ODOR AND SOURCE REMEMBERING IN ADULTHOOD AND AGING:

INFLUENCES OF SEMANTIC ACTIVATION AND ITEM RICHNESS

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"You can check out any time you like

but you can never leave"

The Eagles

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ABSTRACT

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The overall aim of this doctoral thesis was to investigate episodic memory in early and late adulthood. Of particular interest was to examine whether older adults could make use of different forms of cognitive support in order to improve episodic memory performance. In addition to traditional assessments of item memory, memory for source and olfactory information were assessed. Manipulations of the level of cognitive support included experimenter-provided guidance at encoding (i.e., organizational instructions, a blocked presentation format, activation of prior knowledge), the degree of salience in the materials (e.g., words, objects, odors), and the presence of cues provided at retrieval (e.g., category cues, copy cues). Furthermore, the importance of various subject-related factors (i.e., proficiency in semantic memory) as related to episodic odor recognition was examined. **Study I** focused on recall performance as a function of age, item richness, and experimenter-provided support at encoding and retrieval. **Study II and III** examined item memory and source memory for externally derived information differing in degree of salience and modalities engaged at acquisition. Of particular interest here was to investigate whether elderly adults are selectively penalized in source memory tasks relative to item memory tasks. In **Study III, IV, and V** episodic recognition memory for common odors as a function of age and time of testing (immediately and 48 hours after study) were examined. In addition, the relationship between various semantic memory functions and episodic odor recognition was examined in **Study V**. In general, the results across Studies I-IV indicate that the ability to utilize the forms of support examined is well preserved in old age. However, there was little evidence for selective improvement of memory from cognitive support in either old or young adults. Also, the degree of richness inherent in the information to-be-remembered was positively related to memory performance across studies. Materials which were rich in features were better remembered than were materials low in detail. Furthermore, when retrieval support was provided in the form of category cues, elderly adults could use this additional information to enhance their memory performance. Both item memory and memory for source decreased as a function of age, but older adults exhibited greater difficulties in specifying the source of information as compared with memory for the item itself. This was particularly true for olfactory information. Odor recognition memory decreased as a function of age and time. This drop in performance across time was independent of age. Moreover, specific odor knowledge, such as perceived familiarity and identifiability, was strongly and positively related to performance in episodic odor recognition, whereas more general aspects of semantic memory were not associated with odor memory. Most important, accessibility of odor names was critical to episodic odor recognition in general, and mediated completely age-related deficits in odor recognition.

Key words: Odor memory, source memory, aging, cognitive support

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LIST OF PUBLICATIONS

The present doctoral dissertation is based on the following five studies.

I. Bäckman, L., & Larsson, M. (1992). Recall of organizable words and objects in adulthood: Influences of instructions, retention interval, and retrieval cues. *Journal of Gerontology: Psychological Sciences*, *47*, 273-278.

II. Larsson, M., & Bäckman, L. (1994). Did I unplug the iron or did I only look at it? External source monitoring across the adult life span. *Aging: Clinical and Experimental Research, 6*, 35-42.

III. Larsson, M., & Bäckman, L. (in press). Modality memory across the adult life span: Evidence for selective age-related olfactory deficits. *Experimental Aging Research.*

IV. Larsson, M., & Bäckman, L. (1993). Semantic activation and episodic odor recognition in young and older adults. *Psychology and Aging*, *8*, 582-588.

V. Larsson, M., & Bäckman, L. (in press). Age-related differences in episodic odor recognition: The role of access to specific odor names. *Memory.*

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CONTENTS

INTRODUCTION

The present doctoral thesis examines episodic remembering in early and late adulthood. Of particular interest has been to study whether older adults can make use of different forms of cognitive support to improve episodic memory functioning. I have chosen to focus mainly on two forms of memory, both of which witness a recent upsurge of interest in current cognitive research; namely source memory and olfactory memory.

Source memory refers to our ability to recollect the origins of our memories. In a few weeks from now you may recollect reading a text on age differences in source memory functioning and then try to remember where you read it (e.g., a journal, a book, a thesis?). At that moment, you are facing a source memory task. Research has indicated that older adults are impaired in source memory functioning, and there is also some evidence suggesting that this form of memory may be particularly affected by the adult aging process as compared with memory for the event itself (i.e., item memory). Identifying the conditions under which age-related differences in source memory may be exacerbated versus reduced constitutes an important objective of the current thesis.

Odor memory refers to both memory for odors per se and memories that may be associated to or evoked by odors. This thesis is concerned with the former type, that is, episodic recognition for common odors. In contrast to the many studies that have examined source memory functioning, the literature is very sparse as to the mechanisms underlying olfactory memory. Traditionally, memory research has primarily been focused on memory for information that is experienced by our visual and auditory sensory systems and has largely ignored the olfactory sensory system. Little is known regarding whether olfactory memory follows the same principles as does information acquired through other sensory modalities. This is particularly true with respect to odor memory in aging. However, although the olfactory modality has not been a primary study object in cognitive research, it is by no means forgotten by a number of famous authors (e.g., Baudelaire, 1868; Proust, 1919; Süskind, 1985), or in laypersons' anecdotal reports of the power of odors to unlock memories, often involving emotional features. An important aim of the present work is to elucidate factors critical to proficient odor memory, as well as mechanisms underlying potential age-related differences in memory for information encountered in the olfactory system.

