<td>2261 (95)</td>
<td>2281 (97)</td>
<td>2223 (95)</td>
<td>2249 (90)</td>
<td>2254 (46)</td>
</tr>
<tr>
<td>Average</td>
<td>2023 (61)</td>
<td>2057 (57)</td>
<td>2014 (56)</td>
<td>2006 (55)</td>
<td></td>
</tr>
</tbody>
</table>
Group. In all seven measures of response latency, the young adults (both the Y-FA group and the Y-DA group, who never significantly differed) were significantly faster than the old adults (for all ANOVAs $F > 4.41$). Faster RTs for young adults in comparison to old adults in this experiment is similar to the pattern found in Experiment 1, and is consistent with the well known fact that old adults generally respond more slowly than young adults (cf. Salthouse, 1991). Again, it is differences in RT across the levels of processing and, especially, interactions between group and the level of processing that were of more theoretical interest.

Level of Processing. Four of the seven ANOVAs, hits, R responses, R false alarms, and new responses, revealed a significant effect of the levels of processing on the speed with which participants made their responses [in all cases, $F > 3.31$]. Post hoc tests (least squares means, uncorrected $p < .05$) revealed that for hits and R responses, RTs were faster in the Self and Social Desirability conditions (which did not differ significantly from each other) than in the Other and Syllable conditions (which did not differ significantly from each other). The RTs for hits essentially mirror the overall recognition data (i.e., there do not appear to be speed-accuracy trade-offs), and the RTs for R responses show that participants are both faster and make more R responses in the Self and Social Desirability conditions than in the Other and Syllable conditions.

Average RTs for R false alarms were ordered Social Desirability (1845 ms), Syllable (1855 ms), Self (1928 ms), then Other (2044 ms). The average RTs for the three fastest conditions, Social Desirability, Syllable, and Self, did not significantly differ but RTs were significantly faster in the Social Desirability and Syllable
conditions, and had a trend toward being faster in the \textbf{Self} condition (p < .10) than in the \textbf{Other} condition. The meaning of these variations in RTs for R false alarms is unclear.

The average time it took for new responses to be made was ordered \textbf{Social Desirability} (1628 ms), \textbf{Self} (1672 ms), \textbf{Syllable} (1695 ms), then \textbf{Other} (1715 ms). Post hoc tests (least squares means, uncorrected p < .05) revealed that the average RT in the \textbf{Social Desirability} condition was significantly faster than the average RT in the \textbf{Syllable} and \textbf{Other} conditions; none of the other comparisons were significantly different. These RT data are consistent with the suggestion that participants are better at discriminating words in the \textbf{Social Desirability} and \textbf{Self} conditions than in the \textbf{Syllable} and \textbf{Other} conditions.

\textbf{Group by Level of Processing.} Out of the seven ANOVAs only one, R responses, revealed a significant interaction between group and the level of processing [F(6,126) = 3.16, \textbf{MSE} = 33841.87]. A group by level of processing interaction for R responses also was the only interaction found for RTs in Experiment 1. Additional ANOVAs were performed to unravel the interaction. Additional ANOVAs for each group (the mean square error terms were corrected; for each ANOVA the \textbf{MSE} = 33841.87) revealed a significant effect for the Y-FA group and a trend (p = .06) for the Y-DA group [F(3,42) = 11.24 and 2.63, respectively]; the RTs in the Old group did not significantly differ across the levels of processing [F(3,42) = 1.30]. Post hoc tests (least squares means, uncorrected p < .05) revealed that for the Y-FA group only the \textbf{Self} to \textbf{Social Desirability} comparison was not significant. These results are similar to those of Experiment 1. In both experiments
R responses were made most quickly by young adults in the Self and Social Desirability conditions which did not differ. Although the effect of level of processing was significant for the old adults in Experiment 1 but not in Experiment 2, only the comparisons to the Other condition were significant in Experiment 1.

Additional ANOVAs for each level of processing (the mean square error terms were corrected; for each ANOVA the MSE = 111526.93) revealed essentially the same results as Experiment 1 for the young and old adults, that is, the effect of group was significant for the three semantic conditions [F(2,45) = 6.46, 7.26, and 4.77 in the Self, Social Desirability, and Other conditions, respectively] but not the Syllable condition [F(2,42) = 2.28]. Post hoc tests (least squares means, uncorrected p < .05) confirmed that both groups of young adults (i.e., the Y-FA group and the Y-DA group who did not significantly differ) were faster than the old adults in the Self, Social Desirability, and Other conditions; the three groups made R responses equally slowly in the Syllable condition.

Discussion

The results of Experiment 2 confirmed the prediction that the pattern of remembering for self-referential information by young adults whose cognitive resources are reduced at retrieval would resemble that of old adults who have age-related reductions in cognitive resources. The retrieval experience of remembering was similar for young adults under divided attention and old adults, but differed between the Y-FA group and the Old group. As predicted, the R scores by young adults under divided attention fell between those of young adults under full attention and old adults; the R scores for the Y-DA group were numerically between
the scores for the Y-FA group and the Old group, but significantly differed from neither the Y-FA group nor the Old group. The R score for the Old group was smaller than the R score for the Y-FA group but was similar to the R score for the Y-DA group in the Self and Social Desirability conditions. All three groups had similar R scores in the Other and Syllable conditions. K scores were similar for the three groups in each condition, and did not differ across the four levels of processing. Finally, overall recognition in the four conditions did not differ significantly in the two groups of young adults, as predicted, but was better than recognition by the older adults.

The most important finding in this study was that divided attention at retrieval in young adults reduced remembering to the level observed in old adults, but had no effect on knowing. Reduced remembering in young adults who divide their attention at retrieval and in old adults suggests that recognition that is accompanied by the retrieval experience of remembering is resource demanding and, therefore, susceptible to reductions in cognitive resources. These effects are especially prominent for material that is encoded in terms of the self and social desirability. Knowing, on the other hand, was not affected by divided attention at retrieval and aging and, therefore, recognition that is accompanied by the retrieval experience of knowing may be more automatic and place fewer demands on cognitive resources.

The component process model of memory provides a neuropsychological framework within which these findings can be interpreted (e.g., Moscovitch & Umilta, 1990, 1991; Moscovitch, 1992, 1995). Recognition that is accompanied by the
retrieval experience of remembering may involve strategic retrieval processes that are resource demanding and are mediated by the frontal lobes. Because the frontal lobes are also implicated in processes involving self-awareness (e.g., Stuss, 1991), memory for material that is encoded self-referentially is especially vulnerable. Note that the finding in Experiment 1 that aging is associated with a similar reduction in remembering in the Self and Social Desirability conditions was replicated. That finding was also extended in that it was found that young adults whose cognitive resources are reduced perform similarly to old adults in the Self and Social Desirability conditions. The effect of similar reductions in the retrieval experience of remembering for self-referential and social desirability information is reliable in that it occurred in both of the experiments. Though not predicted, the finding fits with some of the theoretical notions that are developed in the General Discussion (e.g., previous research has related social-awareness to frontal function and social desirability judgments may involve social-awareness; Stuss & Benson, 1983; Damasio, 1995; Fuster, 1997).

In contrast to remembering, recognition that is accompanied by the retrieval experience of knowing may involve more automatic associative retrieval processes mediated by MTL/H structures. Other research is consistent with a neuropsychological interpretation of remembering as being more frontal mediated and knowing as being more MTL/H mediated (reviewed in the Introduction to Experiment 1 – e.g., Parkin & Walter, 1992; Düzel et al., 1997; Curran et al., 1997; Levine et al., 1998; Yonelinas et al., 1998; also see Wheeler, Stuss, & Tulving, 1997).
As expected, there were no differences in overall recognition between young adults who divided their attention at retrieval and young adults under full attention. The absence of a deficit in overall recognition for the Y-DA group in comparison to the Y-FA group is consistent with other research (e.g., Craik et al., 1996; Anderson et al., 1998). In comparison to cued-recall and free-recall, recognition places few demands on cognitive resources (see Craik, 1986). Therefore, the allocation of cognitive resources to processes that mediate the secondary task was expected to have little effect on the relatively automatic processes that are thought to mediate recognition.

Finally, in the present experiment, the retrieval success of both the Y-FA group and the Y-DA group differed from the Old group, but the retrieval experience of the Y-FA group but not the Y-DA group differed from the Old group. Although overall recognition for old adults did not differ significantly from that of young adults in Experiment 1 but did so in Experiment 2, the difference between the two studies is not unexpected given the inconsistencies reported in the literature on aging (e.g., Spencer & Raz, 1995). The reduction may be a result of impaired encoding processes and/or MTL/H deterioration in the old adults in comparison to the two groups of young adults.

**General Discussion**

Previous research found that processing and retrieval of self-referential information differed from processing and retrieval of other types of information (e.g., Rogers et al., 1977; Conway & Dewhurst, 1995; Craik et al., in press). The two experiments reported here investigated the effects of aging and divided attention at
retrieval on episodic memory for self-referential information and compared it to episodic memory for material that was processed with reference to another person, social desirability, and phonological structure. The results support three main conclusions. First, the pattern of retrieval associated with retrieval success (recognition) for material encoded with reference to the self, another person, social desirability, and phonological structure can differ from the pattern of retrieval associated with retrieval experience (remembering in comparison to knowing). Second, the retrieval experience of remembering is reduced by aging and shallow processing, and remembering by young adults who divide their attention at retrieval resembles that of old adults. The retrieval experience of knowing, on the other hand, is unaffected by aging, depth of processing, and divided attention at retrieval. Third, the retrieval of traits that are processed with reference to the self is similar to the retrieval of traits that are processed with reference to their social desirability, both in terms of overall recognition and the retrieval experience that accompanies recognition (estimated by R scores and K scores). The retrieval of self-referential and social desirability information also are affected similarly by aging and by divided attention at retrieval in comparison to other-referential and syllable information.

**Mnemonic Similarities of Self-Reference and Social Desirability**

The results of the present experiments clearly show that the retrieval experience of remembering accompanies the recognition of material that was encoded in terms of the self and social desirability more often than it accompanies the recognition of material that was encoded in terms of another person and for
phonological structure. The results also clearly show that the retrieval experience of remembering, that accompanies the recognition of material that was encoded in terms of the self and social desirability, is susceptible to reductions in cognitive resources. The retrieval experience of remembering that accompanies the recognition of material that was processed in terms of a public figure or for phonological structure, on the other hand, appears to be unaffected by reductions in cognitive resources. Although it was predicted that aging and interference would reduce the retrieval experience of remembering in the Self condition more than in the Social Desirability condition, the results show equivalent reductions in both conditions. These results, however, are consistent with a number of others reported in the literature.

In their meta-analysis of the SRE, Symons and Johnson (1997) found that the mean SRE was not significant when the “general” encoding task involved desirability ratings. Consistent with their finding, a significant SRE between self and social desirability also was not found in the present study. Other “general” encoding tasks, such as judging trait adjectives along a positive-negative dimension, are associated with a significant SRE (e.g., Conway & Dewhurst, 1995) which suggests that the memory processes that are available during desirability ratings are superior to those that are available during other “general” judgments. Several hypotheses have been posited to account for similar memory for self-referential and social desirability information. Ferguson, Rule, and Carlson (1983) suggested that similar memory for self-referential information and social desirability information occurs because words are organized in memory along an evaluative dimension. They
proposed that self-descriptiveness and social desirability judgments facilitate the use of that dimension which in turn facilitates processing of material and leads to better memory for the material.

A second hypothesis was posited by Symons and Johnson (1997). They suggested that the mean SRE is not significant when social desirability ratings are used because both self-descriptiveness and social desirability judgments promote both elaborative and organizational processes (i.e., in contrast to other semantic judgments which promote only elaborative or only organizational processes).

A third hypothesis is that the concept of self was more highly activated during social desirability judgments than during judgments about Brian Mulroney and syllable judgments. Others have suggested that people may use the self as a reference point when interpreting social information (e.g., Rogers, 1981; Breckler, Pratkanis, & McCann, 1991). Therefore, the social desirability judgments may have been confounded by self-reference (this possibility has been raised by others; Symons & Johnson, 1997; Ferguson et al., 1983). Anecdotally, but consistent with this idea, many participants in the present experiments indicated that they thought a word was socially desirable because it was a word that they thought was self-descriptive.

Related to the notion that social desirability judgments may be confounded by self-reference, is the possibility that judgments about others also may be confounded by self-reference, and that the confounding may increase as the closeness of the other increases. The participants may have used the self as a reference point when making judgments about Brian Mulroney but to a lesser degree than when they were making social desirability judgments. Support for this idea comes from Aron,
Aron, Tudor, and Nelson (1991) who provided evidence that suggests that the
cognitive representations of close others as opposed to distant others are more
interconnected with the cognitive representation of self. Similarly, the retrieval
experience of remembering associated with self and social desirability is likely also to
be found for information about another person who is close to us, such as a best
friend, as opposed to distant from us such as Brian Mulroney in the present
experiments and John Major in the Conway & Dewhurst (1995) experiment.

There may be nothing extraordinary about the processes used to encode and
retrieve information about the self and social desirability, however (for a similar
view also see Klein & Kihlstrom, 1986; Greenwald & Banaji, 1989; Symons &
Johnson, 1997). These processes may resemble those involved in memory for other
categories of information. The types of processes known to promote memory
include imageability, organization, expertise, rehearsal, affect, elaboration,
distinctiveness, and importance. Information about self and social desirability may
engage one or more of these processes to a greater extent than other information,
and may facilitate processes that lead to better memory because they provide
additional information that can contribute to retrieval. As such, they may also
require more cognitive resources so that depletion will affect them more. This
interpretation is consistent with the cognitive resource hypothesis advanced by
Craik and his colleagues (e.g., Craik & Byrd, 1982; Craik, 1986; Craik & Jennings, 1992)
in which those aspects of memory that make large demands on cognitive resources
are impaired with aging and divided attention.
An alternative, but not incompatible, interpretation of the mnemonic advantage of self and social desirability is related to the idea that personally and socially relevant information may engage frontal cortical regions more than the cognitive representation of others and phonological information. Since cognitive resource reductions have been related especially to reductions in strategic processes mediated by the frontal lobes, to the extent that the self and social desirability involve frontal lobe processes they will be particularly affected by reductions in cognitive resources (e.g., behaviorally in terms of R responses). Although the frontal lobes are engaged by all deep encoding processes and during retrieval (e.g., Kapur et al., 1994; Craik et al., in press, Tulving et al., 1994), self and social desirability may engage additional regions of frontal cortex (e.g., Craik et al., in press). The PET study that is discussed in Chapters 2 and 3 that investigated the retrieval of self-referential, other-referential, social desirability, and phonological information supports this idea, as does previous research that has related impairments in self-awareness to right prefrontal damage (e.g., Stuss, 1991), and impairments in social-awareness to orbitofrontal damage (e.g., Stuss & Benson, 1983; Damasio, 1995; Fuster, 1997). A study by Baddeley, Della Sala, Papagno, and Spinnler (1997) also supports the idea. Baddeley et al. tested dysexecutive and nondysexecutive patients with frontal lesions on two frontal-sensitive tests and on a dual-task test. They found that the two groups were similarly impaired on the two frontal-sensitive tests, but that the dysexecutive group was significantly impaired relative to the nondysexecutive group on the dual-task test. Their results suggest
that cognitive resource reductions may particularly affect specific aspects of frontal function that mediate social behavior.

**Knowing: Unaffected by Aging, Divided Attention, and Level of Processing**

The finding in the present experiments that the retrieval experience of knowing is unaffected by the level of processing and by aging is consistent with other research. In three new studies and a meta-analysis of previous studies, Gardiner et al. (1996) found reduced rates of remembering but stable rates of knowing for information processed shallowly versus deeply. Although Conway and Dewhurst (1995) found increased knowing in their general semantic condition relative to their self condition, it is likely this difference reflects a criterion difference in their between subjects design (see Hirshman & Master, 1997). Mantyla (1993), Schacter et al. (1997), Maylor (1995), Java (1996), Fell (1992, Experiment 1 reported in Perfect et al., 1995), and Perfect and Dusgupta (1997) found reduced levels of remembering but stable levels knowing for old adults in comparison to young adults. Parkin and Walter (1992) compared the number of R and K responses within their young and old groups, but did not perform a between group analysis; examination of their graphs, however, suggest an age-related reduction in remembering but stable knowing in Experiment 2, but an age-related reduction in remembering and an increase in knowing in Experiment 1. It is not clear why Perfect et al. (1995, Experiments 1 and 2B), and Fell (1992, Experiment 2 reported in Perfect et al.) found age-related reductions in remembering but age-related increases in knowing. Perfect et al. speculated that the specificity of the encoding instructions for old adults may be important in that general encoding instructions (e.g., read the
word or remember the word) appear to be associated with age-related decreases in R responses but increases in K responses, whereas specific encoding instructions (e.g., rate the word on a particular dimension) appear to be associated with age-related decreases in R responses but no change in K responses (also see Perfect & Dasgupta, 1997). A second possibility is that the inconsistent age-related effects on knowing that have been reported are related to differences in the way in which response bias was considered in the various studies; re-calculating the estimates of knowing in the various experiments using the same method to account for response bias may reduce the discrepancies (see Yonelinas et al., 1998; Gardiner & Gregg, 1997; Donaldson, 1996; Hirshman & Master, 1997; Perfect & Dasgupta, 1997; Knowlton, 1998; Hirshman & Henzler, 1998).

**Retrieval Success and Retrieval Experience can be Differentiated**

The results of the present experiment support the idea that recognition involves two processes (e.g., Mandler, 1980; Jacoby, 1991; Tulving, 1985). In Experiment 1, overall recognition of the adjectives was similar for the young and old adults across the four conditions, but the retrieval experience of remembering differed for the young and old adults across the four conditions. In Experiment 2, overall recognition by the Y-FA and Y-DA groups was similar, but their recognition was higher than that of old adults; the retrieval experience of young adults under divided attention at retrieval and old adults (both remembering and knowing), however, was similar. The different patterns that emerged between overall recognition, the retrieval experience of remembering, and the retrieval experience
of knowing suggests that different cognitive processes mediate successful recognition, remembering, and knowing.

Age-related reductions in performance on a variety of cognitive tests have been attributed to reductions in the availability of cognitive resources (e.g., Craik, 1986; Craik & Byrd, 1982; for a review see Salthouse, 1991). Reports of inconsistent significant age-related reductions in recognition, but of large age-related reductions on recall tests (e.g., Craik, 1986) suggest that the processes that mediate recognition are less resource demanding and are more automatic than the strategic retrieval processes that mediate recall. Aging may have minimal effects on recognition because even though there are age-related reductions in cognitive resources, few demands are placed on those cognitive resources during recognition.

Similar to aging, divided attention at retrieval in Experiment 2 also had minimal effects on recognition. This finding is consistent with other reports of minimal effects on recognition when attention was divided at retrieval (e.g., Craik et al., 1996). Larger memory costs on recall tests than recognition tests when attention is divided at retrieval (e.g., Craik et al., 1996) suggests that the processes that mediate recognition are less resource demanding and are more automatic than the strategic retrieval processes that mediate recall. Dividing attention at retrieval may have minimal effects on recognition because even though dividing attention reduces the availability of cognitive resources, as does aging, few demands are placed on those cognitive resources during recognition.

In contrast to minimal age-related reductions in recognition, large age-related reductions for the retrieval experience of remembering but not knowing suggests
that the retrieval experience of knowing is less resource demanding and more automatic than the retrieval processes that mediate the retrieval experience of remembering. Moreover, remembering was similar in old adults and young adults who divided their attention at retrieval which suggests that processes that mediate remembering are reduced in both groups. A similar pattern for the two groups was expected because remembering, as opposed to knowing and overall recognition, was predicted to place large demands on the cognitive resources that mediate strategic retrieval processes. The secondary task also was predicted to place large demands on cognitive resources, and aging was expected to be related to reductions in the availability of cognitive resources. Competition for the same limited capacity pool of cognitive resources by the secondary task may have reduced the availability of cognitive resources for processes that mediate the retrieval experience of remembering. This reduction in cognitive resources likely contributed to the reduction in R responses by old adults in comparison to young adults, and to the similar number provided by old adults and young adults who divided their attention at retrieval.

As predicted, the R scores of the young adults who divided their attention at retrieval fell between those of young adults under full attention and old adults; that is, their R scores did not differ significantly from the old adults or the young adults under full attention. The additional memory loss observed in older adults suggests that reductions in processes other than those related to the reduction of cognitive resources at retrieval contribute to age-related reductions in remembering. Impaired encoding processes and/or MTL/H deficiencies are likely sources of the
impairment (see Perfect et al., 1995; Perfect & Dasgupta, 1997; Cohen, Conway, & Maylor, 1994; Moscovitch & Winocur, 1992, 1995). Craik (1982, p.159) suggested that reduced processing resources in older adults forces the system to carry out easier and more habitual encoding operations. The resulting memory traces will thus be more general and similar to past encodings of those types of events; the traces will be less context-specific and less distinctive. Such encodings will support feelings of familiarity, but will be poor specifiers of time and place.

This suggestion is consistent with the results of the present experiment. The retrieval experience of knowing by old adults may have been spared because the encoding and retrieval operations that lead to K responses are automatic, demand few processing resources, and support feelings of familiarity. Remembering by older adults, however, may have been reduced relative to young adults because they have impaired processing resources at both encoding and retrieval. In older adults, the encoding of information that supports R responses may have been reduced in addition to the retrieval processes that lead to the retrieval experience of remembering. Young adults who divided their attention at retrieval, on the other hand, were faced only with reductions in processing resources at retrieval which may account for their R scores that were numerically higher than that of old adults but lower than that of young adults under full attention. Other researchers also have highlighted the importance of the interaction of encoding and retrieval operations to the retrieval experience of remembering (e.g., Conway, Collins, Gathercole, & Anderson, 1996; Wells, Hoffman, & Enzle, 1984).

Together, the results of the present experiments and other aging and divided attention research suggests that the processes that mediate remembering are more
resource demanding than the processes that mediate knowing (and overall recognition), and that reductions in cognitive resources that occur with aging and divided attention at retrieval contribute to reductions in the retrieval experience of remembering. There is also evidence, however, that suggests that resource demanding strategic retrieval processes are mediated by the frontal lobes whereas more automatic retrieval processes are related to the MTL/H (e.g., Moscovitch & Umilta, 1990, 1991; Moscovitch, 1992, 1995). In addition to evidence that aging is associated with reductions in frontal lobe functions, that episodic retrieval processes are related to frontal function, and that remembering may be more related to frontal function than knowing (reviewed above), there are other reports that are consistent with the idea that age-related reductions in the availability of cognitive resources that mediate frontal lobe processes are related to age-related reductions in the retrieval experience of remembering. For example, the retrieval experience of remembering, as opposed to knowing, involves the retrieval of contextual details that accompanied the encoding experience, and age-related reductions in frontal function have been associated with age-related reductions for contextual but not content information (e.g., source memory; Craik, Morris, Morris, & Loewen, 1990; Glisky, Polster, & Routhieaux, 1995).

Although there is less evidence that dividing attention is related to reductions in the availability of cognitive resources that mediate frontal processes, Klingberg and Roland (1997) found that interference effects during dual-task performance were associated with activation in overlapping brain areas. Their finding suggests that interference may be related to competition for the same
cognitive resources or, alternatively, to competition for the same neural structures. The results of the present experiment cannot distinguish whether interference reduced remembering due to competition for a limited pool of cognitive resources, or whether remembering was reduced because the secondary task and remembering placed demands on the same neural structures. The two interpretations are not mutually exclusive in that neural structures may have a limited functional capacity, and processing resources may be defined by the amount of cortical involvement. The two interpretations are similar in that both lend themselves to explanations in terms of frontal lobe deficiencies. Further imaging work may be able to clarify the relationship between cognitive resources and cortical activity.

The retrieval experience of remembering indexes autonoetic or "self-knowing" conscious awareness (Tulving, 1985). The results of the present experiments suggest that aging and divided attention at retrieval are associated with reductions in autonoetic awareness, especially for material that is personally or socially relevant. Others have suggested that autonoetic awareness is associated with frontal function and with the capacity for self-awareness (e.g., Wheeler, Stuss, & Tulving, 1997; Suddendorf & Corballis, 1997). Autonoetic awareness, or mental time travel, also has been related to 'theory of mind' and language which may draw on the capacity for social-awareness (e.g., Suddendorf & Corballis, 1997). The results of the present experiments are consistent with these suggestions.

The two experiments reported here have shed light on processing and retrieval differences for personally relevant information in comparison to socially relevant and nonpersonal information. Further elucidation of processing and
retrieval differences for these types of information will be valuable to cognitive and neuropsychological models of memory as well as to social and clinical conceptualizations of the self construct.

**Summary of Chapter 1**

The retrieval experience that accompanies the recognition of traits that were related to the self at encoding was investigated in old adults under full attention, young adults who divided their attention at retrieval, and young adults under full-attention using a "remember/know" (R/K) recognition procedure. Experiment 1 compared young adults under full attention to old adults under full attention. Overall recognition in all conditions (self-reference, other-reference, social desirability, and syllable) was similar for the two groups, but their retrieval experience differed. The R scores of the young adults were higher than the R scores of the old adults in the self-reference and social desirability conditions, but the R scores for the two groups were similar in the other-reference and syllable conditions. Experiment 2 compared young adults under full attention, young adults who divided their attention at retrieval, and old adults under full attention. Overall recognition by young adults under full attention and young adults who divided their attention at retrieval was similar, but higher than that of old adults. As in Experiment 1, a different pattern emerged when the retrieval experience that accompanied recognition was examined. In comparison to young adults under full attention, old adults had smaller R scores in the self-reference and social desirability conditions, but similar R scores in the other-reference and syllable conditions; the R scores of young adults who divided their attention at retrieval and old adults were
similar in all conditions. In both experiments, K scores were unaffected by group and by the level of processing. The results suggest that the cognitive processes that mediate R scores are similar for self-referential and social desirability information. These processes are reduced in old adults under full attention in comparison to young adults under full attention, and are similar in old adults under full attention and young adults who divide their attention at retrieval. The reductions are interpreted within a neuropsychological framework, and are speculated to be related to deficient frontal function in old adults and in young adults who divide their attention at retrieval.
CHAPTER 2

NEURAL CORRELATES OF THE RETRIEVAL OF SELF-REFERENTIAL INFORMATION:

I. CATEGORY SPECIFIC RETRIEVAL

The two behavioral experiments described in Chapter 1 showed that reductions in cognitive resources, due to aging or to divided attention, reduce R responses, especially for material that was processed in terms of the self or social desirability. It was suggested that reductions in cognitive resources particularly affects resource demanding frontal processes, and that both R responses and the recovery of information that is personally or socially relevant recruit those processes. Therefore, the retrieval of material that had been processed in terms of the self and social desirability may have been especially susceptible to reductions in R responses because the retrieval of material that had been encoded in terms of the self or social desirability (but not in terms of another person or phonological structure) and R responses, draw on the same limited capacity pool of cognitive resources to mediate resource demanding frontal processes. The PET study that is described in the following two chapters allowed this frontal lobe hypothesis to be tested more directly by identifying the patterns of neural activity related to the episodic retrieval of material that was processed in terms of the self, another person, social desirability, and phonological structure.
INTRODUCTION

Episodic memory retrieval involves at least three components that can be separately considered. One component involves the content of retrieval in that the episodic memory may have been initially encoded in terms of a specific category of information (e.g., names, tools, animals). The initial encoding into episodic memory (semantic retrieval) of different categories of information has been associated with activity in different posterior cortical regions (e.g., Warrington & Shallice, 1984; Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995; Martin, Wiggs, Ungerleider, & Haxby, 1996). To the extent that the neural system associated with episodic retrieval overlaps with the neural system associated with episodic encoding, different brain regions will be engaged during episodic retrieval depending on the category of information that was accessed at encoding (see Moscovitch, Kapur, Kohler, & Houle, 1995; Kohler, Moscovitch, Winocur, Houle, & McIntosh, 1998). Note that during episodic encoding and/or episodic retrieval individual items within a category can be equated or varied with respect to their contextual details (e.g., size, color, source, location, temporal order, etc.). The recovery of particular contextual details has been associated with activity in different brain regions (e.g., Nyberg et al., 1996a; Cabeza et al., 1997b). Individual items also can be equated or varied with respect to the nature of the encoding and retrieval operations that are required (Roediger, Weldon, & Challis, 1989).

A second component of episodic memory retrieval involves the success of retrieval, that is, whether or not the stored information was recovered or not recovered. The successful retrieval of stored information has been termed ecphory
Retrieval success is differentiated from "retrieval mode" (Nyberg et al., 1995) or "retrieval attempt" (Kapur et al., 1995) in that the latter two terms refer to processes related to consciously thinking back in time and trying to recover stored knowledge. Although retrieval success may emerge from retrieval mode/attemtp processes, retrieval mode/attemtp processes do not always lead to ecphory. The frontal lobes have been implicated in both retrieval mode/attemtp processes (e.g., Nyberg et al., 1995; Kapur et al., 1995) and in retrieval success (e.g., Wheeler, Stuss, & Tulving, 1995; Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1996).

A third component involves the retrieval experience, that is, the qualitative nature of the experience that accompanies the recovery of the stored information (e.g., Tulving, 1985). These three components can be separately manipulated and measured, and recent imaging techniques have provided a means to observe the pattern of brain activity that is related to each component.

Participants in the present imaging experiment retrieved material that had been encoded in terms of the self, another person (a public figure), social desirability, or phonological structure, and reported the retrieval experience that accompanied retrieval. This procedure allowed for the separate examination of the patterns of neural activity that were associated with the content of retrieval (i.e., the retrieval of information from the categories of self, a public figure, social desirability, and phonological structure), the success of retrieval (i.e., by correlating the proportion of hits from each retrieval task with brain activity), and the experience of retrieval (i.e., by correlating two types of retrieval experience in each retrieval task with brain activity). The patterns of brain activity that were found that were related to the
content of retrieval (i.e., the category that guided encoding processes) are reported in this chapter. The patterns of brain activity that were found that were related to the success of retrieval and to the experience of retrieval are described in Chapter 3.

The elucidation of the pattern of brain activity related to the retrieval of information from the self category was of primary interest. This interest stemmed, in part, from previous research that suggested that the cognitive representation of self may involve frontal regions. The putative involvement of the frontal lobes in the cognitive representation of self is interesting because the representation of other categories of information has been associated with activity in posterior cortical areas (e.g., Martin et al., 1995; Martin et al., 1996). Several studies suggest that the processing of self-referential information involves the frontal lobes, especially the right frontal lobe. Stuss (1991) related deficits in self-awareness to damage in the right prefrontal cortex, and Sellal, Fontaine, Van Der Linden, Rainville, and Labrecque (1996) reported reduced self-awareness in a patient with bilateral mesiofrontal and orbitofrontal damage. Self-awareness "...is revealed as unconcern, absent or deficient monitoring of behavior, and impaired self-regulation of behavior" (Stuss, 1991a, p. 68). The ability to retrieve material that has been processed in terms of the self and self-awareness may involve similar brain structures because both processes involve the self-concept. Fink et al. (1996), using PET, found that in comparison to the retrieval of impersonal episodic information (i.e., imagining an episode that occurred to another person), the retrieval of personal episodic information (i.e., imagining a personal episode) was related to a right hemisphere network of structures including prefrontal areas. Markowitsch et al.
(1997) reported reduced perfusion in right temporal and frontal areas, as revealed by single photon emission computed tomography (SPECT), in a patient who had severe memory deficits for personal episodic information. PET was used to examine another patient who also had severe memory deficits for personal episodic information (Markowitsch, Fink, Thone, Kessler, & Heiss, 1997a). This study revealed left frontal activation in the patient but right frontal activation in controls during the retrieval of personal episodic information. Levine et al. (1998) associated self-related deficits with right prefrontal damage in a patient who had isolated retrograde amnesia. Finally, a PET study by Craik et al. (in press) revealed that processing adjectives in terms of the self, a public figure, or for social desirability was associated with activity primarily in the left prefrontal lobe, but that the self-referential task also was associated with right frontal activity whereas the social desirability task was not. Previous PET studies using a variety of materials and methods have revealed that episodic encoding/semantic retrieval processes are primarily lateralized to the left prefrontal lobe whereas episodic retrieval processes are primarily lateralized to the right prefrontal lobe. This laterality difference is the basis of the hemispheric encoding and retrieval asymmetry (HERA) model of episodic memory (Tulving, Kapur, Craik, Moscovitch, & Houle, 1994; Nyberg, Cabeza, & Tulving, 1996). Therefore, the additional right lateralized activation observed in the self-referential encoding task in the Craik et al. (in press) study was important because it showed that the encoding of material in terms of the self involves right prefrontal cortex even though encoding processes per se are generally left lateralized.
On the basis of these previous studies, it was predicted that the retrieval of self-referential information would be related to frontal activity more than the retrieval of other types of information. Although it was expected that the right prefrontal cortex would be active during all of the episodic retrieval tasks, consistent with the HERA model (Tulving et al., 1994; Nyberg et al., 1996), it was predicted that prefrontal cortex especially on the right would be even more active in the self-referential retrieval task than in the tasks that required participants to retrieve material that was processed in terms of its social desirability and in terms of a public figure. Some additional frontal activity also was expected in the social desirability retrieval task because previous research has suggested that social-awareness involves the frontal lobes, particularly ventromedial/orbital frontal areas (e.g., Fuster, 1997; Damasio, 1995; Rolls, 1996; Stuss & Benson, 1983). No specific predictions were made about which areas of the brain would be preferentially activated during the other-referential retrieval task, though posterior cortical areas were likely candidates.

The other-referential retrieval task was included because both the self-referential and other-referential encoding tasks involved judgments about a person. Therefore, if a pattern of brain activity differentiated the self-referential retrieval task from the other tasks, the activity could not be interpreted as arising because the self-referential task involved judgments of a "person" category during encoding. The social-desirability condition was included because it does not involve a "person" category at encoding but is associated with a similar level of retrieval success as the self-referential and other-referential conditions (e.g., Symons &
Johnson, 1997; Chapter 1). The retrieval of material that was encoded in terms of phonological structure (number of syllables) was included because it does not involve semantic processing. Therefore, differences in brain activity at retrieval that depend on the use of semantic vs. nonsemantic encoding processes could be identified.

**Methods**

**Participants**

Eight right-handed young adults (4 men and 4 women) were recruited for participation in the present investigation. The volunteers were between the ages of 19 and 27 years ($M = 21.4, SE = .96$), had a mean education of 15.8 years ($SE = .56$), and a mean score of 15.8/20 ($SE = .56$) on a shortened version of the Mill Hill Vocabulary Scale (Raven, 1938; Appendix B). English was the primary language used by each participant. All participants were screened for a history or current evidence of any serious medical, neurological, or psychological disorder; they were also screened for recreational drug abuse. Informed consent was obtained prior to participation from all volunteers, and each volunteer received a $50 reimbursement for their participation. The study was approved by the local ethics committee of the University of Toronto.

**Cognitive Task Design**

In outline, participants made one of four judgments about personality trait adjectives on a 4-point scale, then their relative regional cerebral blood flow (rCBF)
was measured while their memory for the adjectives was tested using a “remember/know” (R/K) recognition procedure.

The same 16 lists of 32 personality trait adjectives used by Craik et al. (in press) and in the two behavioral experiments in Chapter 1 were used in the present experiment. Each adjective occurs in only one list. The words are listed in Appendix C.

Eight of the 32-word lists were shown during encoding (the words within each list were randomly presented), and 8 served as distractors on the recognition test subsequent to encoding. Half of the participants made judgments on the first 8 lists; the remaining half made judgments on the other 8 lists. The lists were presented in a pseudo-random order, counterbalanced across participants. Each word was presented in the center of a computer screen positioned a comfortable viewing distance from the participant (all encoding conditions were performed outside of the scanner).

Reaction time (RT) was measured while participants performed one of four encoding tasks; each task was performed twice for a total of eight measurements. The four tasks were presented in an ABCDDCBA design (counterbalanced across participants) to control for order effects. Each task involved making judgments about personality trait adjectives on a four point scale. To ensure that the adjectives primarily were encoded incidentally, participants were informed that their judgments about the adjectives were required simply as a baseline measure prior to scanning.
In one condition, representing the processing of words in terms of the self (Self), participants judged how well they thought each trait described them. In a second condition, representing the processing of words in terms of another person (Other), participants judged how well they thought each trait described Brian Mulroney (a former Canadian Prime Minister). In a third condition, representing the processing of words in terms of their social desirability (Social Desirability), participants judged how socially desirable they thought each trait was. For each word in each of these three conditions, participants pressed the key beneath their index, middle, ring or pinkie finger to indicate a judgment of “almost never”, “rarely”, “sometimes”, or “almost always”, respectively. In a fourth condition, representing the processing of words in terms of phonological structure (Syllable), participants judged the number of syllables in each trait adjective. They pressed the key beneath their index, middle, ring or pinkie finger, if they thought the adjective had 2, 3, 4 or 5 syllables, respectively.

Each trial consisted of a 500 ms fixation point followed by an adjective for 2500 ms, then another fixation point for 1000 ms. The participant could enter his or her response any time between the onset of the stimulus and the onset of the 500 ms fixation point of the next trial. Participants were told that if they had not made a judgment by the time the fixation point appeared they should do so quickly because it means that the next trait adjective is about to appear. If a judgment had not been made within the 4000 ms window, then the next adjective automatically appeared. This strict timing was used to ensure that each participant used a similar amount of time to make each judgment and to make the present experiment comparable to the
Craik et al. (in press) study which investigated the neural correlates of these four judgments.

Subsequent to the presentation of the last list, participants were positioned in the scanner and given an unexpected recognition test for the words they had just judged. The recognition test was divided into 8 blocks, the same 8 blocks and in the same order as the 8 encoding blocks. Within each block, half of the adjectives were from the list of adjectives that the participant encoded (i.e., 32 words) and half were new (i.e., 32 words). An old word/new word ratio of 88/12 was sandwiched between old/new ratios of 30/60 and 25/75. This non-random distribution of old and new words during recognition was used so that the process of interest (i.e., recognition of target items) would be the primary process being utilized during the scanning (middle) window.

At retrieval, an adjective appeared on the computer monitor for 3000 ms followed by a 1000 ms interstimulus interval. The participant could enter his or her response at any time during this 4000 ms window. Before each scan, the participant was informed of the encoding condition from which the old adjectives would occur.

Rather than have the participants simply indicate whether each word is old or new, they were requested to indicate for old words whether they "remembered" the word (i.e., whether they "re-experienced" the original encoding of the word and recollected some additional detail from the original presentation of the word) or

---

2 Subsequent to scanning, 7 participants reported that they were not expecting a memory test for the adjectives; 1 participant reported that while he was making the judgments he thought his memory might be tested for the words but he felt that he judged the words according to the instructions (i.e., he did not strategically attempt to memorize the words).
simply "knew" the word (i.e., they knew that the word was presented earlier in a list of words that they judged, but they could not retrieve any additional details from the original presentation of the word). Participants were given examples of R and K responses, and were told that the distinction was not just one of confidence (see Appendix D). They were instructed to press the key beneath their index, middle, and ring finger for R, K, and new responses, respectively. The R/K procedure, rather than a simple yes/no recognition procedure, was used because the neural correlates of the retrieval experience also were of interest. The behavioral results for remembering and knowing, and the results from the analyses of the patterns of brain activity that are related to retrieval success (hits) and to retrieval experience (remembering and knowing) are discussed in Chapter 3.

**PET Scanning Techniques**

Relative rCBF was measured by recording the regional distribution of cerebral radioactivity using a GEMS-Scanditronix PC2048-15B head scanner. Each participant was custom-fitted with a thermoplastic mask that was used to stabilize his or her head position throughout scanning; the mask was attached to the headrest of the scanner bed. A transmission scan with a 68-Ge/68-Ga rotating pin source was used to correct emission scans for photon attenuation. Eight emission scans were then conducted with bolus injections of 40 mCi of $^{15}$O-H$_2$O for each scan. Injections were administered through an intravenous catheter in the participant's left arm at the start of each cognitive task. Each task lasted approximately 2 min; data acquisition for each scan occurred in the middle 1 min of the task. The scans were 11 min apart
to allow for adequate decay of the radioactivity. Three min before each scan, participants were given instructions for the next task and some practice trials.

**Image Analysis**

The analysis of the PET data involved two steps. First, statistical parametric mapping (SPM) software (SPM94 provided by the MRC Cyclotron Unit, Hammersmith Hospital, London, England) was used to interpolate, realign, normalize, and smooth the images from each participant. Interpolation involved the reconstruction of each rCBF scan into 15 transverse planes which were then interpolated into 43 planes. The realignment procedure corrects for any head movements, and normalization involves the transformation of the images into a standard stereotactic anatomical space (Talairach & Tournoux, 1988) to correct for variations in brain size and shape across participants. Smoothing reduces variance due to individual anatomical variability (a 10 mm fullwidth at half-maximum isotropic Gaussian filter was used).

Second, the images were analyzed using partial-least squares (PLS). PLS is a multivariate statistical technique that recently has been adapted for brain imaging analyses (McIntosh, Bookstein, Haxby, & Grady, 1996). A PLS task analysis identifies spatially distributed patterns of brain activity that are maximally associated with the experimental design.

In outline, a PLS task analysis is similar to conventional univariate image subtraction methods in that it can determine regions of brain activity that are significantly activated across conditions. Because it is a multivariate rather than univariate technique, however, it is more sensitive in its detection of changes in
activity—in a single step it can use all of the information contained in the images and all of the information contained in the experimental design (i.e., rather than from pre-specified task comparisons as in the univariate subtraction methods). Therefore, PLS identifies regions of activity, as in univariate methods, but the regions it identifies are from within a pattern of activity that significantly co-varied with the experimental design. The peak voxels that are identified as significantly differing across conditions by the PLS task analysis are generally similar to those that are identified by more conventional univariate techniques. Because the PLS task analysis is more sensitive, however, it also often identifies voxels that cannot be detected by analyses using univariate subtraction methods.

The task analysis can be summarized in three steps. First, the crosscovariance between a matrix containing vectors that code the experimental design and a matrix of all of the voxels of each image for each participant is computed. The matrix for the task analysis in the present experiment coded the 4 conditions (self, other, social desirability, and syllable) using orthogonal contrasts. The matrix that coded the brain images was composed of the values for each voxel for 4 images for each of the 8 participants (the two images for the same condition were averaged).

Second, the newly computed matrix is decomposed using singular value decomposition yielding pairs of latent variables (LVs) that optimally relate the experimental design to brain activity using orthogonal dimensions. Each LV pair depicts a set of brain regions that show the greatest covariance with an experimental effect represented by the experimental design contrasts. The first LV pair that is extracted (i.e., LV1) represents the largest experimental effect and identifies the
contrast representing the effect and the collection of voxels showing the effect. Subsequent LVs account for progressively less of the cross-covariance of the contrasts and images until all covariance is accounted for. The number of LV pairs extracted is equal to the number of contrasts for the task analysis (i.e., 3 in the present experiment).

The first element of each LV pair, the design LV, represents the weights of experimental design contrasts (i.e., the experimental effect) yielding the largest covariation with the brain images. The second element of each pair, the brain LV, represents the weights of voxels that are most closely related to the first element (i.e., the collection of voxels showing the experimental effect). The image produced by the brain LV is referred to as a singular image (the singular image is plotted on a standard MRI in the present experiment). The design LV and brain LV weights are referred to as saliences. The saliences for the design LV indicate how strongly the experimental effects coded in the experimental design contrasts are represented by the pattern of brain activity for a given LV. The saliences for the brain LV index the voxel's relation to the experimental effect (i.e., increased or decreased activity).

Third, design scores for each LV and a single brain score for each participant in each condition for each LV are derived. Design scores for each LV are calculated by multiplying the original matrix containing the vectors that code the experimental design by the design LV weights. Brain scores are derived by multiplying each participants’ image in each condition by the brain LV weights and summing the cross-products. The design scores can then be plotted against the brain scores to aid the interpretation of each LV. Larger differences in design scores between
conditions indicates larger differences between those conditions in terms of the pattern of brain activity seen in the LV. Brain scores indicate how well each participant expresses the pattern of brain activity for a given LV in each condition.

The results were then assessed using two tests. The first test, a permutation test, is used to assess the significance of each LV as a whole (i.e., Does the LV represent a strong effect that is due to the entire pattern of brain activity, not just individual voxels?). The permutation test involves the random reordering of the rows of the experimental design matrix and recalculating the singular value with the new ordering. This is done multiple times (500 in the present experiment), and each time the singular value is compared with the singular value from the original singular value decomposition. The obtained statistic is the number of times (i.e., the actual probability) that the singular value from the permuted data exceeded the singular value from the original decomposition.

The second test assesses the reliability of each salience in the singular image (i.e., Are the voxel activations stable, or do they depend on which participants are included in the sample?). This test involves the submission of all brain LV saliences to a bootstrap estimation of their standard error. The bootstrap estimation involves the random resampling of participants, with replacement, and the computation of the standard error of the saliences after a sufficient number of bootstrap samples (100 in the present experiment). All peak voxels that were within a spatially contiguous set of greater than 20 voxels, and that had a salience/standard error ratio equal to or greater than 2.0 were considered stable (see Grady, McIntosh, Rajah, & Craik, 1998) and were reported in the present experiment.
RESULTS

Behavioral Data

Encoding Reaction Time (RT). The participants judged over 99% of the adjectives within the 4000 ms window, and the mean RT to make judgments in each of the four tasks was similar. The mean RTs for the four tasks were ordered Social Desirability (1482 ms, SE = 49), Syllable (1597 ms, SE = 134), Self (1617 ms, SE = 109), then Other (1711 ms, SE = 83), but an analysis of variance (ANOVA) revealed that these differences were not significant [F(3,21) = 1.71, MSE = 41198.51, p > .05].

Hits minus False Alarms. Although recognition (proportion hits minus proportion false alarms) was numerically highest in the Self condition (M = .48, SE = .04), followed by the Social Desirability (M = .46, SE = .06), Other (M = .41, SE = .06), then Syllable condition (M = .20, SE = .04), an ANOVA [F(3,21) = 11.98, MSE = .01, p = .0001], and post-hoc tests (least square means, uncorrected p < .05) confirmed that recognition in the three semantic conditions (Self, Social Desirability, and Other) was similar, but better than recognition in the phonological condition (Syllable). These recognition data are similar to the data presented in Chapter 1. Similar recognition performance in the three semantic conditions suggests that differences in the pattern of neural activity across the three conditions may be more related to differences in the category that guided encoding than to differences in retrieval success.
**PET Data**

The PLS task analysis identified three patterns of rCBF changes across tasks (LV1 to LV3). These were all significant according to the permutation tests \( (p \leq .10) \), and accounted for 37, 34, and 29%, respectively, of the cross-block covariance. The positive and negative brain LV saliences of LV1, LV2, and LV3 are listed in Tables 8 to 10, respectively, and their rCBF changes (singular images) are illustrated in Figures 2, 4, and 6, respectively. The average normalized brain score of the participants in each condition in LV1, LV2, and LV3 are displayed in Figures 1, 3, and 5, respectively. The frontal regions with positive or negative saliences in the three LVs are listed in Appendix E in terms of estimates of Brodmann’s areas (Talairach & Tournoux, 1988) and estimates of areas identified by Petrides and Pandya (1994).

LV1 identified a pattern of activation that primarily distinguished the **Self** condition from the other three conditions. The positive saliences correspond to areas within that pattern that were found to be more active in the **Self** condition than the other three conditions, and the negative saliences correspond to areas within that pattern that were less active in the **Self** condition than in the other three conditions. For the remainder of the paper LV1 will be referred to as the **Self** LV. Positive saliences were found in bilateral prefrontal areas. These prefrontal areas included the medial frontal lobe and frontal operculum in the left hemisphere, and the middle frontal gyrus in the right hemisphere. Negative saliences were found in bilateral posterior areas. These posterior areas included the basal ganglia, precentral gyrus, fusiform gyrus, middle temporal gyrus, and cuneus in the right hemisphere,
and the hippocampus, posterior cingulate and inferior temporal gyrus in the left hemisphere.

Table 8. Peaks of brain regions with stable positive and negative saliences from LV1 (Self).

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>BA</th>
<th>L/R</th>
<th>Voxels</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive Saliences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>medial frontal lobe</td>
<td>8/9</td>
<td>L</td>
<td>88</td>
<td>-16</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>middle frontal gyrus</td>
<td>9/44</td>
<td>R</td>
<td>27</td>
<td>52</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>frontal operculum</td>
<td>44/45</td>
<td>L</td>
<td>64</td>
<td>-40</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td><strong>Negative Saliences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>caudate</td>
<td></td>
<td>R</td>
<td>138</td>
<td>18</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>lateral globus pallidus</td>
<td>R</td>
<td>41</td>
<td>14</td>
<td>4</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>precentral gyrus</td>
<td>6/4/43</td>
<td>R</td>
<td>70</td>
<td>40</td>
<td>-8</td>
<td>24</td>
</tr>
<tr>
<td>fusiform gyrus</td>
<td>20</td>
<td>R</td>
<td>88</td>
<td>-10</td>
<td>-24</td>
<td></td>
</tr>
<tr>
<td>hippocampus</td>
<td></td>
<td>L</td>
<td>36</td>
<td>-40</td>
<td>-18</td>
<td>-12</td>
</tr>
<tr>
<td>middle temporal gyrus</td>
<td>21</td>
<td>R</td>
<td>23</td>
<td>58</td>
<td>-46</td>
<td>-4</td>
</tr>
<tr>
<td>posterior cingulate</td>
<td>30</td>
<td>L</td>
<td>22</td>
<td>-4</td>
<td>-48</td>
<td>16</td>
</tr>
<tr>
<td>inferior temporal gyrus</td>
<td>37</td>
<td>L</td>
<td>21</td>
<td>-60</td>
<td>-58</td>
<td>-12</td>
</tr>
<tr>
<td>cuneus</td>
<td>18</td>
<td>R</td>
<td>20</td>
<td>-78</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

Coordinates (xyz) and Brodmann’s Areas (BA) from Talairach and Tournois (1988). L = left hemisphere; R = right hemisphere; Voxels = number of voxels.
Figure 1. Average normalized brain score in each condition in LV1.
LV2 identified a pattern of activation that distinguished the Other condition primarily from Syllable condition and weakly from the Self condition. The Social Desirability condition did not contribute to the LV. The positive saliences correspond to areas within the pattern that were more active in the Other condition than in the Syllable and Self conditions, and the negative saliences correspond to
areas within the pattern that were less active in the Other condition than in the Syllable and Self conditions. For the remainder of the paper, LV2 will be referred to as the Other LV. There were three regions with positive saliences, one in the left anterior cingulate gyrus and two in the left middle temporal gyrus; only one region with a negative salience was found and it was located in the right inferior parietal lobule.

Table 9. Peaks of brain regions with stable positive and negative saliences from LV2 (Other).

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>BA</th>
<th>L/R</th>
<th>Voxels</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Saliences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>anterior cingulate gyrus</td>
<td>32</td>
<td>L</td>
<td>34</td>
<td>-10</td>
<td>16</td>
<td>36</td>
</tr>
<tr>
<td>middle temporal gyrus</td>
<td>21/37</td>
<td>L</td>
<td>27</td>
<td>-44</td>
<td>-46</td>
<td>8</td>
</tr>
<tr>
<td>middle temporal gyrus</td>
<td>39</td>
<td>L</td>
<td>45</td>
<td>-50</td>
<td>-62</td>
<td>20</td>
</tr>
<tr>
<td>Negative Saliences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>inferior parietal lobule</td>
<td>40</td>
<td>R</td>
<td>22</td>
<td>34</td>
<td>-30</td>
<td>32</td>
</tr>
</tbody>
</table>

Coordinates (xyz) and Brodmann’s Areas (BA) from Talairach and Tournoux (1988). L = left hemisphere; R = right hemisphere; Voxels = number of voxels.
Figure 3. Average normalized brain score in each condition in LV2.
LV3 identified a pattern of activation that primarily distinguished the Social Desirability condition from the Other and Syllable conditions. The Self condition did not contribute to the LV. The positive saliences correspond to areas within the pattern that were found to be more active in the Social Desirability condition than the Other and Syllable conditions, and the negative saliences correspond to areas within the pattern that were less active in the Social Desirability condition than the Other and Syllable conditions. For the remainder of the paper, LV3 will be referred to as the Social Desirability LV. Brain regions with positive saliences were found in
the left middle frontal gyrus, the anterior cingulate, the right insula, and the right cerebellum. Brain regions with negative saliences were found in the left inferior frontal gyrus, the right anterior cingulate gyrus, the right posterior cingulate gyrus, and left midbrain.

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>BA</th>
<th>L/R</th>
<th>Voxels</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive Saliences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>middle frontal gyrus</td>
<td>8/9</td>
<td>L</td>
<td>23</td>
<td>-28</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>anterior cingulate gyrus</td>
<td>24</td>
<td>L/R</td>
<td>36</td>
<td>0</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>insula</td>
<td>40/42</td>
<td>R</td>
<td>22</td>
<td>32</td>
<td>-14</td>
<td>16</td>
</tr>
<tr>
<td>anterior cerebellum</td>
<td>R</td>
<td>41</td>
<td>30</td>
<td>-40</td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td><strong>Negative Saliences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>inferior frontal gyrus</td>
<td>46</td>
<td>L</td>
<td>44</td>
<td>-50</td>
<td>38</td>
<td>12</td>
</tr>
<tr>
<td>anterior cingulate gyrus</td>
<td>32</td>
<td>R</td>
<td>21</td>
<td>14</td>
<td>22</td>
<td>36</td>
</tr>
<tr>
<td>posterior cingulate gyrus</td>
<td>30</td>
<td>R</td>
<td>34</td>
<td>8</td>
<td>-48</td>
<td>16</td>
</tr>
<tr>
<td>midbrain</td>
<td>L</td>
<td>31</td>
<td>-6</td>
<td>-36</td>
<td>-16</td>
<td></td>
</tr>
</tbody>
</table>

Coordinates (xyz) and Brodmann's Areas (BA) from Talairach and Tournoux (1988). L = left hemisphere; R = right hemisphere; Voxels = number of voxels.
Figure 5. Average normalized brain score in each condition in LV3.
The participants in the present experiment recognized (hits minus false alarms) a similar number of words that were processed in terms of the self, social desirability, and another person. More words were recognized in these three semantic conditions than in a shallow condition in which they retrieved words that were processed in terms of phonological structure. The PLS task analysis identified three patterns of brain activity. Each pattern distinguished brain activity that was associated with the retrieval of adjectives from one of the three semantic conditions.
(i.e., Self, Other, and Social Desirability) in comparison to the remaining three
conditions or a combination of two conditions. Since the main hypotheses were
related to frontal lobe activity, the following discussion emphasizes the putative
contribution of the frontal lobes to the pattern of brain activity identified in each LV.
I speculate only briefly about the functional roles of the other regions that
contributed to the three patterns of brain activity.

**Contributions of Frontal Regions to the Neural Networks**

In general, the predictions were confirmed. Prefrontal activations were
observed during the retrieval of material from personally and socially relevant
categories. A right prefrontal region was part of the network that showed higher
activation in the Self condition than in the Other, Social Desirability, and Syllable
conditions. Some left prefrontal activity also was observed in the Social Desirability
LV. The only anterior activation in the Other LV was in anterior cingulate.

Only a small region of right prefrontal activity was found in the Self LV, and
none in the other two LVs as would be predicted by the HERA model of memory
(Tulving et al., 1994; Nyberg et al., 1996). Right prefrontal activity is typically
associated with episodic memory retrieval, especially retrieval mode/attempt
processes (Nyberg et al., 1995; Kapur et al., 1995). The absence of substantial right
prefrontal activity in each of the LVs may be related to the design of the experiment.
Because all four conditions in the present study involved episodic memory
retrieval, it is in principle not possible for a LV to identify a pattern activity
associated with episodic retrieval processes per se. A LV that distinguished the three
semantic conditions (Self, Other, and Social Desirability) from the shallow condition
(Syllable) may not have been identified because the differences among the three semantic conditions may be greater than the difference between them and the shallow condition.

The LVs that were identified in the task analysis, therefore, most likely represent aspects of retrieval that are related to the semantic category that guided encoding. These aspects may be related to the processes involved in recovering information from the different categories or to the representation of the category specific knowledge stores that were used during the encoding of the episode. At the moment, there is no principled way to distinguish between the process and representational accounts.

Two particularly interesting differences in the general pattern of frontal activity emerged between the Self, Social Desirability, and Other LVs. One interesting difference occurred along the anterior-posterior axis. Activity was more anterior-frontal in the Self LV (BA 8/9, y-coordinate = 36), more middle-frontal in the Social Desirability LV (BA 8/9 and 24, y-coordinates = 18 and 24, respectively), and more posterior-frontal in the Other LV (BA 32, y-coordinate = 16). This anterior-posterior continuum may reflect the increasing involvement of self from posterior to anterior areas of the frontal lobes. It previously has been suggested that the cognitive representation of self is accessed for information that is processed in terms of its social desirability (e.g., Ferguson, Rule, & Carlson, 1983; Symons & Johnson, 1997; also see the data in Chapter 1). It also has been previously suggested that the cognitive representation of self is also accessed for information that is processed in terms of another person, especially close others such as your mother or
best friend more than distant others such as a former Prime Minister as in the present experiment (e.g., Aron, Aron, Tudor, & Nelson, 1991; Symons & Johnson, 1997; also see Chapter 1). Though speculative, if the frontal lobes play a primary role in the cognitive representation of self, with more anterior areas playing a more central role than posterior areas (see Wheeler, Stuss, & Tulving, 1997), then the increasingly anterior involvement that was found from the (distant) Other LV, to the Social Desirability LV, to the Self LV is consistent with this possibility.

The second interesting difference occurred along the left-right axis. Whereas the Self LV was associated with a pattern of neural activity that included bilateral frontal areas, the Social Desirability LV was associated with a pattern of neural activity that included a left frontal area and medial anterior cingulate, and the Other LV was associated with a pattern of neural activity that included only medial anterior cingulate. This laterality difference suggests that the cognitive representation of self involves right frontal areas more than the cognitive representation of others and of social desirability. The idea that the right frontal lobe is involved in the cognitive representation of self is consistent with the finding that some right frontal damaged patients have impaired self-related processes (e.g., Stuss, 1991; Levine et al., 1998). It also is consistent with a PET study that revealed that the encoding of self-referential information involves right prefrontal cortex (Craik et al., in press), and with other PET studies that have related right prefrontal areas to the retrieval of personal episodic information (Fink et al., 1996; Markowitsch et al., 1997a).
The left frontal activation in the Social Desirability LV in the present study suggests that this area is involved in the retrieval of information that required social judgments. This finding complements previous research that has found deficits in social relations in patients who have damage to prefrontal cortex (cf. Fuster, 1997). Note, however, that the left middle frontal gyrus was activated in the Social Desirability LV. This area is in contrast to the ventromedial/orbital frontal area that is usually damaged in patients who have deficits in social relations (e.g., Fuster, 1997; Rolls, 1996; Rolls, Hornak, Wade, & McGrath, 1994; Damasio, 1995; Stuss & Benson, 1983). Neuropsychological impairments in ventral frontal function also have been related to psychopathy (e.g., Lapierre, Braun, & Hodgins, 1995).

Patients with bilateral damage to ventral areas usually have intact social knowledge but are unable to use that knowledge to guide their social reasoning and decision-making (e.g., Damasio, 1996; Rolls et al., 1994). The present study, together with previous research relating impaired social relations to damaged ventromedial/orbital frontal cortex suggests, therefore, that the retrieval of information that required social judgments and the use of that information preferentially engage different prefrontal regions, that is, the left middle frontal gyrus and ventromedial/orbital frontal cortex, respectively.

It is interesting that the only frontal area activated in the Other LV was medial anterior cingulate. There was no a priori reason to predict frontal activation in the Other LV, and the absence of an activation in noncingulate frontal areas is consistent with other PET studies that have observed activation in posterior cortical areas during the semantic retrieval of category specific information (e.g., Martin et
al., 1995; Martin et al., 1996). The activations that were observed in the Other LV suggest that the retrieval of material that has been processed in terms of another person preferentially engages the left middle temporal gyrus (BA 21/37 and BA 39). BA 39 is multimodal association cortex and may be involved in the cognitive representation of others. BA 21/37, on the other hand, may simply reflect additional processing of the word form in the Other condition in comparison to the Self and Syllable conditions. Activity in this area is commonly observed in PET studies of word reading (reviewed in Fiez & Peterson, 1998).

In addition to these two general differences in the patterns of activation across the Self, Social Desirability, and Other LVs (i.e., anterior/posterior and left/right patterns), the specific areas of prefrontal cortex that were activated in the three LVs are broadly consistent with observations and speculations from previous PET studies. Significant changes in activity in medial (BA 8/9), lateral (BA 44), inferior (BA 46), and premotor (BA 6) frontal areas were observed in the three LVs. Both the Self and Social Desirability LVs were associated with increases in activity in BA 8/9. Previous PET research has found this area to be related to episodic retrieval (reviewed in Grady, 1998). The more posterior activation in this area in the Social Desirability LV is consistent with previous PET research using recognition; recall tends to be associated with activation in the more dorsal areas of 8/9 (see Grady, 1998).

Particularly striking, however, is the location of the peak in area 8/9 in the Self LV. The peak is remarkably close to the peak activation in three ‘theory of mind’ PET experiments (see Table 11). ‘Theory of mind’ is a phrase used to describe
an individual’s ability to use mental states to describe and predict behavior in ourselves and others (Premack & Woodruff, 1978). In the first of these experiments, Goel, Grafman, Sadato, and Hallett (1995) compared a condition that involved simple semantic decisions to a condition that involved ‘theory of mind’. In the semantic decision condition participants inferred whether unfamiliar objects are used for food preparation or for personal care and adornment. In the ‘theory of mind’ condition participants made similar inferences but from the point of view of someone living in Christopher Columbus’ time. Greater activity in area 8/9 was found during the ‘theory of mind’ condition. In a second experiment, Fletcher et al. (1995a) had participants evaluate stories requiring judgments of another’s thoughts, actions, and feelings, and compared that evaluation to the evaluation of stories requiring factual judgments. As in Goel et al.’s study, the ‘theory of mind’ condition led to greater activation in BA 8/9. In the third experiment, Happe et al. (1996) compared patients with Asperger’s syndrome to neurologically normal volunteers. The patients performed more poorly than the neurologically normal volunteers on a ‘theory of mind’ task but not on two control tasks. The patients also had reductions in activity in only that one frontal area, BA 8/9, during the ‘theory of mind’ task. Together, the present finding and those of Goel et al. (1995), Fletcher et al. (1995a), and Happe et al. (1996) suggest that the retrieval of self-knowledge and ‘theory of mind’ engage the same medial aspect of the left frontal lobule, BA 8/9. Accessing the self-concept may be the common process during the retrieval of self-knowledge and ‘theory of mind’ that engages this region. This idea is consistent with speculations that to make inferences about others requires self-awareness and
may be related to frontal function (e.g., Suddendorf & Corballis, 1997; Zelazo & Frye, 1997).

**Table 11.** Coordinates (Talairach & Tournoux, 1988) of brain activity observed in the medial aspect of the frontal lobe (Brodman’s area 8/9) in the **Self** LV in the present experiment and in previous ‘theory of mind’ PET investigations.

<table>
<thead>
<tr>
<th></th>
<th>L/R/M</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>present study</td>
<td>L</td>
<td>-16</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>Goel et al. (1995)</td>
<td>L</td>
<td>-12</td>
<td>38</td>
<td>32</td>
</tr>
<tr>
<td>Fletcher et al. (1995a)</td>
<td>L</td>
<td>-12</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Happe et al. (1996)</td>
<td>L</td>
<td>-12</td>
<td>40</td>
<td>36</td>
</tr>
</tbody>
</table>

The location of the peak activation in the right frontal area in the **Self** LV (BA 9/44) is similar to the peak found by Kosslyn et al. (1993, Experiment 2) who had participants engage in object imagery (x = 52, y = 10, z = 28 and x = 48, y = 19, z = 28, in the present study and Kosslyn et al.’s study, respectively). It is possible that processing material in terms of the self lends itself more easily to imagery than processing material in terms of another person or for social desirability (Brown, Keenan, & Potts, 1986). The later recognition of the material that was processed in terms of the self, therefore, may bring to mind the image that arose during encoding and this additional imagery may have occurred more often in the **Self** condition than in the **Other**, **Social Desirability**, and **Syllable** conditions.

The **Self** LV, but not the **Other** and **Social Desirability** LVs, also was associated with an activation in the left frontal operculum bordering BA 44. This area traditionally has been viewed as being primarily involved in language production,
and lesions to this area result in aphemia which is a syndrome of speech impairment without language deficit (Alexander, Benson, & Stuss, 1989). The retrieval tasks in the present experiment did not require motor speech output, however, which makes a speech production interpretation of the activation unlikely. One possibility related to the speech production interpretation, however, is that the activation is related more to subvocal speech in the *Self* LV than the other conditions.

A second possibility is that the activation in the *Self* LV is related to the activation of more orthographic to phonological transformation processes than the other three conditions. Fiez and Peterson (1998) found that the left frontal operculum was consistently activated in word-reading studies and tentatively suggested on the basis of the PET data and neuropsychological evidence that this area is involved in the process of orthographic to phonological transformation.

A third possibility, though clearly speculative, is that the episodic retrieval of material that has been processed in terms of the self, more so than the retrieval of other types of information, is associated with a specific (non-vocal) communication ability mediated by this area that may be uniquely human. Petrides and Pandya (1994, p. 51) have suggested that “as human communication abilities (including linguistic communication) evolved, [area 44] of the brain and the parietal areas with which it is connected were in a unique position to subserve certain specific aspects of action required for vocal and non-vocal communication”.

The activation of a frontal area involved in communication and a frontal area involved in ‘theory of mind’ during a task that involves the self-concept would
not be surprising. Human language has been closely associated with ‘theory of mind’ (e.g., Premack & Premack, 1994), and a number of investigators have suggested that a close relationship exists between frontal system functions on the one hand, and some communication abilities, ‘theory of mind’, self-awareness, and episodic memory on the other hand, all of which are considered by many to be uniquely human abilities (e.g. Suddendorf & Corballis, 1997; Levine et al., 1998; Wheeler et al., 1997; Zelazo & Frye, 1997; Stuss, 1991; Stuss, Picton, & Alexander, in press; Andreasen et al., 1995; Heyes, 1998; Petrides & Pandya, 1994).

A decrease in activity was observed in left BA 46 in the Social Desirability LV. Activity in this area has been observed in other PET studies of episodic memory, but usually involves increases in activity that are less lateral (see Grady, 1998). This area is most commonly activated in imaging studies of verbal working memory (Grady, 1998). The significance of the decrease in activity in this area is puzzling because there is no obvious reason for greater reductions in working memory in the Social Desirability condition in comparison to the Other and Syllable conditions. The decrease in right premotor cortex (BA 6/4/43) that was found in the Self LV also is puzzling because the motor output was the same in each condition.

**Contributions of Posterior Regions to the Neural Networks**

In addition to changes in frontal activity, changes in activity across the three conditions in the parietal lobe, insula, basal ganglia, hippocampus, cingulate, cerebellum, and brain stem also were observed. Activation of these areas is commonly observed in PET studies of verbal episodic memory retrieval and they may form part of neural network involved in episodic memory processes (e.g.,
Cabeza & Nyberg, 1997; Cabeza et al., 1997a; Gabrieli, 1998; Middleton & Strick, 1994; Markowitsch, 1995). Although the precise function of these areas remains unknown, I speculate briefly about the putative function of each of these areas.

A reduction in activity in inferior parietal cortex (BA 40) was observed in the Other LV. This decrease is in contrast to increased activity in inferior parietal areas (BA 40) that often is observed in PET studies examining recognition. Cabeza et al. (1997a), for example, found more activity in BA 40 during recognition than during recall and attributed the difference to the larger perceptual component in recognition than in recall. Further research may be able to elucidate the role of this area in episodic memory, though the elucidation may require a better understanding of the significance of decreases in activity (i.e., decreases may reflect priming, inhibitory processes, or the use of more automatic processes; Andreasen et al., 1995a).

The largest area of decrease in the Self LV occurred in the right caudate nucleus. Traditionally, the basal ganglia have been implicated in the planning and execution of movement. More recently, the basal ganglia and the fronto-striatal system have been implicated in cognitive processes (e.g., Middleton & Strick, 1997; Houk, 1997; Brown & Marsden, 1998), and the most commonly reported symptom in patients with damage to the caudate nucleus is behavioral disturbance, with the syndrome of abulia being the most prevalent (Bhatia & Marsden, 1994). With respect to episodic memory function, the basal ganglia appear to be particularly involved in working memory, reasoning, and strategic memory processes (reviewed in Gabrieli, 1998). Although changes in basal ganglia activity are commonly
observed in PET studies of episodic memory (e.g., Fink et al., 1996; Andreasen et al., 1995; Cabeza et al., 1997a; Nyberg, McIntosh, Houle, Nilsson, & Tulving, 1996b; Imaizumi et al., 1997; Fujii et al., 1997; Nyberg et al., 1995), the significance of the decrease in activity in the right caudate in the Self LV is unclear. Several theories of basal ganglia function have been posited. One hypothesis is that the basal ganglia "facilitate the synchronization of cortical activity underlying the selection and promulgation of an appropriate movement, or ... sequence of thoughts" (Brown & Marsden, 1998, p. 1803). A second hypothesis is that cortical-basal ganglionic modules initiate partial thoughts for subsequent elaboration and refinement (Houk, 1997). Whether one or both of these hypotheses accounts for greater basal ganglia deactivation in the Self LV remains to be determined.

The hippocampus has long been implicated in episodic memory. A recent review of hippocampal activity, as observed in PET, revealed that more anterior areas of the hippocampus tend to be activated during encoding, and that more posterior areas tend to be activated during retrieval (Lepage, Habib, & Tulving, 1998). The finding that a more anterior area of the hippocampus was associated with reductions in activity during the self retrieval task is consistent with the observations of Lepage et al., though it is puzzling why decreases occurred only in the Self LV.

Increases in activity were observed in anterior cingulate cortex in the Other and Social Desirability LVs (BA 32 and BA 24, respectively). A decrease in activity in a different region of the anterior cingulate also was observed in the Social Desirability LV (BA 32). Changes in activity in the anterior cingulate are almost
always observed in PET studies of episodic memory, but the function of the anterior cingulate in episodic memory is far from clear. The functions that the anterior cingulate have been implicated in are diverse and include affect, premotor functions, response selection, initiation, motivation, social behavior, and attention (reviewed in Devinsky, Morrell, & Vogt, 1995).

Decreases in activity in the posterior cingulate (BA 30) also were observed in the Self and Social Desirability LVs. In contrast to anterior cingulate regions that are involved in affective and motor functions, posterior cingulate regions are involved in memory and visuospatial functions (cf. Devinsky et al., 1995).

Increased activity in the cerebellum was observed in the Social Desirability LV. Similar to the basal ganglia, the cerebellum has been traditionally implicated in the coordination of movements, but it is now clear that the cerebellum has a significant role in cognitive and affective processes (see Schmahmann, 1997; Fiez, 1996; Houk, 1997; Schmahmann & Sherman, 1997). Reciprocal cerebrocerebellar connections provide the anatomical basis for cognitive and affective cerebellar functions (Schmahmann & Pandya, 1997). It is interesting to note that cerebellar abnormalities are common in autism, and that one characteristic of autism is a deficit in social communication (Courchesne, 1997). Social communication and the retrieval of social desirability information may involve similar cerebellar mediated processes.

Cerebellar activation occurs during a variety of cognitive tasks, and there are numerous hypotheses about the role of the cerebellum in cognition (reviewed by Parsons & Fox, 1997). With respect to memory, cerebellar activity is commonly
observed in PET studies of verbal episodic retrieval (Cabeza & Nyberg, 1997; Cabeza et al., 1997a; Andreasen et al., 1995b). Although there is little neuropsychological evidence that cerebellar damage affects memory functions per se, some “frontal” functions are affected by cerebellar damage which, in turn, may affect episodic memory retrieval processes (Daum & Ackermann, 1997; also see Hallett & Grafman, 1997). One hypothesis suggested by Cabeza et al. (1997a) is that the cerebellum is involved in the “generation of candidate responses” with the right cerebellum playing a greater role during semantic retrieval and the left cerebellum playing a greater role during episodic memory retrieval (the cerebello-frontal connections are crossed so this proposal is an extension of the HERA model; Tulving et al., 1994). The finding is opposite to the prediction from this extended HERA model in that increases were found in the right cerebellum during episodic retrieval. One possibility, however, is that whereas episodic retrieval processes primarily were involved in recognition in all three conditions, semantic retrieval processes also may have been involved. For example, participants may have re-evaluated the adjectives in terms of the self, another person, and social desirability (which would involve semantic retrieval processes), and used their re-evaluation of the words as an additional retrieval cue to help them determine whether the word was old or new (also see Andreasen et al., 1995b). Activation in the left prefrontal cortex in all three conditions is consistent with this possibility though the absence of right cerebellar activity in the Self and Other LVs is difficult to reconcile with this hypothesis.
A decrease in activity was observed in the brain stem in the Social Desirability LV. Although changes in activity in this area previously have been reported in PET studies of episodic memory retrieval (e.g., Fink et al., 1996; Cabeza et al., 1997a; Nyberg et al., 1996a; Nyberg et al., 1996b), the function of this area requires elucidation in further research.

Finally, activity in the right posterior insula was observed in the Social Desirability LV. Changes in insular activity have been observed in other PET studies of episodic memory (e.g., Andreasen et al., 1995, 1995a, 1995b; Imaizumi et al., 1997). The memory-related function of this area also is unclear.

CONCLUSION

Together, the results of the task analysis revealed that the retrieval of self-referential, social desirability, and other-referential information are each associated with a specific pattern of neural activity. Two additional clarifications should be made, however, about the patterns of activity that were discussed. First, the analysis revealed only areas that differed across the categories. Therefore, common brain regions that were engaged during retrieval in each of the conditions will not have been identified in the analysis. The right prefrontal cortex, for example, was likely to have been similarly engaged in retrieval processes in each of the conditions (Tulving et al., 1994; Nyberg et al., 1996). Second, it is acknowledged that the category specific patterns of neural activity observed may reflect access to category specific knowledge stores, the differential utilization of commonly available retrieval processes in each of the conditions, or, most likely, a combination of these two possibilities.
Irrespective of which possibility turns out to be correct, the most important finding in the present experiment is that personally and socially relevant information activate frontal areas. These category specific frontal activations contrast with the posterior activations observed in other PET investigations of category specific information related to objects, faces, and words (e.g., Martin et al., 1995; Martin et al., 1996).

It also was shown that the retrieval of self-referential information engages more anterior and more right-lateralized areas of prefrontal cortex than social desirability and other-referential information. The more anterior activation of frontal cortex in the self-referential condition is consistent with the speculation that anterior frontal areas are more involved in self-related processes than more posterior frontal areas (e.g., Wheeler et al., 1997). The more right-lateralized activation of frontal cortex in the self-referential condition is consistent with neuropsychological (e.g., Stuss, 1991; Levine et al., 1998) and imaging (e.g., Markowitsch et al., 1997a; Markowitsch et al., 1997; Fink et al., 1996; Levine et al., 1998) data that suggest that self-related processes involve right prefrontal areas.

Self-related processes are presumably accessed during the retrieval of material that was encoded in terms of the self (the present experiment), during self-awareness (Stuss, 1991), and during the retrieval of autobiographical episodes (e.g., Fink et al., 1996). The "level" of self being accessed in each of these cases, however, may differ (Mitchell, 1994; Stuss, 1991; Suddendorf & Corballis, 1997). Whereas the retrieval of material that was encoded in terms of the self may access self as a category of knowledge, self-awareness has been defined as the ability to use self-
knowledge to guide behavior (Stuss, 1991). This distinction parallels the distinction that was described earlier between the retrieval of material that was encoded in terms of social desirability, which may access social desirability as a category of knowledge, and social-awareness which involves the use of social knowledge to guide behavior. Although some aspects of the neural patterns that mediate personally and socially relevant knowledge may be common to the neural patterns that mediate the use of personally and socially relevant knowledge, respectively, it is likely that the use of personally and socially relevant knowledge recruits additional neural processes.

The most interesting finding in the present experiment is that the retrieval of self-referential information engages the same left medial frontal area as 'theory of mind' tasks. This finding is interesting because it is consistent with the observation that there is a relationship between self, episodic memory, the frontal lobes, and 'theory of mind' (e.g., Suddendorf & Corballis, 1997; Wheeler et al., 1997). The results of the present experiment provide empirical evidence that supports the relationship, and suggest that continued scientific attempts to uncover the relationship may be fruitful.

**Summary of Chapter 2**

Previous neuroimaging studies have shown that posterior cortical areas are activated during the retrieval of category specific information. The hypothesis that the retrieval of personally and socially relevant category specific information would engage frontal regions was tested. Participants recognized adjectives that were encoded in terms of the self, another person, for social desirability, or for
phonological structure while their relative regional cerebral blood flow was measured using positron emission tomography. It was found that both left [Brodmann's Area (BA) 8/9 and BA 44] and right frontal areas (BA 9/44) were activated during the retrieval of self-referential information. The retrieval of social desirability information was related to activity in a left frontal region (BA 8/9), and in anterior cingulate cortex (BA 24). The only anterior activation in the other-referential condition was in cingulate cortex (BA 32). The retrieval of self-referential information appears to involve more anterior frontal areas and also engages right prefrontal cortex in comparison to the retrieval of social desirability and other-referential information. Interestingly, the location of the activity in the left frontal area in the self-reference task was similar to the area of activation observed in 'theory of mind' tasks. Accessing the self-concept may be the common process in both tasks that engages this region. Similar recognition performance in the self-reference, other-reference, and social desirability conditions suggests that different patterns of neural activity in the three conditions is more related to the semantic category that guided the encoding process than to differences in retrieval success. The results support the idea that the retrieval of information that has been encoded in terms of a specific semantic category engages anterior cortical areas when the category is of personal or social relevance.
CHAPTER 3

NEURAL CORRELATES OF THE RETRIEVAL OF SELF-REFERENTIAL INFORMATION:

II. RETRIEVAL SUCCESS AND RETRIEVAL EXPERIENCE

Chapter 2 described the results of the PLS task analysis of the PET data that was collected while participants retrieved information that had been encoded in terms of the self, another person, social desirability, or phonological structure. The task analysis identified patterns of brain activity associated with retrieval content. One pattern was associated with retrieval from the Self condition (in comparison to the Other, Social Desirability, and Syllable conditions), one pattern was associated with retrieval from the Other condition (in comparison to the Self and Syllable conditions), and one pattern was associated with retrieval from the Social Desirability condition (in comparison to the Other and Syllable conditions). The present chapter describes the results of two behavioral analyses of the same PET data. The behavioral analyses were conducted to determine the patterns of brain activity (commonalities and differences across conditions) associated with retrieval success (hits) and retrieval experience (R and K responses).

Most of the relevant literature has been presented in Chapters 1 and 2, but is briefly reviewed in following Introduction. Also note that the methodology for PLS task and behavioral analyses is similar. Therefore, the Methods section in Chapters 2 and 3 are similar, but the differences between the task and behavioral analyses should be noted.
Retrieval content, retrieval success, and retrieval experience are three components of episodic memory that are separable. Recent neuroimaging techniques such as positron emission tomography (PET), combined with more sophisticated statistical analyses for imaging data, have provided the means to determine the neural correlates of each of these components. The PET study described in this Chapter was designed to elucidate the neural correlates of these three components for personally relevant episodic memories.

Personally relevant episodic memories were investigated for two main reasons. First, many studies have shown that the retrieval of material can be improved by processing the material in terms of the self. Better memory for material that is processed in terms of the self in comparison to material that is processed in other ways has been termed the self-reference effect (SRE). Rogers, Kuiper, and Kirker (1977) were the first researchers to demonstrate the SRE. They had participants judge adjectives in four conditions: self-reference (e.g., Does happy describe you?), semantic (Does happy mean the same as glad?), phonemic (Does happy rhyme with sad?) and structural (Does happy appear in big letters?). They found that more adjectives were recalled in the self condition than in the other three conditions and, similar to other levels of processing studies, they also found that more words were recalled in their semantic condition than in their phonemic and structural conditions (e.g., Craik & Tulving, 1975).

Consistent with the SRE found by Rogers et al., the general conclusion by Symons and Johnson (1997), who conducted a meta-analysis of the SRE, was that
processing material in terms of the self is mnemonically advantageous in that it is associated with better memory for material than other encoding tasks. They also noted, however, that the SRE can be attenuated or even lost under several conditions. One condition is when the organization and elaboration that is encouraged by the encoding task is similar in the self-referential task and in the comparison encoding tasks (e.g., Klein and Loftus, 1988). A second condition is when the comparison encoding task involves the processing of material in terms of an intimate other person (e.g., mother, best friend) as compared to a distant other person (e.g., Walter Cronkite, John Major) (e.g., Keenan & Baillet, 1980). A third condition is when the comparison encoding task involves social desirability judgments (e.g., Ferguson, Rule, & Carlson, 1983; also see Chapter 1).

The PET study described in Chapter 2 and the present chapter compared the brain activity associated with the retrieval of material that was encoded in terms of the self, another person, social desirability, and phonological structure. On the basis of previous research, including the results of the two behavioral experiments in Chapter 1, the overall recognition of adjectives that were encoded in terms of the self, another person, and social desirability were expected to be approximately equal but better than the recognition of adjectives that were encoded in terms of phonological structure. Because the three semantic conditions were expected to be approximately equal in terms of retrieval success, observed differences in brain activity patterns across the conditions were more likely to be attributable to differences in retrieval content than to differences in retrieval success. By comparing the different patterns of brain activity associated with retrieval from each
category of information, the neural system that is unique to the retrieval of information that was encoded in terms of the self (in comparison to the neural systems that are associated with the retrieval of other types of information) could be determined. The elucidation of this neural system could provide some insight into the neural correlates that mediate the mnemonic advantage of self-referential processing that is commonly observed (i.e., the SRE).

Second, although the three aforementioned conditions reduce or get rid of the SRE, Conway and Dewhurst (1995, Experiment 3) found that even when the organization and elaboration that is encouraged across the different encoding tasks is equated, an SRE is observed when the retrieval experience that accompanies successful recognition is considered. Consistent with other studies, they found similar overall recognition of words in their self and general semantic conditions. They also found, however, that the recognition of words in their self condition was more likely to be accompanied by the retrieval experience of "remembering", indexed by a remember or R response, versus "knowing", indexed by a know or K response, than words in their general semantic condition. R responses are given when retrieval is accompanied by rich contextual detail and involves a "re-experiencing" of the original encoding episode; K responses, on the other hand, are given when retrieval is accompanied only by a feeling of familiarity (Tulving, 1985; for reviews of the R/K paradigm see Gardiner & Java, 1993; Donaldson, 1996; Rajaram & Roediger, 1997).

Therefore, on the basis of previous research (e.g., Chapter 1; Conway & Dewhurst, 1995), it was expected that the pattern of retrieval experience would differ
from the pattern of retrieval success across the conditions. The PET study used a
R/K recognition procedure so that retrieval experience (R responses and K
responses) and retrieval success (the sum of correct R and K responses) could be
determined. It was predicted that R responses would be similar for the self-
referential and social desirability conditions but higher in these two conditions than
the other-referential condition which, in turn, was expected to have more R
responses than the phonological condition. In light of variations in retrieval
success between the three semantic conditions and the phonological condition, and
variations in retrieval experience across the four conditions, commonalties and
differences in the pattern of brain activity associated with hits and R and K
responses across conditions could be determined.

Within a single study, therefore, the neural correlates of the retrieval of self-
referential, other-referential, social desirability, and syllable information could be
examined in terms of retrieval content, retrieval success, and retrieval experience.
The results of the category specific analysis (i.e., the patterns of neural activity that
are related to the retrieval of adjectives encoded in terms of the self, another person
and for social desirability) were discussed in Chapter 2. The present chapter
describes the neural correlates of retrieval success and retrieval experience.

It is now well established that the right prefrontal cortex is preferentially
involved during episodic retrieval whereas the left prefrontal cortex is preferentially
involved during episodic encoding/semantic retrieval. This observation is the basis
of the hemispheric encoding and retrieval asymmetry (HERA) model of memory
(Tulving, Kapur, Craik, Moscovitch, & Houle, 1994; Nyberg, Cabeza, & Tulving
1996). Consistent with the HERA model, it was expected that the right prefrontal
cortex would be more active than the left prefrontal cortex in each of the episodic
retrieval conditions. Some studies have suggested that the right frontal activity
during episodic retrieval is more related to "retrieval mode" (Nyberg et al., 1995) or
"retrieval attempt" (Kapur et al., 1995) than to retrieval success, but other imaging
and neuropsychological studies have demonstrated that the right prefrontal lobe
also plays a role in retrieval success (e.g., Rugg, Fletcher, Frith, Frackowiak, & Dolan,
1996; Nyberg, McIntosh, Houle, Nilsson, & Tulving, 1996b; Wheeler, Stuss, &
Tulving, 1995; Stuss, Sayer, Franchi, & Alexander, 1996). These studies, however,
did not separate retrieval success from retrieval experience. Therefore, the right
frontal activity that has been observed in previous imaging studies of episodic
memory presumably reflects retrieval success that is accompanied by a combination
of R and K responses. By correlating brain activity with behavioral performance in
terms of hits, R responses, and K responses, the contribution of frontal regions to
retrieval success per se could be compared to the contribution of frontal regions to
the retrieval experiences of remembering and knowing.

Studies are beginning to emerge that suggest that R responses are related to
frontal function more than K responses. An event related potential study by Düzel,
Yonelinas, Mangun, Heinze, and Tulving (1997) revealed that in comparison to K
responses, R responses are associated with a larger positivity in the 600 - 1000 ms
post-stimulus onset time window in bifrontal and left parietotemporal areas. K
responses, on the other hand, were associated with a frontocentral negativity during
the 600 - 1000 ms time window as well as an early temporoparietal positivity. A late
right frontal positivity was associated with both R responses and K responses in their study. Remembering and knowing also have been tested in two patients with right frontal damage. Curran, Schacter, Norman, and Galluccio (1997) found that although their patient could perform the R/K task he had an extraordinarily high R response false alarm rate. They speculated that his high false alarm rate may be related to an impairment in his ability to utilize specific contextual details to distinguish new from old items. Levine et al. (1998) found that their traumatic brain injured patient, who had focal retrograde amnesia, provided fewer R responses relative to controls. Patients with damage to the MTL/H or diencephalon, on the other hand, have reductions in both R and K responses as would be expected in light of their memory loss (see Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998; Knowlton, 1998). Aging also has been related to deficits in frontal function (e.g., Moscovitch & Winocur, 1992, 1995; Stuss et al., 1996). Consistent with the idea that R responses are related to frontal function, Parkin and Walter (1992) found that R responses by older adults correlated with their scores on the Wisconsin Card Sorting Test (WCST). The WCST is sensitive to frontal disturbance (Milner, 1963), though additional brain regions are known to mediate performance on this test (Lezak, 1995; Berman et al., 1995). Poorer performance on the WCST correlated with fewer R responses. Finally, the two studies presented in Chapter 1 suggest that R responses may be related to frontal function. The studies showed that aging reduced R responses but not K responses, and that young adults who divided their attention at retrieval performed similarly to old adults; PET studies have observed reductions in frontal activity in older adults relative to younger adults (e.g., Cabeza et al., 1997;
Grady et al., 1995) and when attention is divided as compared to full attention (e.g., D'Esposito et al., 1995; Fletcher, Shallice, & Dolan, 1998; Shallice et al., 1994; Fletcher et al., 1995). On the basis of these previous studies, it was predicted that the proportion hits by participants on a R/K recognition test would be more related to frontal activity, especially on the right, than misses, and that R responses would be related to frontal activity more than K responses.

An alternative hypothesis is that the frontal lobes may be recruited as much, if not more so, during K responses but that this frontal activity is not crucial for K responses. Inspection of the response latencies in the previous behavioral studies (Chapter 1) shows that K responses were longer than R responses suggesting that there was greater uncertainty or more cognitive computations associated with a K response. R responses may be associated with the rapid recovery of a vivid contextually rich memory about which the participant is certain, and for which few strategic search and strategic monitoring and verification processes are needed. Consequently, frontal activity, though necessary for the recovery of that information, may be minimal. In contrast, K responses by their very nature may elicit more strategic search and strategic verification processes even though these processes may not be necessary for K responses.

Methods

Participants

Eight right-handed young adults were recruited for participation in the present investigation. The volunteers had a mean age of 21.4 years ($SE = .96$), and a
mean education of 15.8 years (SE = .56). Additional participant details can be found in Chapter 2 which describes the results of the category specific analysis.

Cognitive Task Design

In outline, participants made one of four judgments about personality trait adjectives on a 4-point scale, then their relative regional cerebral blood flow (rCBF) was measured while their memory for the adjectives was tested using a R/K recognition procedure.

Eight lists of 32 adjectives were shown during encoding, and an additional 8 lists of 32 adjectives served as distractors on the recognition test subsequent to encoding (counterbalanced across participants). Participants performed one of four encoding tasks; each task was performed twice for a total of eight measurements. The four tasks were presented in an ABCDDCBA design (counterbalanced across participants) to minimize order effects. Each task involved making judgments about personality trait adjectives on a four point scale.

In one condition, representing the processing of words in terms of the self (Self), participants judged how well they thought each trait described them. In a second condition, representing the processing of words in terms of another person (Other), participants judged how well they thought each trait described Brian Mulroney (a former Canadian Prime Minister). In a third condition, representing the processing of words in terms of their social desirability (Social Desirability), participants judged how socially desirable they thought each trait was. For each word in each of these three conditions, participants pressed the key beneath their index, middle, ring or pinkie finger to indicate a judgment of "almost never",
“rarely”, “sometimes”, or “almost always”, respectively. In a fourth condition, representing the processing of words in terms of phonological structure (Syllable), participants judged the number of syllables in each trait adjective. They pressed the key beneath their index, middle, ring or pinkie finger, if they thought the trait had 2, 3, 4 or 5 syllables, respectively.

Subsequent to the presentation of the last list, participants were positioned in the scanner and given an unexpected recognition test for the words they just judged. The recognition test was divided into 8 blocks, the same 8 blocks and in the same order as the 8 encoding blocks. Within each block, half of the adjectives were from the list of adjectives that the participant encoded (i.e., 32 adjectives) and half were new (i.e., 32 adjectives). An old word/new word ratio of 88/12 was sandwiched between old/new ratios of 30/60 and 25/75. This non-random distribution of old and new words during recognition was used so that the process of interest (i.e., recognition of target items) would be the primary process being utilized during the scanning (middle) window.

Rather than have the participants simply indicate whether each word is old or new, they were requested to indicate for old words whether they “remembered” the word (i.e., whether they “re-experienced” the original encoding of the word and recollected some additional detail from the previous presentation of the word) or simply “knew” the word (i.e., they knew that the word was presented earlier in a list of words that they judged, but they could not retrieve any additional details from the prior presentation of the word). Participants were given examples of R and K responses, and were told that the distinction was not just one of confidence. They
were instructed to press the key beneath their index, middle, or ring finger for R, K, and new responses, respectively. Additional details of the cognitive task design can be found in Chapter 2.

**PET Scanning Techniques**

Relative rCBF was measured by recording the regional distribution of cerebral radioactivity using a GEMS-Scanditronix PC2048-15B head scanner. Each participant was custom-fitted with a thermoplastic mask that was used to stabilize his or her head position throughout scanning; the mask was attached to the headrest of the scanner bed. A transmission scan with a 68-Ge/68-Ga rotating pin source was used to correct emission scans for photon attenuation. Eight emission scans were then conducted with bolus injections of 40 mCi of $^{15}$O-H$_2$O for each scan. Injections were administered through an intravenous catheter in the participant's left arm at the start of each cognitive task. Each task lasted approximately 2 min; data acquisition for each scan occurred in the middle 1 min of the task. The scans were 11 min apart to allow for adequate decay of the radioactivity. Three min before each scan, participants were given instructions for the next task and some practice trials.

**Image Analysis**

The analysis of the PET data involved two steps. First, statistical parametric mapping (SPM) software (SPM94 provided by the MRC Cyclotron Unit, Hammersmith Hospital, London, England) was used to interpolate, realign, normalize, and smooth the images from each participant. Interpolation involved the reconstruction of each rCBF scan into 15 transverse planes which were then
interpolated into 43 planes. The realignment procedure corrects for any head movements, and normalization involves the transformation of the images into a standard stereotactic anatomical space (Talairach & Tournoux, 1988) to correct for variations in brain size and shape across participants. Smoothing reduces variance due to individual anatomical variability (a 10 mm fullwidth at half-maximum isotropic Gaussian filter was used).

Second, the images were analyzed using partial-least squares (PLS). PLS is a multivariate statistical technique that recently has been adapted for brain imaging analyses (McIntosh, Bookstein, Haxby, & Grady, 1996). PLS identifies spatially distributed patterns of brain activity that are maximally associated with the experimental design (task analysis) or some behavioral measure (behavioral analysis). In the present experiment a task analysis and two behavioral analyses were performed on the data. The task analysis was conducted to answer the question "How are the retrieval of words that were encoded with respect to the self, another person, social desirability, and phonological structure related to brain activity?". The results of this analysis are presented in Chapter 2. The behavioral analyses were conducted to answer the questions "How are hits/misses and how are R/K responses related to brain activity, in terms of commonalities and differences in the brain-behavior relationship, across conditions?"

The behavioral analyses can be summarized in three steps. First, the cross-covariance between a matrix containing vectors that code the behavior and a matrix of all of the voxels of each image for each participant is computed. There were two matrices for the behavior analyses; one matrix coded the proportion of hits provided
by each participant in each condition, and one matrix coded the proportion of hits that were R responses for each participant in each condition. The matrix that coded the brain images was composed of the values for each voxel for 4 images for each of the 8 participants (the two images for the same condition were averaged).

Second, this newly computed matrix is decomposed using singular value decomposition yielding pairs of latent variables (LVs) that optimally relate the behavior to brain activity using orthogonal dimensions. The first pair that is extracted (i.e., LV1) represents the largest behavioral effect (i.e., commonality or difference across conditions) and the collection of voxels showing the effect. Subsequent LVs account for progressively less of the cross-covariance of the contrasts and images until all covariance is accounted for [the number of LV pairs extracted is equal to the number of conditions for the behavioral analysis (4 in the present experiment)].

The first element of each LV pair, the behavior LV, represents the weights of the behavioral measures across conditions that has the largest covariation with the brain images. The second element of each pair, the brain LV, is a weighted linear combination of voxels that is most closely related to the first element (i.e., the collection of voxels showing the behavior effect). The image produced by the brain LV is referred to as a singular image (the singular image is plotted on a standard MRI in the present experiment). The behavior LV and brain LV weights are referred to as saliences. The saliences for the behavior LV indicate how strongly the coded behavior is represented by the pattern of brain activity for a given LV. The
saliences for the brain LV index the voxel's relation to the behavior effect (i.e., increased or decreased activity).

Third, behavior scores for each LV and a single brain score for each participant in each condition for each LV are derived. Behavior scores for each LV are calculated by multiplying the original matrix containing the vectors that code the behavior by the behavior LV weights. Brain scores are derived by multiplying each participants' image in each condition by the brain LV weights and summing the cross-products. The behavior scores can then be plotted against the brain scores to aid the interpretation of each LV. The behavior scores index the commonality or difference across conditions in the brain-behavior relationship seen in the LV. The brain scores indicate how well each participant expresses the pattern of brain activity for a given LV in each condition.

The results were then assessed using a test that determines the reliability of each brain LV salience in the pattern of activation (i.e., Are the voxel activations stable, or do they vary depending upon which participants are included in the sample?). This test involves the submission of all brain LV saliences to a bootstrap estimation of their standard error. The bootstrap estimation involves the random resampling of participants, with replacement, and the computation of the standard error of the saliences after a sufficient number of bootstrap samples (100 in the present experiment). All peak voxels that were within a spatially contiguous set of greater than 20 voxels, and that had a salience/standard error ratio equal to or greater than 2.0 were considered stable (see Grady, McIntosh, Rajah, & Craik, 1998) and were reported here.
RESULTS

Behavioral Data

The mean proportion of hits/misses, proportion hits minus proportion false alarms, and proportion of hits that were R/K responses, for each condition, are displayed in Table 12. The mean proportion of hits/misses and the proportion of hits that were R/K responses were used in the behavioral PLS analyses. The average proportion hits minus proportion false alarms data for each condition are included for comparison to related research. As was expected, retrieval success (proportion hits minus proportion false alarms) was similar in the Self, Other, and Social Desirability conditions but was better in these 3 conditions than in the Syllable condition. Also as was expected, a similar number of R responses were provided in the Self and Social Desirability conditions but more were provided in these two conditions than in the Other condition, and more were provided in the Other condition than in the Syllable condition.
Table 12. Mean proportion of hits/misses, proportion hits minus proportion false alarms (FA), and proportion of hits that were remember/know responses in each condition (standard error in parentheses).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Hits/Misses</th>
<th>Hits minus FA</th>
<th>Remember/Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self</td>
<td>.80/.20 (.04)</td>
<td>.48 (.04)</td>
<td>.57/.43 (.07)</td>
</tr>
<tr>
<td>Social Desirability</td>
<td>.76/.24 (.04)</td>
<td>.46 (.06)</td>
<td>.60/.40 (.08)</td>
</tr>
<tr>
<td>Other</td>
<td>.70/.30 (.06)</td>
<td>.41 (.06)</td>
<td>.50/.50 (.08)</td>
</tr>
<tr>
<td>Syllable</td>
<td>.64/.36 (.03)</td>
<td>.20 (.04)</td>
<td>.35/.65 (.07)</td>
</tr>
</tbody>
</table>

The mean proportion of hits by the participants in each condition was co-varied with brain activity in the first brain-behavior imaging analysis. The participants correctly identified the most adjectives in the Self condition, followed by the Social Desirability, Other, then Syllable conditions. An ANOVA revealed a significant difference between the conditions [F(3,21) = 6.11, MSE = .01, p < .01]. Post hoc tests (least squares means, uncorrected p < .05) revealed that significantly more adjectives were correctly identified in the Self condition than in the Other and Syllable conditions, and in the Social Desirability condition than the Syllable condition. These data are not precisely as was predicted (i.e., it was predicted that the number of hits in the Self, Social Desirability, and Other conditions would be similar but would be greater than the number of hits in the Syllable condition). Note, however, that they are in the right direction, are limited in that they are based on data from only 8 participants, and are as predicted when the false alarm rate is considered.
Retrieval success calculated as proportion hits minus proportion false alarms reveals the pattern that was predicted and is consistent with previous research (e.g., Conway & Dewhurst, 1995; also see Chapter 1). Participants recognized more adjectives from the three semantic conditions, which appeared to be recognized equally well, than from the phonological condition. This impression was confirmed by an ANOVA \[ F(3,21) = 11.98, \text{MSE} = .01, p = .0001 \], and post-hoc tests (least square means, uncorrected \( p < .05 \)).

**Remember and Know Responses**

R responses were assessed by calculating the proportion of hits that were R responses; K responses are the remainder of that proportion. The mean proportion of R responses for participants in each of the four conditions was used in the second brain-behavior analysis of the imaging data. As was predicted, an ANOVA confirmed a significant difference in the proportion of R responses across the conditions \[ F(3,21) = 24.21, \text{MSE} = .004, p = .0001 \]. Post-hoc tests (least squares means, uncorrected \( p < .05 \)) revealed that the proportion of R responses did not significantly differ for the Social Desirability and Self conditions, but that the proportion in these two conditions was greater than the proportion in the Other condition which, in turn, was greater than the proportion in the Syllable condition. This pattern of R responses also is similar to other research (e.g., Conway & Dewhurst, 1995; also see Chapter 1).
**Remember and Know Response Times**

For comparison to other research, the average response time (RT) was determined for correct R responses and correct K responses in each condition (Table 13). An ANOVA was used to verify the impression that R responses are made more quickly than K responses. The ANOVA confirmed this impression \([F(1,7) = 9.72, \text{MSE} = 246198.88, \, p < .05]\). It also revealed a main effect of condition \([F(3,21) = 5.97, \text{MSE} = 36520.86, \, p < .01]\), and a trend toward a significant interaction between response type (R or K) and condition \([F(3,21) = 2.40, \text{MSE} = 22075.50, \, p < .10]\). Post hoc tests (least squares means, uncorrected \(p < .05\)) on the main effect of condition revealed that the RT to make a correct R or K response did not significantly differ between the **Self** and **Social Desirability** conditions, or between the **Other** and **Syllable** conditions. To investigate the trend toward an interaction between response type and condition, separate ANOVAs (the mean square error terms were corrected; for each ANOVA the \(\text{MSE} = 29298.18\)) were performed on the R response RTs and K response RTs. Consistent with previous reports (e.g., Chapter 1), the average RT for correct R responses was affected by the level of processing whereas the average RT to make a K response was not influenced by the level of processing \([\text{for correct R response RTs, } F(3,21) = 7.82, \, p = .001, \text{ and for correct K response RTs, } F(3,21) = 1.43, \, p > .05]\). Post hoc tests (least squares means, uncorrected \(p < .05\)) revealed that the mean RT for correct R responses did not differ between the **Self** and **Social Desirability** conditions or between the **Other** and **Syllable** conditions.
**Table 13.** Mean response time (ms) for correct remember responses and correct know responses in each condition (standard error in parentheses).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Remember</th>
<th>Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self</td>
<td>1406 (48)</td>
<td>1949 (155)</td>
</tr>
<tr>
<td>Social Desirability</td>
<td>1500 (77)</td>
<td>1891 (112)</td>
</tr>
<tr>
<td>Other</td>
<td>1681 (127)</td>
<td>2024 (116)</td>
</tr>
<tr>
<td>Syllable</td>
<td>1779 (85)</td>
<td>2050 (124)</td>
</tr>
</tbody>
</table>

**PET Data**

**Behavioral Analyses**

**Hits/Misses.** The PLS behavioral analysis identified four patterns of rCBF changes that related brain activity to hits (LV1 to LV4). Because a permutation test, which assesses the significance of the LV as a whole, can be conducted for task analyses but not behavioral analyses, to be conservative only the first LV pair (LV1) was interpreted. LV1 accounted for 65% of the cross-block covariance. The correlations between brain score and proportion hits in each condition are illustrated in Figure 7. The brain regions with stable positive and negative saliences for this LV are listed in Tables 14 and 15, respectively, and the rCBF changes are illustrated in Figure 8. Frontal regions with stable positive or negative saliences in the LV are listed in Appendix F in terms of estimates of Brodmann’s areas (Talairach & Tournoux, 1988) and estimates of areas identified by Petrides and Pandya (1994).
LV1 identified a pattern of activation that primarily related hit rate to brain activity, across all conditions. Put another way, this LV identified a pattern of brain activity that was associated with making a hit, irrespective of whether the word was recognized in the Self, Social Desirability, Other, or Syllable condition. I am interpreting only the first LV which identified a commonality across the conditions. It is possible that the remaining LVs may identify patterns of brain activity related to hits that differentiate the conditions. The positive saliences correspond to regions within the pattern of brain activity that positively correlated with hits. The negative saliences correspond to regions within the pattern of brain activity that negatively correlated with hits (i.e., positively correlated with misses). The largest and most significant region with a positive salience included the basal ganglia bilaterally. Other regions with positive saliences were found in bilateral frontal areas (the left frontal operculum/insula, right superior frontal gyrus, and right medial frontal lobe), the right insula, and bilateral temporal areas (left superior temporal gyrus, and right middle temporal gyrus). Regions with negative saliences were found in bilateral posterior areas (left > right). In the left hemisphere these areas included the middle temporal gyrus, thalamus, superior temporal gyrus, insula, posterior cingulate gyrus, lingual gyrus, and midbrain. In the right hemisphere these areas included the inferior parietal lobule and the cerebellum.
Figure 7. Correlations between brain score and proportion of hits in each condition.
**Table 14.** Peaks of brain regions (stable positive saliences) that correlated with increased hits.

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>BA</th>
<th>L/R</th>
<th>Voxels</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>superior frontal gyrus</td>
<td>10</td>
<td>R</td>
<td>64</td>
<td>16</td>
<td>58</td>
<td>8</td>
</tr>
<tr>
<td>medial frontal lobe</td>
<td>10</td>
<td>R</td>
<td>32</td>
<td>20</td>
<td>36</td>
<td>-8</td>
</tr>
<tr>
<td>frontal operculum</td>
<td>47</td>
<td>L</td>
<td>21</td>
<td>-26</td>
<td>20</td>
<td>-4</td>
</tr>
<tr>
<td>superior temporal gyrus</td>
<td>38</td>
<td>L</td>
<td>26</td>
<td>-48</td>
<td>12</td>
<td>-16</td>
</tr>
<tr>
<td>putamen</td>
<td></td>
<td>R</td>
<td>798</td>
<td>24</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>anterior cingulate gyrus</td>
<td>32</td>
<td>L</td>
<td>-4</td>
<td>40</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>caudate</td>
<td></td>
<td>R</td>
<td>14</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>claustrum</td>
<td></td>
<td>L</td>
<td>35</td>
<td>-32</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>insula</td>
<td>40/43</td>
<td>R</td>
<td>75</td>
<td>46</td>
<td>-8</td>
<td>16</td>
</tr>
<tr>
<td>middle temporal gyrus</td>
<td>21</td>
<td>R</td>
<td>34</td>
<td>46</td>
<td>-12</td>
<td>-16</td>
</tr>
</tbody>
</table>

Coordinates (xyz) and Brodmann’s Areas (BA) from Talairach and Tournoux (1988). L = left hemisphere; R = right hemisphere; Voxels = number of voxels.
Table 15. Peaks of brain regions (stable negative saliences) that correlated with increased misses.

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>BA</th>
<th>L/R</th>
<th>Voxels</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>middle temporal gyrus</td>
<td>21</td>
<td>L</td>
<td>21</td>
<td>-62</td>
<td>-14</td>
<td>-12</td>
</tr>
<tr>
<td>thalamus</td>
<td></td>
<td>L</td>
<td>67</td>
<td>-16</td>
<td>-24</td>
<td>8</td>
</tr>
<tr>
<td>midbrain</td>
<td></td>
<td>L</td>
<td>27</td>
<td>-6</td>
<td>-24</td>
<td>-16</td>
</tr>
<tr>
<td>superior temporal gyrus</td>
<td>22</td>
<td>L</td>
<td>21</td>
<td>-50</td>
<td>-38</td>
<td>16</td>
</tr>
<tr>
<td>insula</td>
<td>40/42</td>
<td>L</td>
<td>61</td>
<td>-34</td>
<td>-40</td>
<td>20</td>
</tr>
<tr>
<td>posterior cingulate gyrus</td>
<td>31/23</td>
<td>L</td>
<td>65</td>
<td>-22</td>
<td>-50</td>
<td>28</td>
</tr>
<tr>
<td>inferior parietal lobule</td>
<td>39/40</td>
<td>R</td>
<td>93</td>
<td>32</td>
<td>-52</td>
<td>36</td>
</tr>
<tr>
<td>lingual gyrus</td>
<td>18</td>
<td>L</td>
<td>120</td>
<td>-10</td>
<td>-68</td>
<td>4</td>
</tr>
<tr>
<td>posterior cerebellum</td>
<td></td>
<td>R</td>
<td>70</td>
<td>8</td>
<td>-68</td>
<td>-28</td>
</tr>
</tbody>
</table>

Coordinates (xyz) and Brodmann’s Areas (BA) from Talairach and Tournoux (1988). L = left hemisphere; R = right hemisphere; Voxels = number of voxels.
Figure 8. Singular Image of Hits/Misses.
Stable positive saliences are indicated in white, stable negative saliences are indicated in black. Saliences are displayed on a standard magnetic resonance image from -28 mm (top left slice) to +44 mm (bottom right slice) relative to the anterior commissure-posterior commissure line (in 4 mm increments). The right side of the image represents the right side of the brain.

R/K Responses. The second PLS behavioral analysis identified four patterns of rCBF changes that related brain activity to the proportion of hits that were R responses (LV1 to LV4). As in the first behavioral analysis, because a permutation test could not be conducted, only the first LV (LV1) was interpreted. LV1 for this second analysis accounted for 87% of the cross-block covariance. The correlations
between brain score and proportion of correct R responses in each condition are illustrated in Figure 9. The brain regions with stable positive and negative saliences for this LV are listed in Tables 16 and 17, respectively, and the rCBF changes are illustrated in Figure 10. Frontal regions with stable positive or negative saliences in the LV are listed in Appendix F in terms of estimates of Brodmann's areas (Talairach & Tournoux, 1988) and estimates of areas identified by Petrides and Pandya (1994).

LV1 identified a pattern of brain activity that was associated with making a correct R response, irrespective of whether the R response was made for words correctly recognized from the Self, Social Desirability, Other, or Syllable condition. I am interpreting only the first LV which identified a commonality across the conditions. It is possible that the remaining LVs may identify patterns of brain activity related to R responses that differentiate the conditions. The positive saliences correspond to areas within the pattern of brain activity that were positively correlated with R responses. The negative saliences correspond to areas within the pattern of brain activity that were negatively correlated with R responses (i.e., positively correlated with K responses).

The largest and most significant region with a positive salience was found in the right anterior cingulate gyrus and extended to the left putamen. Other regions with positive saliences were observed in the left hemisphere and included the putamen, pons, and posterior cerebellum. Positive saliences in the right hemisphere were observed in the right amygdala, parahippocampal gyrus, and anterior cerebellum. Negative saliences were found in bilateral prefrontal areas (left
> right) and in bilateral posterior areas. The largest negative salience occurred in the left precentral gyrus and extended into the inferior and middle frontal gyri. Several smaller negative saliences were observed in right frontal areas and included the medial frontal lobe, middle frontal gyrus, anterior cingulate gyrus, and inferior frontal gyrus. In posterior cortex, negative saliences were observed bilaterally in the posterior cingulate gyrus and cuneus, and in the right middle temporal gyrus, right inferior parietal lobule, and right middle occipital gyrus.

\[ \text{Figure 9. Correlations between brain score and proportion of correct remember responses in each condition.} \]
Table 16. Peaks of brain regions (stable positive saliences) that correlated with increases in the retrieval experience of remembering.

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>BA</th>
<th>L/R</th>
<th>Voxels</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior cingulate gyrus</td>
<td>24</td>
<td>R</td>
<td>2212</td>
<td>6</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>posterior cingulate gyrus</td>
<td>23</td>
<td>L</td>
<td></td>
<td>-12</td>
<td>-30</td>
<td>24</td>
</tr>
<tr>
<td>putamen</td>
<td></td>
<td>L</td>
<td></td>
<td>-14</td>
<td>10</td>
<td>-8</td>
</tr>
<tr>
<td>anterior cingulate gyrus</td>
<td>24/32</td>
<td>L</td>
<td>85</td>
<td>-24</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>putamen</td>
<td></td>
<td>L</td>
<td>43</td>
<td>-24</td>
<td>-4</td>
<td>4</td>
</tr>
<tr>
<td>amygdala/</td>
<td>35</td>
<td>R</td>
<td>71</td>
<td>18</td>
<td>-10</td>
<td>-8</td>
</tr>
<tr>
<td>parahippocampal gyrus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pons</td>
<td></td>
<td>L</td>
<td>34</td>
<td>-8</td>
<td>-36</td>
<td>-24</td>
</tr>
<tr>
<td>anterior cerebellum</td>
<td></td>
<td>R</td>
<td>284</td>
<td>24</td>
<td>-42</td>
<td>-20</td>
</tr>
<tr>
<td>parahippocampal gyrus</td>
<td></td>
<td>R</td>
<td>24</td>
<td>-40</td>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>parahippocampal gyrus</td>
<td></td>
<td>R</td>
<td>36</td>
<td>-46</td>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>posterior cerebellum</td>
<td></td>
<td>L</td>
<td>26</td>
<td>-20</td>
<td>-62</td>
<td>-12</td>
</tr>
</tbody>
</table>

Coordinates (xyz) and Brodmann's Areas (BA) from Talairach and Tournoux (1988). L = left hemisphere; R = right hemisphere; Voxels = number of voxels.
Table 17. Peaks of brain regions (stable negative saliences) that correlated with increases in the retrieval experience of knowing.

<table>
<thead>
<tr>
<th>Brain Region</th>
<th>BA</th>
<th>L/R</th>
<th>Voxels</th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>medial frontal lobe</td>
<td>9</td>
<td>R</td>
<td>39</td>
<td>10</td>
<td>42</td>
<td>32</td>
</tr>
<tr>
<td>middle frontal gyrus</td>
<td>47</td>
<td>R</td>
<td>27</td>
<td>48</td>
<td>40</td>
<td>-4</td>
</tr>
<tr>
<td>anterior cingulate gyrus</td>
<td>32</td>
<td>R</td>
<td>31</td>
<td>22</td>
<td>22</td>
<td>32</td>
</tr>
<tr>
<td>precentral gyrus</td>
<td>6</td>
<td>L</td>
<td>591</td>
<td>-46</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>inferior frontal gyrus</td>
<td>9</td>
<td>L</td>
<td>-48</td>
<td>12</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>middle frontal gyrus</td>
<td>46</td>
<td>L</td>
<td>-50</td>
<td>34</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>inferior frontal gyrus</td>
<td>9</td>
<td>R</td>
<td>32</td>
<td>50</td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>middle temporal gyrus</td>
<td>21</td>
<td>R</td>
<td>32</td>
<td>58</td>
<td>-4</td>
<td>-12</td>
</tr>
<tr>
<td>posterior cingulate gyrus</td>
<td>24</td>
<td>R</td>
<td>73</td>
<td>6</td>
<td>-10</td>
<td>40</td>
</tr>
<tr>
<td>posterior cingulate gyrus</td>
<td>31</td>
<td>L</td>
<td>42</td>
<td>-10</td>
<td>-36</td>
<td>36</td>
</tr>
<tr>
<td>inferior parietal lobule</td>
<td>39/40</td>
<td>R</td>
<td>119</td>
<td>40</td>
<td>-48</td>
<td>24</td>
</tr>
<tr>
<td>cuneus</td>
<td>18</td>
<td>L</td>
<td>78</td>
<td>-6</td>
<td>-70</td>
<td>16</td>
</tr>
<tr>
<td>cuneus</td>
<td>7</td>
<td>R</td>
<td>179</td>
<td>10</td>
<td>-72</td>
<td>32</td>
</tr>
<tr>
<td>middle occipital gyrus</td>
<td>19</td>
<td>R</td>
<td>113</td>
<td>40</td>
<td>-78</td>
<td>4</td>
</tr>
<tr>
<td>cuneus</td>
<td>18</td>
<td>R</td>
<td>33</td>
<td>14</td>
<td>-98</td>
<td>12</td>
</tr>
</tbody>
</table>

Coordinates (xyz) and Brodmann's Areas (BA) from Talairach and Tournoux (1988). L = left hemisphere; R = right hemisphere; Voxels = number of voxels.
To summarize, the participants in the present experiment recognized (proportion hits minus proportion false alarms) a similar number of words that were processed in reference to the self, social desirability, and another person. More words were recognized in these three semantic conditions than in a shallow condition in which they recognized words that were processed with respect to phonological structure. When recognition was analyzed in terms of the retrieval experience that accompanied recognition, however, participants reported the

**Figure 10.** Singular Image of Remembering/Knowing. See legend of Figure 8.

**Discussion**

To summarize, the participants in the present experiment recognized (proportion hits minus proportion false alarms) a similar number of words that were processed in reference to the self, social desirability, and another person. More words were recognized in these three semantic conditions than in a shallow condition in which they recognized words that were processed with respect to phonological structure. When recognition was analyzed in terms of the retrieval experience that accompanied recognition, however, participants reported the
retrieval experience of remembering more in the **Self** and **Social Desirability** conditions which did not differ, than in the **Other** and **Syllable** conditions (more words were remembered in the **Other** condition than in the **Syllable** condition). These behavioral data are similar to those reported in Chapter 1. In addition, the brain activity that was related to hits/misses, and to R/ K responses was determined.

**Neural Correlates of Hits/Misses**

A widely distributed pattern of brain activity correlated with successful recognition. Areas that were identified within this pattern that positively correlated with hits were predominantly right lateralized and involved both prefrontal and posterior areas. Areas that were identified within the pattern that negatively correlated with hits/positively correlated with misses, on the other hand, were predominantly left lateralized and involved only posterior areas. This lateralization is consistent with the HERA model of memory which proposes that episodic retrieval processes primarily engage right lateralized frontal regions whereas episodic encoding/semantic retrieval processes primarily engage left lateralized frontal regions (Tulving et al., 1994; Nyberg et al., 1996). It also is consistent with the idea that the frontal lobes play a role in successful recognition (e.g., Wheeler et al., 1995; Rugg et al., 1996; Stuss et al., 1996).

**Brain Regions Within The Neural Network That Positively Correlated With Hits**

**Basal Ganglia.** The largest and most significant area of activity within the neural network that positively correlated with hits was in the right putamen and extended into the anterior cingulate (BA 32) and the right caudate; the left claustrum
also was significantly activated. Although the basal ganglia are traditionally associated with procedural memory, the reciprocal connections between the basal ganglia and the frontal lobes (Middleton & Strick, 1994, 1997) suggest that the basal ganglia may contribute to frontal system processes. These processes may include retrieval processes that are engaged during episodic memory. Although changes in basal ganglia activity are commonly observed in PET studies of episodic memory (e.g., Fink et al., 1996; Andreasen et al., 1995; Cabeza et al., 1997a; Nyberg et al., 1996b; Imaizumi et al., 1997; Fujii et al., 1997; Nyberg et al., 1995), the contribution of the basal ganglia to episodic memory is unknown. The results of the present study suggest that the basal ganglia mediate the processes involved in successful recognition. Those processes appear to be largely independent from the processes involved in "retrieval mode" (Nyberg et al., 1995) or "retrieval attempt" (Kapur et al., 1995) because the analysis identified areas associated with retrieval success (Rugg et al., 1996). This suggestion is at odds with the common neuropsychological observation of unimpaired recognition following basal ganglia damage (e.g., Saint-Cyr, Taylor, & Lang, 1988). Further research may elucidate the specific role of the basal ganglia during recognition.

**Frontal Lobes.** Activity in three frontal areas within the neural network positively correlated with hits. These areas included two frontal polar areas on the right (BA 10), and a small frontal opercular area on the left (BA 47). The predominantly right lateralization is consistent with the HERA model of memory which posits that episodic retrieval processes are predominantly right lateralized whereas semantic retrieval processes are predominantly left lateralized (Tulving et
al., 1994; Nyberg et al., 1996). Additionally, the localization of the activity in BA 10 is consistent with the findings of Rugg et al. (1996) who found that activity in right frontal polar areas was related to the degree to which recognition was successful (they also found increases in right dorsolateral, right medial, and left polar frontal areas that were related to increases in the ratio of old words to new words).

Similarly, Nyberg et al. (1996b) found a positive correlation between activity in bilateral inferior prefrontal areas and recognition performance (they also found that activity in the left medial temporal lobe and cingulate cortex was highly correlated with recognition performance).

**Posterior Areas.** Three posterior areas contributed to the neural network that positively correlated with hits. These areas included left and right temporopolar regions (BA 38 and BA 21, respectively), and right posterior insula (BA 40/43). Bilateral activity in temporal polar cortex is consistent with activity in this region in other PET studies of episodic memory (e.g., Nyberg et al., 1996a; Markowitsch, Fink, Thone, Kessler, & Heiss, 1997a). Temporal polar cortex has been hypothesized to be a critical area for ephory, with the left and right temporopolar cortices primarily involved in the ephory of semantic and episodic memories, respectively (Kroll, Markowitsch, Knight, & von Cramon, 1997; Markowitsch, 1995a; Markowitsch et al., 1997a). The term “ephory” was used by Tulving (1983) to describe a process that involved the interaction of retrieval cues with stored information to produce an image or representation of the information in question. The finding in the present analysis that temporal polar cortex is correlated with retrieval success is consistent
with the suggestions of Markowitsch and his colleagues that temporopolar cortex is critical for ephory and not just retrieval attempt/mode processes.

**Brain Regions Within The Neural Network That Negatively Correlated With Hits**

Only posterior areas contributed to the neural network that negatively correlated with hits/positively correlated with misses, and these areas were predominantly left lateralized. The pattern of brain activity associated with misses may be related to further processing of the items. The predominant left lateralization of regions involved in word reading supports this idea (Fiez & Peterson, 1998). Consistent with the activations that were observed in left temporal areas (BA 21 and 22) and posterior cingulate (BA 31/23), Nyberg et al. (1996c) found that activity was higher in a network of regions including bilateral temporal areas and posterior cingulate cortex during reading than during recognition. Similarly, in their review of neuroimaging studies of reading, Fiez and Petersen (1998) found that activity in left temporal areas, the left thalamus, right cerebellum, and left occipital lobe were common. The left insula, left midbrain, and right inferior parietal activations also may be related to sensory processes. In general, this pattern is consistent with patterns of activation observed during the incidental encoding of non-semantic aspects of stimuli, and suggests that when a word is not recognized it undergoes further incidental encoding (also see Andreasen et al., 1995a). Further incidental encoding also may occur during successful recognition, but to a lesser degree.
Neural Correlates of R/K Responses

The regions of brain activity within the neural network that positively correlated with R responses, and the regions within the neural network that positively correlated with K responses (negatively correlated with R responses) were similar in that both sets of regions included bilateral anterior and bilateral posterior areas. The brain-behavior relationship supports the hypothesis that prefrontal activity is positively correlated to a greater extent with K responses than R responses. The only anterior region within the pattern that was positively correlated with R responses was anterior cingulate cortex; R responses were positively correlated with activity primarily in right limbic areas. These findings are consistent with those reported by Rugg (1998) who found greater frontal involvement during K responses than R responses. The implications of these findings are discussed below.

Brain Regions Within The Neural Network That Positively Correlated With R Responses

R responses were positively correlated with a pattern of activation that included the anterior and posterior cingulate cortex, basal ganglia, amygdala, parahippocampus, cerebellum, and brainstem. Anatomically, these areas are extensively interconnected (Schmahmann & Pandya, 1997; Haber, Kunishio, Mizobuchi, & Lynd-Balta, 1995; Markowitsch, 1995; Devinsky, Morrell, & Vogt, 1995; Nieuwenhuys, Voogd, & van Huijzen, 1988; Middleton & Strick, 1994), and may form the neural network that is activated during episodic retrieval that is accompanied by autonoetic awareness. Autonoetic awareness is the type of
conscious awareness that has been speculated to be coincident with the retrieval experience of remembering in comparison to knowing. Autonoetic awareness is characterized by the feeling of traveling back in time and "re-experiencing" the original encoding episode with its affective and contextual detail (see Tulving, 1985; Wheeler, Stuss, & Tulving, 1997).

Note, however, that R responses were not correlated with activity in temporal polar areas. Markowitsch and his colleagues (Kroll et al. 1997; Markowitsch 1995a) suggested that temporal polar areas including BA 38 are involved in the ecphory of personal episodes. Markowitsch et al. (1997a) further speculated that right BA 38 is involved in the retrieval of personal episodic memory whereas left BA 38 is involved in the retrieval of factual knowledge. Activity in BA 38 was not observed in the category specific analysis of retrieval in the Self condition (see Chapter 2), and activity in this area did not correlate with R responses. It was found, however, that activity in left BA 38 correlated with hits. The absence of an activation in BA 38 in the Self condition and for R responses is difficult to reconcile with the PET results of Markowitsch et al. because the participants in the present PET study also retrieved episodic memories that were personal in that they were processed in terms of the self. Furthermore, it is likely that the retrieval of personal episodic memories (vs. impersonal episodic memories) in Markowitsch et al.'s study was accompanied primarily by the retrieval experience of remembering in comparison to knowing. The main difference in Markowitsch et al.'s condition and the present study may be that Markowitsch et al.'s condition had sentences as auditory cues for the retrieval of the personal episode whereas the present study
used single words as visual cues for the retrieval of the personal episode. The Self condition in the present study, therefore, may have encouraged the retrieval of personal episodic memories that were less contextually rich and emotionally charged. Activity in right BA 38 may be more related to the emotional nature of autobiographical memories than to other aspects of the retrieval experience.

**Cingulate.** The largest and most significant region within the neural network that positively correlated with R responses was an area that included right anterior cingulate cortex (BA 24), and extended into left posterior cingulate cortex (BA 23). Left anterior cingulate cortex (BA 24/32) also was a region with in the neural network that positively correlated with R responses. The cingulate areas may be related to cognitive and affective aspects of memory (e.g., Devinsky et al., 1995). The direct connections that BA 23 has with the hippocampal formation and its indirect connections to the parahippocampal area from parasensory and multimodal association areas (Nieuwenhuys et al., 1988) also puts it in a position to be involved in ecphory by providing a link between the hippocampus and the cortical areas that are involved in the storage of the memory (see Nadel & Moscovitch, 1997).

**Amygdala.** The human amygdala has long been implicated in memory and affect. Phelps and Anderson (1997) have suggested that the human amygdala plays a role in emotional memory and in the evaluation of emotional stimuli. They proposed "...that the human amygdala may be necessary for our enhanced memory for arousing events" (p. 312), and Rolls (1996) has suggested that affect provides additional details to episodic memory traces that may be advantageous in similar situations in the future. Activation of the amygdala during the retrieval experience
of remembering in comparison to knowing is consistent with the idea that affect is a contextual cue that contributes to the retrieval experience of remembering, and with William James' idea that "[r]emembrance is like direct feeling; its object is suffused with a warmth and intimacy to which no object of mere conception ever attains" (1890, p. 239). The correlation between the retrieval experience of remembering and amygdala activation also is consistent with the suggestion by Kroll et al. (1997, p. 1393) that "the ecphory (triggering stimulus) required by episodic memories may often need a synchronized activation of affect-coding structures of the limbic system (amygdala)". Markowitsch et al. (1997a) and Fink et al. (1996) also observed right amygdala activation, as revealed by PET, during the retrieval of personal but not impersonal episodic information. Though their studies were not designed to assess the retrieval experience of remembering in comparison to knowing, it is possible that amygdala activation in their personal but not impersonal conditions was associated with the retrieval of more contextually and, particularly, affectively rich memories that would have been indexed as R responses in the present experiment.

It should also be noted that specific areas of the amygdala have been associated with particular functions (see Davidson & Sutton, 1995). Future research using imaging tools with a finer spatial resolution may shed light on the more specific function of the amygdala during episodic retrieval that is accompanied by the retrieval experience of remembering. Future research also may be able to elucidate whether the right lateralized amygdala activation in the present study and in the Markowitsch et al. (1997a) and Fink et al. (1996) studies is related to episodic retrieval as opposed to encoding processes as in the HERA model (i.e., Tulving et al.,
1994; Nyberg et al., 1996), and/or to lateralized affect-related processes (e.g., Davidson & Sutton, 1995).

**Medial Temporal Cortex/Hippocampus.** R responses were correlated with activity in the right limbic lobe including perirhinal cortex (BA 35) and the parahippocampal gyrus. The medial temporal lobes including the hippocampus (MTL/H) are necessary for episodic memory (e.g., Squire & Zola-Morgan, 1991). The finding that MTL/H activity was a region within the neural network that positively correlated with R responses suggests that the MTL/H may be more involved in processes that mediate the conscious awareness that accompanies remembering (i.e., autonoetic consciousness; Tulving, 1985; Wheeler et al., 1997) than the conscious awareness that accompanies knowing (i.e., noetic consciousness; Tulving, 1985; Wheeler et al., 1997). Although the MTL/H are likely necessary for R and K responses (only areas that correlated with R responses were identified by the analysis), different MTL/H regions and/or different interactions with other brain areas may contribute to different aspects of conscious awareness.

Although the exact extent of the parahippocampal activation is unclear due to the limited spatial resolution of PET, there is a peak activation at the very posterior end \((x = 36, y = -46, z = -4)\) that appears to extend forward to the very anterior end of the parahippocampal gyrus \((x = 18, y = -10, z = -8)\) though the anterior extent is not well-defined. Additional research aimed at elucidating the contributions of specific MTL/H regions to ecphory and conscious awareness will help clarify the role of the MTL/H in episodic retrieval. The significance of the right lateralization also will have to be elucidated by further research since right medial temporal areas have
been activated during the episodic retrieval of both verbal and non-verbal materials [for a review see Lepage, Habib, & Tulving (1998) who also noted that encoding and retrieval are associated with more anterior and posterior hippocampal areas, respectively]. One plausible interpretation of the right hippocampal activity, however, is that it is related to affective aspects of the episodic memory that lead to R responses. Previous research has implicated the right hemisphere in affect-related processes (Davidson & Sutton, 1995), and the hippocampus and amygdala are reciprocally connected (Nieuwenhuys et al., 1988). Support for this interpretation comes from a recent PET study that found that the right parahippocampal gyrus was activated during the identification of emotion from spoken words whereas the left parahippocampal gyrus was activated during the identification of speaker from spoken words (Imaizumi et al., 1997).

**Basal Ganglia and Brain Stem.** Within the neural network, activity in the left putamen positively correlated with R responses, as did activity in the left brainstem (pons). Interestingly, activity in the right putamen positively correlated with hits, whereas activity in the left brainstem (midbrain) negatively correlated with hits. Further research may be able to uncover the reliability and possible significance of the left/right lateralization difference in the putamen for R responses and hits, respectively, and of the positive/negative correlation difference in the left brainstem for R responses and hits, respectively.

**Cerebellum.** Within the neural network, R responses positively correlated with bilateral activation of the cerebellum. Similar to the basal ganglia, the cerebellum has been traditionally implicated in the coordination of movements, but
it is now clear that the cerebellum (like the basal ganglia) has a significant role in cognitive and affective processes (see Schmahmann, 1997; Fiez, 1996; Houk, 1997; Schmahmann & Sherman, 1997). Reciprocal cerebrocerebellar connections provide the anatomical basis for cognitive and affective cerebellar functions (Schmahmann & Pandya, 1997). Cerebellar activation occurs during a variety of cognitive tasks, and there are numerous hypotheses about the role of the cerebellum in cognition (reviewed by Parsons & Fox, 1997). With respect to memory, cerebellar activity is commonly observed in PET studies of verbal episodic retrieval (Cabeza & Nyberg, 1997; Cabeza et al., 1997a; Andreasen et al., 1995b). Although there is little neuropsychological evidence that cerebellar damage affects memory functions per se, some "frontal" functions are affected by cerebellar damage which, in turn, may affect episodic memory retrieval processes (Gabrieli, 1998; Daum & Ackermann, 1997; also see Hallett & Grafman, 1997). The cerebellar activations that correlated with R responses were in the posterior lobe (declive) of the left cerebellum, and in the anterior lobe (culmen) of the right cerebellum. Bilateral cerebellar activity also was observed in the PET study by Imaizumi et al. (1997) during the identification of emotion but not of speaker from spoken words. Imaizumi et al. speculated that a relationship between the cerebellum and frontal lobe may exist that contributes to emotion-related processes. The results are consistent with this idea. The left posterior cerebellar activation is particularly intriguing in light of a recent report suggesting that lesions to the posterior lobe of the cerebellum produce a cognitive affective syndrome that is characterized by disturbances of executive function, visual-spatial disorganization and impaired visual-spatial memory, personality
change including a flattening or blunting of affect, difficulty with interpreting and producing logical sequences, and language difficulties (Schmahmann & Sherman, 1997). Since the cerebrocerebellar pathways are crossed (i.e., the left cerebellum is connected with the right cerebral areas), an affective contribution by the left posterior cerebellum would be consistent with the affective contributions of the right limbic regions that were postulated.

**Brain Regions Within The Neural Network That Negatively Correlated With R Responses**

*Frontal Cortex.* In comparison to R responses, which positively correlated with anterior activations in only cingulate cortex, K responses were positively correlated with the bilateral activation of several frontal areas (left > right). The activation on the left extended from the precentral gyrus (BA 6) into BA 9 of the inferior frontal gyrus and BA 46 of the middle frontal gyrus. The activation on the right included the inferior and medial aspects of BA 9, BA 47 of the middle frontal gyrus, and anterior cingulate (BA 32). Areas 9, 46, and 47 previously have been associated with episodic retrieval (Grady, 1998). In contrast to contributions to the retrieval experience of knowing per se, it is tentatively proposed that the positive correlation of these areas with K responses may be related to additional strategic processes, including strategic search processes and strategic monitoring and verification processes, that are engaged during the retrieval experience of knowing in comparison to remembering. These additional processes are not necessary for R responses or K responses, but instead are engaged when the participant evaluates their basis for providing a K response.
The idea that K responses may involve more strategic search processes than R responses is related to the idea that K responses may elicit a search by participants for contextual cues to support their feeling of familiarity and, thus, to change the quality of their retrieval experience from one of knowing to one of remembering. This idea is consistent with the common observation of a longer latency for K responses in comparison to R responses (e.g., see Chapter 1; Conway & Dewhurst, 1995). The longer latency for K responses may reflect the time that is required for the recruitment of additional strategic search processes during knowing in comparison to remembering. The right frontal areas that were positively correlated with K responses are likely candidates for strategic search processes. Strategic search processes may be similar to "retrieval mode" (Nyberg et al., 1995) or "retrieval attempt" (Kapur et al., 1995) processes which have been associated with right prefrontal activity.

K responses also may be associated with more strategic monitoring and verification processes than R responses. A K response may be more difficult to verify as correct because the memory is based only on a feeling of familiarity and is relatively void of contextual details that can serve as cues for a verification process. The retrieval experience of remembering, on the other hand, may require fewer verification processes in that a R response is based on the ability to successfully recover contextual details of the encoding episode. Those details may reduce the necessity of further verification and monitoring processes since the details themselves can serve as cues against which the oldness or newness of the word can be validated. The predominantly left lateralization of the frontal activation is
consistent with the idea that the left prefrontal cortex is related more to response monitoring than the right prefrontal cortex (cf. Stuss, Eskes, & Foster, 1994), and to further encoding processes (Andreasen et al., 1995a). The idea that the right prefrontal cortex is involved in the monitoring and verifying of the products of episodic retrieval also has been previously suggested (e.g., Gabrieli, 1998). In line with this idea, a PET study by Fletcher, Shallice, Frith, Frackowiak, and Dolan (1998) implicated the dorsal region of the right prefrontal cortex (BA 9/46) during episodic retrieval that involved monitoring demands; the ventral region of the right frontal lobe, on the other hand, was preferentially activated when the task demands required little monitoring (i.e., the condition involved external cueing). The dorsal region of the right prefrontal cortex (BA 9) was correlated with \( K \) responses in the present study as would be predicted by their results.

**Posterior Cortex.** Bilateral occipital areas positively correlated with \( K \) responses. These areas included the cuneus bilaterally (left and right BA 18, right BA 7), and the right middle occipital gyrus (BA 19). Activity of these areas during \( K \) responses may reflect the reactivation of the areas that processed the visual word form during encoding. The reactivation of these areas may lead to feelings of familiarity, but re-processing the visual word form may not contain contextual detail that can lead to the retrieval experience of remembering indexed by \( R \) responses.

The activity that was observed in the dorsal region of the parietal lobe (BA 7) also may be related to increases in monitoring processes during the retrieval experience of knowing in comparison to remembering. In addition to dorsal frontal
areas being related to monitoring, Fletcher et al. (1998) also found that dorsal parietal areas were preferentially active in their monitoring condition; ventral frontal and parietal regions, on the other hand, showed more activation in their condition that emphasized external cueing.

Activity in the right middle temporal gyrus (BA 21) and the right inferior parietal lobule (BA 39/40) also were positively correlated with K responses. These areas have been activated in other episodic retrieval studies and have been related to ecphoric processes (e.g., Markowitsch, 1995a; Markowitsch et al., 1997a; Nyberg et al., 1995, 1996a) and perceptual recognition processes (e.g., Cabeza et al., 1997a). Finally, medial posterior cingulate cortex was positively correlated with K responses (BA 31 and BA 24). Posterior cingulate cortex is involved in visuospatial and memory functions with few affective functions (cf. Devinsky et al., 1995).

**What IS the Relationship Between the Right Prefrontal Cortex and R Responses?**

On the one hand, the absence of a correlation between right prefrontal regions and R responses is not unexpected. According to the HERA model of memory (Tulving et al., 1996; Nyberg et al., 1996), right prefrontal regions are activated during episodic retrieval per se. The specific aspects of episodic retrieval that engage right prefrontal regions, however, are unknown. Therefore, there is no reason to expect retrieval success (hits) and retrieval experience (R/K responses) to correlate with right prefrontal activity. Other aspects of retrieval [e.g., "retrieval mode" (Nyberg et al., 1995)/"retrieval attempt" (Kapur et al., 1995)] may drive the right prefrontal activation that is typically observed in PET studies of episodic retrieval. Although it was found that right frontal polar cortex correlated with hits (also see Nyberg et al.,
1996b; Rugg et al., 1996; Wheeler et al., 1995), this region is only one of many regions that has been activated during episodic retrieval tasks. The frontal lobes are anatomically and functionally heterogeneous (e.g., Fuster, 1997), and different frontal regions undoubtedly have specific contributions to episodic retrieval processes. Unfortunately, the way in which the present PET study was designed precludes the identification of brain regions that were common to episodic retrieval processes per se across the conditions. Such an analysis would have been possible if a comparison condition had been included in the design that did not involve retrieval processes (e.g., word reading, encoding, etc.). It is predicted that if such a control condition was included, the task analysis described in Chapter 2 would have revealed a pattern of activity that distinguished the retrieval conditions from the control condition, and the corresponding right greater than left prefrontal activity. This hypothesis can be easily tested in a future study. In the meantime, the presence of right prefrontal activity during each of the tasks is assumed on the basis of previous research (Tulving et al., 1994; Nyberg et al., 1996). Additionally, only the first LV, which identified a commonality across the four conditions, was interpreted. It is possible that right prefrontal regions contribute to the patterns of activity identified by the remaining LVs.

On the other hand, however, the absence of a correlation between R responses and activity in the right prefrontal cortex is unexpected. There are several lines of evidence that suggest that R responses involve the right prefrontal cortex (reviewed in the Introduction) and, therefore, a correlation between right prefrontal activity and R responses was a tenable prediction. A tentative hypothesis is that the
activation of the right prefrontal lobe may be necessary for the neural system that mediates R responses to be "switched on" (A.R. McIntosh, personal communication). The right prefrontal lobe, therefore, would be responsible for activating the neural system that mediates R responses but would not be involved in R responses per se. The idea that the frontal lobes can play a "switching on" role during episodic retrieval has been hinted at by Kroll et al. (1997, p. 1395) who concluded that "...the prefrontal cortex contributes to memory retrieval both by providing the impetus or trigger for an active search of the engrams...and by its capacity as a temporal organizer".

The frontal lobe "switch" hypothesis is based on two assumptions. One assumption is that the right frontal lobe was activated in each of the conditions in the present experiment. The second assumption is that the neural system that mediates R responses requires right prefrontal lobe activity to be "switched on", but the neural system that mediates K responses does not require right prefrontal lobe activity to be "switched on". This second assumption is required to account for the evidence that R responses are more related to frontal function than K responses (reviewed in the Introduction). Furthermore, given the functional and anatomical heterogeneity of the frontal lobes, it is hypothesized that a very specific region or set of regions in the right prefrontal lobe are responsible for acting as the "on switch". Therefore, only very circumscribed damage to that specific region or set of regions would completely abolish the retrieval experience of remembering. This idea is consistent with the observation of only one report espousing a substantial loss of the capacity for remembering (Levine et al., 1998). All other reports of frontal lobe
impairments being related to reductions in R responses can be interpreted as stemming from at least three sources: 1) from reductions in the contribution of the frontal lobes to the encoding of contextual details that would support R responses at retrieval, 2) from reductions in the contribution of the frontal lobes to strategic retrieval processes that would search for contextual detail to support R responses, and/or 3) from reductions in frontal-mediated strategic monitoring and verification processes that would lead to increases in R response false positives. Each of these three interpretations of R response reductions associated with reduced frontal function are separately addressed.

First, evidence is beginning to accumulate that suggests that age-related reductions in R are due to impaired encoding processes. Perfect and Dasgupta (1997; also see Perfect, Williams, & Anderton-Brown, 1995) found that by accounting for encoding differences between young and old adults, age-related differences in the retrieval experience of remembering disappeared. They also found that although R responses correlated with scores on their frontal-sensitive tests, performance on the tests did not remove the age-related variance in R responses. Therefore, they concluded that age-related changes in R responses are not caused by reductions in frontal function. Similarly, no age-related reductions in R responses were found by Mark and Rugg (1997) following highly constrained and elaborative encoding processes, and Rajaram (1998) showed that the processing of distinctive or salient attributes increases R responses. Together, these studies highlight the role of encoding processes to the later provision of R responses, and suggest that deficient encoding of material in terms of its contextual and/or affective detail may
contribute to reductions in R responses. Consistent with this idea, the use of
defective encoding strategies by frontal damaged patients (Stuss et al., 1994) and by old adults (Craik & Jennings, 1992) has been reported.

Second, similar to reductions in strategic processes at encoding, frontal damaged patients and old adults also have reductions in strategic processes at retrieval that may lead to fewer R responses (Shimamura, Janowsky, & Squire, 1991; Stuss et al., 1994; Craik & Jennings, 1992). It is reasonable to assume that some proportion of K responses are changed to R responses after frontal-mediated strategic search processes have been engaged and additional contextual or affective details have been successfully retrieved that change the retrieval experience from one of knowing to one of remembering. If this is the case, then frontal damage or age-related frontal system dysfunction would attenuate the search process and reduce the likelihood that a K response would be changed to a R response. The number of R responses provided by patients with frontal damage and by old adults who have age-related reductions in frontal system functions would, therefore, be reduced relative to younger neurologically intact adults who would benefit from additional frontal mediated search processes. The R responses provided by frontal patients and by old adults may primarily result from retrieval cues (i.e., the presentation of the adjective) that automatically elicit the retrieval experience of remembering without recourse to additional search strategies. Also note that although age-related reductions in frontal function are generally greater than age-related reductions in MTL/H function, in the young adults in the present experiment medial temporal structures were part of the neural network that
positively correlated with R responses. Therefore, age-related reductions in R responses also may be associated with age-related reductions in MTL/H function at encoding and/or retrieval (also see Chapter 1).

Third, deficient frontal mediated strategic monitoring and verification processes may reduce measures of the retrieval experience of remembering by increasing the number of R responses that are false positives. The patient with right frontal damage described by Curran et al. (1997) was able to make R and K responses, but he had an extraordinarily high R response false alarm rate. Elevated R response false positives in old adults relative to young adults also has been reported (e.g., Norman & Schacter, 1997). Frontal damage and age-related reductions in frontal system function may impair processes involved in the monitoring and the verification of the source of the relatively automatic retrieval experience of remembering. Therefore, frontal damaged and old adults may be impaired relative to young adults in distinguishing whether the experience that is elicited is due to a "re-experiencing" of the original encoding episode or an "experiencing" of a new encoding episode. Again, however, although the frontal lobes would be involved in reducing measures of R by increasing R response false positives, the frontal lobes per se would not be required for an R response.

CONCLUSIONS

The present experiment showed that retrieval success and retrieval experience correlate with different patterns of brain activity. Moreover, the correlations were content independent in that the pattern was the same for the retrieval of material that was encoded in terms of the self, another person, social
desirability, or phonological structure. Regions within the retrieval success neural network that positively correlated with hits included prefrontal regions (right > left), and the left temporal pole; the latter region may be critical for ephory (e.g., Kroll et al., 1997; Markowitsch, 1995a). Several posterior regions also were positively correlated with hits. Regions within the neural network that positively correlated with misses, on the other hand, included only posterior regions (left > right).

The retrieval experience of remembering is distinguished from knowing in that it is rich in contextual detail, rich in affect, and is personal. Frontal regions within the retrieval experience neural network were positively associated with knowing more than remembering. Frontal regions may contribute to knowing via strategic search and strategic verification and monitoring processes to verify the output of retrieval and to try to bring to mind additional details of the encoding episode to change the quality of the experience from one of knowing to one of remembering. The absence of a correlation between right prefrontal activity and R responses suggests that the right prefrontal lobes may not mediate R responses per se. Instead, the neural network that correlated with R responses may deliver its output to right prefrontal regions, or right prefrontal activity may be necessary to "switch on" the neural network that mediates the retrieval experience of remembering (A.R. McIntosh, personal communication). This neural network includes areas that have been related to ephory (i.e., the parahippocampal gyrus) and affect (amygdala and cingulate). These areas may contribute to the personal qualities that are the hallmarks of human episodic memory and of autonoetic awareness.
Two components of episodic memory are the success of retrieval, measured as the proportion of hits vs. misses, and the experience that accompanies retrieval, measured as "remembering" and "knowing". "Remembering" can be indexed by a remember or R response to indicate that the episodic memory is contextually rich and that the rememberer traveled back in time and "re-experienced" the original encoding episode. "Knowing" can be indexed by a know or K response to indicate that the episodic memory is accompanied only by a feeling of familiarity. It was hypothesized that hits and R responses are more correlated with frontal activity, especially on the right, than misses and K responses. Using a R/K procedure, participants recognized adjectives that were encoded in terms of the self, another person, social desirability, or phonological structure while their relative regional cerebral blood flow was measured using positron emission tomography. The data were analyzed using partial least squares to determine the neural correlates of retrieval success by correlating brain activity with hits/misses. The neural correlates of retrieval experience were determined by correlating brain activity with the proportion of hits that were R/K responses. Consistent with the prediction, the retrieval success neural network included frontal regions, especially on the right [right Brodman’s Area (BA) 10 and left BA 47], that positively correlated with hits. There was no region of frontal activity identified within the network that negatively correlated with hits (i.e., positively correlated with misses). The retrieval experience neural network included frontal regions [left (BA 6/9/46) > right (BA 9, 47)] that primarily correlated negatively with R responses (i.e., positively correlated with K
responses). Regions within the network that positively correlated with R responses, on the other hand, included limbic regions and anatomically related structures (anterior and posterior cingulate cortex, bilateral basal ganglia, right amygdala and parahippocampal gyrus, left brainstem, and bilateral cerebellum). The results support previous suggestions that right frontal regions are involved in retrieval success. With respect to retrieval experience, it is speculated that additional right frontal regions are recruited for K responses to verify and monitor the output, and to engage additional strategic search processes to try to change the quality of the retrieval experience from one of knowing to one of remembering. The right prefrontal cortex may not participate in R responses per se. Instead, the neural network that correlated with R responses may deliver its output to right prefrontal regions, or right prefrontal activity may be necessary to "switch on" the neural system that mediates the retrieval experience of remembering.
OVERALL SUMMARY

The goal of the present series of experiments was to shed light on the nature of the neuro-cognitive system that mediates the retrieval of personally-relevant information in comparison to other types of episodic information. This goal was met in several ways. The behavioral studies revealed that the retrieval of self-referential information is particularly susceptible to age-related effects, and that the retrieval of self-referential information is similar in old adults and in young adults who divide their attention at retrieval. Both aging and divided attention have been related to frontal deficits suggesting that the retrieval of self-referential information also is mediated by frontal processes. Somewhat surprisingly, the results also showed that the retrieval of social desirability information is particularly susceptible to age-related effects. As was the case for self-referential information, the young adults who divided their attention at retrieval retrieved material that was encoded in terms of its social desirability similarly to the old adults. The aging and divided attention findings suggest that social desirability information also is mediated by frontal processes. Converging evidence for the idea that the retrieval of both personally and socially relevant information involves frontal regions comes from previous research that has reported deficits in self-awareness and social-awareness in frontal-damaged patients. The PET study also provided converging evidence for the suggestion in that it showed that frontal areas are preferentially involved in the retrieval of self-referential and social desirability information relative to other-referential and phonological information.
In addition to providing information regarding the pattern of neural activity related to the retrieval of information from the category of self, the PET study also provided information regarding the pattern of neural activity related to the retrieval success and retrieval experience aspects of episodic memory for personally-relevant information. By teasing apart different aspects of retrieval that contribute to the overall episodic memory for personally-relevant information, common and disparate components of retrieval for self-referential, other-referential, and social desirability information, and their respective neural correlates, were determined.

Although the empirical evidence that was accumulated from the series of experiments does not resolve the philosophically old question regarding the nature of self, it has provided new insights that can guide the direction in which further models of memory and the self-construct are formulated.
REFERENCES


Craik, F.I.M. (1982). Selective changes in encoding as a function of reduced processing capacity. In F. Klix, J. Hoffmann, & E. van der Meer (Eds.), *Cognitive research in psychology* (pp. 152-161). Berlin: Deutscher Verlag der Wissenschaften.


Vocal identification of speaker and emotion activates different brain regions.

*NeuroReport.* 8, 2809-2812.


Clinical and theoretical issues (pp. 63-83). New York: Oxford University Press.


APPENDIX A

PARTICIPANT SCREENING QUESTIONNAIRE

Today's date (month/day/year): _______________________________________
Surname __________________________ First name __________________________
Gender ________ Date of birth (m/d/y) _________________________________
phone: home __________ work __________________________

Please Answer the Following Questions:

1. What is the highest grade you reached in high school? __________________
How many years of post secondary education do you have? __________________
What degrees/diplomas? ___________________________________________
What field(s)? ___________________________________________________

2. What is your first/native language? _________________________________
If your first language is not English, when did you learn English? ___________
Do you speak any other languages? _________________________________

3. In what country were you born? _________________________________
For how many years have you lived in Canada? ______________ Since when? _______

4. I am: right-handed ______ left-handed ______ ambidextrous _______
Mother is: right-handed ______ left-handed ______ ambidextrous _______
Father is: right-handed ______ left-handed ______ ambidextrous _______
Siblings are: right-handed ______ left-handed ______ ambidextrous _______

5. Do you presently take any medications on a regular basis? (e.g., prescriptions for seizures, depression? Sleeping pills? Etc.) Please name the problem and the medication. where possible ____________________________________________

6. Have you had any operations or major illnesses within the past 5 years? Describe ____________________________________________________________________________________________

7. Do you have any problems with vision? (glasses, operations etc.) ____________________________________________________________________________________________________________________________
With hearing? (weak, hearing aids, etc.) __________________________________________________________________________________________

8. Have you ever had any of the following:
   a/ stroke Y N b/ head injury Y N
d/ tumor Y N d/ aneurysm Y N
e/ neurological disease Y N e/ learning disability Y N
f/ concussion Y N g/ psychiatric illness Y N
h/ depression Y N h/ epilepsy Y N
i/ seizures Y N

9. Have you ever been in a serious car accident? Y N
Have you ever been unconscious? Y N
Have you ever hit your head badly? Y N

10. Is there anything else that you feel we should know about? (e.g., health problems, disabilities, etc.) ____________________________________________________________________________________________________________________________

202
APPENDIX B

MILL HILL VOCABULARY TEST (SHORTENED VERSION)

VOCABULARY TEST

Name: ____________________________
Date: ____________
Age: ________
Sex: ______
Last grade in school: _____________
Occupation: ____________________

In each group of six words below, underline the word which means the same as the word in capital letters above the group, as has been done in the first example.

1. CONNECT
   accident join flourish cry
   lace bean trash leap
   flirt field think blame

2. PROVIDE
   harmonize commit natural stupid
   hurt supply faulty grand
   annoy divide small exact

3. STUBBORN
   obstinate steady revolve move
   hopeful hollow raise work
   orderly slack waver disperse

4. SCHOONE
   building man selfish unaccountable
   ship singer romantic lawful
   plant scholar praise extravagant

5. LIBERTY
   worry freedom mountain descend
   rich serviette overcome concede
   forest cheerful appease snub

6. COURTESY
   dreadful proud pompous democratic
   truthful short bickering cautious
   curtsey polite anxious destructive

7. RESEMBLANCE
   fondness assemble activate contemplate
   attendance repose surround estrange
   likeness memory enfeebled regress

8. THRIVE
   15. PERPETRATE
   appropriate commit
   propitiate deface
   control pierce

9. PRECISE
   16. LIBERTINE
   missionary rescuer
   profligate canard
   regicide farrago

10. ELEVATE
    17. QUERULOUS
    astringent fearful
    petulant curious
    inquiring spurious

11. LAVISH
    18. FECUND
    esculent optative
    profound prolific
    sublime salic

12. SURMOUNT
    19. ABNEGATE
    contradict decry
    renounce execute
    belie assemble

13. BOMBASTIC
    20. TRADUCE
    challenge attenuate
    suspend establish
    misrepresent conclude

14. ENVISAGE
    21. TEMERITY
    impermanence rashness
    nervousness stability
    submissiveness punctuality
APPENDIX C

WORD LISTS OF PERSONALITY TRAIT ADJECTIVES

Practice Lists

1: jolly, immoral, enticeable, cosmopolitan
2: dandy, insulting, overbearing, modifiable
3: bitter, masculine, demonstrative, homogeneous
4: abrupt, feminine, mysterious, inconsiderate
5: regal, conformist, contemplative, unentertaining
6: handy, dependent, benevolent, unemotional
7: loud-voiced, leisurely, contemptuous, encyclopedic
8: huffy, mild-tempered, dominating, organizable

Encoding and Retrieval Lists

1: industrious, intelligent, unselfish, reasonable, alert, admirable, accurate, independent, composed, sociable, cool-headed, self-assured, definite, fearless, moralistic, prideful, restless, self-satisfied, timid, absent-minded, down-hearted, noisy, pessimistic, showy, irrational, disagreeable, irresponsible, humorless, self-centered, spiteful, disreputable, unlikeable
2: passionate, dependable, cheerful, courteous, imaginative, intellectual, creative, respectable, relaxed, decisive, venturesome, positive, obedient, daring, talkative, impulsive, extravagant, rebellious, modest, preoccupied, nervous, reckless, domineering, overcritical, careless, lazy, boastful, unreliable, snobbish, liar, rigid, uncreative
3: open, loyal, trustful, well-spoken, respectful, sportsmanlike, lively, inventive, vigorous, cooperative, easygoing, moral, social, mathematical, excited, aggressive, self-righteous, unsystematic, critical, silly, unpoised, disturbed, depressed, hot-headed, messy, gossipy, irritating, unpleasant, ill-tempered, awful, simple, unenergetic

4: athletic, rugged, reliable, educated, enthusiastic, kindly, punctual, wholesome, cultured, modern, light-hearted, untiring, careful, objective, perfectionistic, reserved, discriminating, self-conscious, radical, resigned, compulsive, frustrated, listless, wasteful, uncompromising, negligent, shallow, grouchy, hostile, offensive, awkward, stupid

5: musical, theoretical, kind-hearted, pleasant, level-headed, versatile, logical, congenial, entertaining, charming, self-confident, candid, fashionable, nonconforming, persistent, painstaking, self-concerned, dissatisfied, discontented, withdrawn, indifferent, possessive, scolding, neglectful, uninteresting, profane, meddlesome, bossy, belligerent, heartless, backward, unjust

6: powerful, considerate, interesting, outstanding, ambitious, constructive, energetic, attentive, adventurous, modest, studious, obliging, dignified, righteous, reputable, forward, forceful, old-fashioned, withdrawing, worrying, insecure, unwise, inattentive, hot-tempered, antisocial, gloomy, cowardly, childish, underhanded, unkind, cliannish, unpatriotic

7: pragmatic, truthful, earnest, tactful, original, spirited, tolerant, purposeful, hospitable, gracious, discreet, confident, soft-spoken, thrifty, cautious, self-
contented, self-possessed, eccentric, forgetful, demanding, mediocre, pompous, overconfident, neurotic, tactless, touchy, ungrateful, bragging, annoying, malicious, dirty, unscientific

8: successful, friendly, humorous, forgiving, resourceful, progressive, self-controlled, competent, skillful, curious, informal, artistic, serious, subtle, inoffensive, excitable, theatrical, lonely, crafty, submissive, obstinate, uncongenial, unobliging, disagreeable, fault-finding, helpless, self-conceited, oversensitive, unethical, greedy, unreasonable, unattractive

9: attractive, wealthy, happy, responsible, sharp-witted, clear-headed, capable, clean-cut, amiable, able, upright, thorough, precise, persuasive, normal, outspoken, conservative, ordinary, passive, unstudious, headstrong, jumpy, unintelligent, unproductive, unruly, tiresome, aimless, prejudiced, boring, conceited, phony, authoritative

10: knowledgeable, sincere, appreciative, warm-hearted, well-read, perceptive, observant, active, optimistic, patriotic, well-bred, casual, orderly, sophisticated, middleclass, quiet, unpredictable, cunning, conforming, spendthrift, impractical, unobservant, cynical, short-tempered, sloppy, disobedient, maladjusted, jealous, distrustful, ill-mannered, inhospitable, undependable

11: flexible, peace-loving, open-minded, broad-minded, self-disciplined, witty, ingenious, self-reliant, cordial, romantic, literary, consistent, scientific, sentimental, lucky, moderate, hesitant, wordy, anxious, gullible, unoriginal,
inconsistent, angry, unattentive, unsympathetic, foolish, unappealing, petty, quarrelsome, selfish, insensitive, uneducated

12: colorful, graceful, trustworthy, gentle, likable, grateful, well-mannered, generous, experienced, proficient, popular, self-sufficient, direct, self-critical, meditative, satirical, average, naive, clownish, frivolous, fearful, imitative, illogical, boisterous, envious, misfit, hypochondriac, deceptive, impolite, ultra-critical, vulgar, quick-tempered

13: complex, stable, thoughtful, trusting, quick-witted, patient, peaceful, sympathetic, diligent, rational, practical, hopeful, comical, soft-hearted, prudent, meticulous, emotional, skeptical, impressionable, troubled, sarcastic, inaccurate, moody, suspicious, foolhardy, scornful, egotistical, uncivil, abusive, loud-mouthed, noninquisitive, traditional

14: leader, honest, mature, clever, brilliant, talented, sensible, tender, eager, enterprising, refined, strong-minded, religious, democratic, deliberate, methodical, lonesome, unmethodical, silent, inhibited, high-strung, unenterprising, squeamish, fickle, unsporting, stingy, unsportsmanlike, incompetent, intolerant, insolent, dishonorable, treacherous

15: liberal, understanding, good-natured, honorable, polite, good-tempered, productive, high-spirited, decent, vivacious, humble, exuberant, philosophical, disciplined, systematic, innocent, solemn, daydreamer, opinionated, temperamental, clumsy, inefficient, uninspiring, scheming, finicky, troublesome, superficial, unfair, unforgiving, thoughtless, cruel, unaggressive
16: delicate, companionable, good-humored, helpful, efficient, ethical, amusing, realist, realistic, agreeable, tidy, outgoing, idealistic, convincing, sensitive, nonchalant, bashful, conventional, unskilled, indecisive, unhappy, stubborn, untidy, unsociable, resentful, ungracious, lifeless, hard-hearted, nosey, narrow-minded, obnoxious, argumentative
APPENDIX D

TEST INSTRUCTIONS

Encoding Instructions

I am trying to determine which areas of the brain are used when people make various judgments about personality traits. In the next 2 hours you will be asked to make various judgments about personality trait adjectives. To begin, eight different lists of personality trait adjectives will be presented. The adjectives within each list will be presented one at a time, and you will be asked to make one of four judgments about each adjective within a list.

Self

For the [list number] list, I would like you to judge how well you think each trait adjective describes YOU. Each trait adjective will be presented in the center of the screen, one at a time. You will be using your index, middle, ring, and pinkie fingers on these four keys on this keyboard to indicate your judgment.

If you think that the trait adjective almost never describes you, then press the key beneath your index finger. If you think that the trait adjective rarely describes you, then press the key beneath your middle finger. If you think that the trait adjective sometimes describes you, then press the key beneath your ring finger. If you think that the trait adjective almost always describes you, then press the key beneath your pinkie finger.

Although each trait adjective will remain on the screen for a few seconds, the time it takes you to make each judgment will be recorded. Therefore, make each judgment as quickly as possible, but concentrate primarily on making each
judge accurately and truthfully. A fixation point (a small cross) will appear before each trait adjective is presented. If you haven’t made a decision by the time the fixation point appears, then you should do so quickly because it means that the next trait adjective is about appear. Try pressing each of your four fingers down one at a time on their respective keys to get a feel for the four judgments: index, almost never; middle, rarely; ring, sometimes; pinkie, almost always.

We will begin with a few practice trials. Do you have any questions before we begin?

Other

For the [list number] list, I would like you to judge how well you think each trait adjective describes BRIAN MULRONEY. Each trait adjective will be presented in the center of the screen, one at a time. You will be using your index, middle, ring, and pinkie fingers on these four keys on this keyboard to indicate your judgment.

If you think that the trait adjective almost never describes Brian Mulroney, then press the key beneath your index finger. If you think that the trait adjective rarely describes Brian Mulroney, then press the key beneath your middle finger. If you think that the trait adjective sometimes describes Brian Mulroney, then press the key beneath your ring finger. If you think that the trait adjective almost always describes Brian Mulroney, then press the key beneath your pinkie finger.

Although each trait adjective will remain on the screen for a few seconds, the time it takes you to make each judgment will be recorded. Therefore, make each judgment as quickly as possible, but concentrate primarily on making each judgment accurately and truthfully. A fixation point (a small cross) will appear
before each trait adjective is presented. If you haven’t made a decision by the time
the fixation point appears, then you should do so quickly because the fixation point
means that the next trait adjective is about appear. Try pressing each of your four
fingers down one at a time on their respective keys to get a feel for the four
judgments: index, almost never; middle, rarely; ring, sometimes; pinkie, almost
always.

We will begin with a few practice trials. Do you have any questions before we
begin?

Social Desirability

For the [list number] list, I would like you to judge the SOCIAL
DESIRABILITY each trait adjective. Each trait adjective will be presented in the
center of the screen, one at a time. You will be using your index, middle, ring, and
pinkle fingers on these four keys on this keyboard to indicate your judgment.

If you think that the trait adjective is almost never socially desirable, then
press the key beneath your index finger. If you think that the trait adjective is rarely
socially desirable, then press the key beneath your middle finger. If you think that
the trait adjective is sometimes socially desirable, then press the key beneath your
ring finger. If you think that the trait adjective is almost always socially desirable,
then press the key beneath your pinkie finger.

Although each trait adjective will remain on the screen for a few seconds, the
time it takes you to make each judgment will be recorded. Therefore, make each
judgment as quickly as possible, but concentrate primarily on making each
judgment accurately and truthfully. A fixation point (a small cross) will appear
before each trait adjective is presented. If you haven’t made a decision by the time the fixation point appears, then you should do so quickly because the fixation point means that the next trait adjective is about appear. Try pressing each of your four fingers down one at a time on their respective keys to get a feel for the four judgments: index, almost never; middle, rarely; ring, sometimes; pinkie, almost always.

We will begin with a few practice trials. Do you have any questions before we begin?

Syllable

For the [list number] list, I would like you to judge how many SYLLABLES are in each trait adjective. Each trait adjective will be presented in the center of the screen, one at a time. You will be using your index, middle, ring, and pinkie fingers on these four keys on this keyboard to indicate your judgment.

If you think that the trait adjective has 2 syllables, then press the key beneath your index finger. If you think that the trait adjective has 3 syllables, then press the key beneath your middle finger. If you think that the trait adjective has 4 syllables, then press the key beneath your ring finger. If you think that the trait adjective has 5 syllables, then press the key beneath your pinkie finger.

Although each trait adjective will remain on the screen for a few seconds, the time it takes you to make each judgment will be recorded. Therefore, make each judgment as quickly as possible, but concentrate primarily on making each judgment accurately and truthfully. A fixation point will appear before each trait adjective is presented. If you haven’t made a decision by the time the fixation point
appears, then you should do so quickly because the fixation point means that the next trait adjective is about appear. Try pressing each of your four fingers down one at a time on their respective keys to get a feel for the four judgments: index, 2; middle, 3; ring, 4; pinkie, 5.

We will begin with a few practice trials. Do you have any questions before we begin?

Retrieval Instructions for Young and Old Conditions

(Modification of the instructions found in Conway and Dewhurst, 1995)

As an additional measure of how people process personality trait adjectives, I am going to test your memory for the trait adjectives that you just made various judgments about. Eight lists of trait adjectives are going to be presented, one at a time, in the center of the screen in front of you. Some of the words are words you just made a judgment about, others are new; that is, they have not been presented in any of the lists of adjectives that you just judged. Your task is to indicate whether the word is one that you made a judgment about, or whether it is new. Instead of just indicating whether the word is old or new, however, if you believe that the word is old I’d like you to indicate whether you remember the word or know the word. This is what I mean by remember and know.

Sometimes when we recognize an item we have seen before, we can consciously remember specific details about the previous occurrence of the item. For example, perhaps you can remember some details about watching a television show last night like the name of the show you watched, the show that came on before it, or who you watched it with. At other times we simply know that we have
seen an item before, even though we cannot recall specific details about the event. For example, you may see someone on the street and be very confident that you know that the person is from your personal past, but not remember any details about the person such as his or her name or how you know him or her.

When you see a word in this test that you recognize, you may be able to remember specific details about the presentation of the word earlier. You may for example recollect the thoughts or feelings that the word evoked when you saw it presented earlier (e.g., that it really described you or that it was a weird word), some aspect of the word’s physical appearance on the screen (e.g., that it was a really short word or an unusual word), some other detail, or a combination of details. In short, if you remember any additional detail that supports your belief that the word was presented earlier in a list of words that you made a judgment about, then you should indicate that you remember the word.

For other items in the test, you may know that they appeared in a list of words that you judged, even though you cannot recall any specific details of the word’s occurrence. If the word is familiar but you do not recollect any details then you should indicate that you know the word. (Give an example of a word and a R, K, and N response.)

Each word will remain on the screen for the same amount of time that it stayed on the screen when you were making the judgments about the words. That is, you should have plenty of time to make each judgment. There will not be a fixation point, however, to indicate that the next word is about to appear. Please think carefully about each decision, and try to enter a response for each word.)
Instructions for each list:

For the [list number], the words either are from the [first or second] list of trait adjectives that you made [type of judgment] about or they are totally new. If you remember the word, press the key beneath your index finger, if you know the word, press the key beneath your middle finger, if you think that the word is new, press the key beneath your ring finger.

Do you have any questions? We will begin with some practice trials.

Retrieval Instructions for Young Interference Condition (Experiment 2)
(Modification of the instructions found in Conway and Dewhurst, 1995)

As an additional measure of how people process personality trait adjectives, I am going to have you perform two tasks at the same time. One task involves your ability to recollect the trait adjectives that you just judged. The second task involves monitoring a list of auditorily presented digits for the occurrence of three odd digits in a row. I will explain each of these two tasks in more detail.

The first task is a memory test for the trait adjectives that you just made various judgments about. Eight lists of trait adjectives are going to be presented, one at a time, in the center of the screen in front of you. Some of the words are words you just made a judgment about, others are new; that is, they have not been presented in any of the lists of adjectives that you just judged. Your task is to indicate whether the word is one that you made a judgment about, or whether it is new. Instead of just indicating whether the word is old or new, however, if you believe that the word is old I’d like you to indicate whether you remember the word or know the word. This is what I mean by remember and know.
Sometimes when we recognize an item we have seen before, we can consciously remember specific details about the previous occurrence of the item. For example, perhaps you can remember some details about watching a television show last night like the name of the show you watched, the show that came on before it, or who you watched it with. At other times we simply know that we have seen an item before, even though we cannot recall specific details about the event. For example, you may see someone on the street and be very confident that you know that the person is from your personal past, but not remember any details about the person such as his or her name or how you know him or her.

When you see a word in this test that you recognize, you may be able to remember specific details about the presentation of the word earlier. You may for example recollect the thoughts or feelings that the word evoked when you saw it presented earlier (e.g., that it really described you or that it was a weird word), some aspect of the word’s physical appearance on the screen (e.g., that it was a really short word or an unusual word), some other detail, or a combination of details. In short, if you remember any additional detail that supports your belief that the word was presented earlier in a list of words that you made a judgment about, then you should indicate that you remember the word.

For other items in the test, you may know that they appeared in a list of words that you judged, even though you cannot recall any specific details of the word’s occurrence. If the word is familiar but you do not recollect any details then you should indicate that you know the word. (Give an example of a word and a R, K, and N response.)
Each word will remain on the screen for the same amount of time that it stayed on the screen when you were making the judgments about the words. That is, you should have plenty of time to make each judgment. There will not be a fixation point, however, to indicate that the next word is about to appear. Please think carefully about each decision, and try to enter a response for each word.

While you are making a remember, know, or new response to each word, I'd like you to perform a second task at the same time. The second task involves listening to a list of auditorily presented digits, and keeping a running count in your mind of the number of times 3 odd digits occur in a row. This task is just as important as deciding whether you remember, know or think that an adjective is new so you should try to divide your attention evenly between the two tasks.

Instructions for each list:

For the [list number], the words either are from the [first or second] list of trait adjectives that you made [type of judgment] about or they are totally new.

If you remember the word, press the key beneath your index finger, if you know the word, press the key beneath your middle finger, if you think that the word is new, press the key beneath your ring finger.

Do you have any questions? We will begin with some practice trials.

At the end of each list participants were requested to provide an example of a word that they gave an R response to, and the detail that made them give an R rather than a K response. They also were requested to approximate the proportion of words that they gave R responses to so that the experimenter good judge whether
or not the participant understood the task requirements. Participants also were reminded that the R/K distinction is not merely a confidence judgment.
APPENDIX E
FRONTAL LOBE CYTOARCHITECTONIC DESIGNATIONS IN CHAPTER 2:
BRODMANN (TALAIRACH & TOURNOUX, 1988) AND PETRIDES AND PANDYA (1994)

<table>
<thead>
<tr>
<th>LV (+/-)*</th>
<th>Brain Region</th>
<th>L/R**</th>
<th>Brodmann</th>
<th>Petrides and Pandya</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV1 (+)</td>
<td>medial frontal cortex</td>
<td>L</td>
<td>8/9</td>
<td>8B/9</td>
</tr>
<tr>
<td></td>
<td>(Self)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV1 (+)</td>
<td>middle frontal gyrus</td>
<td>R</td>
<td>9/44</td>
<td>9/46v/44</td>
</tr>
<tr>
<td></td>
<td>(Self)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV1 (+)</td>
<td>frontal operculum</td>
<td>L</td>
<td>44/45</td>
<td>44/45B</td>
</tr>
<tr>
<td></td>
<td>(Self)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV3 (+)</td>
<td>middle frontal gyrus</td>
<td>L</td>
<td>8/9</td>
<td>9/46d/9/46v/8Av</td>
</tr>
<tr>
<td></td>
<td>(SocDes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV3 (-)</td>
<td>inferior frontal gyrus</td>
<td>L</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>(SocDes)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* LV = Latent Variable; +/- = positive/negative salience; SocDes = Social Desirability

** L/R = left/right hemisphere
# APPENDIX F


<table>
<thead>
<tr>
<th>Saliences*</th>
<th>Brain Region</th>
<th>L/R**</th>
<th>Brodmann</th>
<th>Petrides and Pandya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits</td>
<td>superior frontal gyrus</td>
<td>R</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Hits</td>
<td>medial frontal lobe</td>
<td>R</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Hits</td>
<td>frontal operculum</td>
<td>L</td>
<td>47</td>
<td>47/12</td>
</tr>
<tr>
<td>Know</td>
<td>medial frontal lobe</td>
<td>R</td>
<td>9</td>
<td>9/10</td>
</tr>
<tr>
<td>Know</td>
<td>middle frontal gyrus</td>
<td>R</td>
<td>47</td>
<td>47/12</td>
</tr>
<tr>
<td>Know</td>
<td>inferior frontal gyrus</td>
<td>L</td>
<td>9/44</td>
<td>9/46v/44</td>
</tr>
<tr>
<td>Know</td>
<td>middle frontal gyrus</td>
<td>L</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Know</td>
<td>inferior frontal gyrus</td>
<td>R</td>
<td>9/44</td>
<td>9/46v/44</td>
</tr>
</tbody>
</table>

* Hits = frontal regions within the pattern of brain activity that positively correlated with hits; Know = frontal regions from within the pattern of brain activity that positively correlated with correct know responses

** L/R = left/right hemisphere