Theories of Memory

Much contemporary work has been devoted to the organization of human memory. The idea that memory is composed of a series of interdependent brain systems has been contrasted with process-related accounts of how memory works. It is of interest to note that research performed on normal memory has tended to argue for a process-oriented view (e.g., Blaxton, 1995; Roediger, 1990; but see Tulving, 1993), whereas the study of abnormal memory has often been conceptualized in terms of a systems framework (Cohen & Squire, 1980; Gabrieli, 1995; Tulving & Schacter, 1990).

In the context of the relationship between awareness and memory, Graf and Schacter (1985) drew an important distinction between implicit and explicit memory tasks. In tasks tapping explicit memory (e.g., recall, recognition), test instructions are directed toward conscious recollection of a prior event or study episode. In contrast, in implicit memory tasks (e.g., perceptual identification, fragment completion, stem completion), no reference is given to a prior learning episode; subjects are not informed of the connection between study and test.

The explicit/implicit distinction is supported by evidence that amnesic patients show impairment in explicit tasks and relative preservation in various tasks assessing implicit memory (e.g., Graf & Schacter, 1985; Shimamura, 1986). Such findings along with other evidence of dissociated explicit/implicit performance in normal adults (Tulving, Schacter, & Stark, 1982) and in aging (Light & Singh, 1987; Parkin & Russo, 1990), have played an important role for views advocating the existence of distinct memory systems, or separate neural networks that mediate different forms of learning (Cohen & Squire, 1980; Gabrieli, 1991, 1995; Tulving, 1985).

Although it is still based on hypothetical constructs, the view that human memory is composed of five interrelated memory systems, has been highly influential (Nyberg & Tulving, 1996; Tulving, 1983, 1985, 1993; Tulving & Schacter, 1990). According to this perspective, memory may be decomposed into: *procedural memory*, which is expressed through skilled behavioral and cognitive procedures; *perceptual representation system* (PRS), which is primarily concerned with improving identification of perceptual objects; *semantic memory*, which is concerned with acquisition and use of factual knowledge; *working memory*, which registers and retains incoming information in a highly accessible form, for a relatively short period of time; and *episodic memory*, which involves memory of personally experienced events.

According to proponents of systems theory, it is assumed that the above ordering of systems corresponds to their presumed developmental sequence in both a phylogenetical and an ontogenical sense; procedural memory is conceived of as the earliest to develop, and episodic memory the latest. The ordering also reflects the assumed relations among the systems: many operations of subsequently evolved systems are assumed to be dependent and supported by the operations of earlier systems, whereas earlier systems can operate essentially independently of the later ones. Furthermore, Tulving (1993) has made certain assumptions about the relations between memory systems and states of awareness. To consciously recollect or remember something is a product from of the episodic system. Feelings of familiarity or knowing are characteristic of retrieval from semantic memory which is thus implicit in nature. Lack of awareness is characteristic of retrieval from the procedural and

PRS systems. Working memory or primary memory gives rise to a fleeting awareness of recently experienced events.

Alternative theories opposed to the systems approach are those who emphasize process differences within a unitary memory system (e.g., Roediger, 1990; Blaxton, 1995). According to the process view, memory performance is influenced by the degree to which the type of processing engaged in at study is recapitulated at test (i.e., transfer-appropriate processing). Given that there is a mismatch between study and test, performance will drop. Jacoby (1983) proposed that two kinds of processes are involved in implicit and explicit memory: conceptually driven processes, which are concerned with stimulus meaning; and perceptual processes, which are concerned with stimulus format. The processing framework posits that dissociations occur (e.g., between explicit/implicit memory and normal/amnesic persons) on the basis of the degree to which the memory test involves perceptual and conceptual processes, irrespective of whether the test format is explicit or implicit.

In a broad sense, neither the process view or the systems view can be rejected. Both perspectives are supported by a wealth of data, and there is also research that would seem to be at variance with both views. To be sure, it may be difficult, if not impossible, to conduct the critical experiment that would adequately discriminate between the two positions. To complicate matters further, it may also be that a certain perspective (e.g., one emphasizing processes) is feasible at a behavioral level, whereas another perspective (e.g., one emphasizing structures) makes more sense at a neurobiological level. Perhaps there is also room for interaction between these views. This is so because processes may not operate in a vacuum, but rather within particular structures. Likewise, a system deprived of processes would appear maladaptive.

Importantly, irrespective of whether one subscribes to a process or systems account of human memory, most researchers would agree that episodic memory is the form of memory that is most sensitive to the process of aging (e.g., Kausler, 1994; Light, 1991; Salthouse, 1991). As noted, this form of memory requires conscious recollection of previously experienced events acquired in a particular place at a particular time. The age-sensitivity of this form of memory was recently documented by Nyberg, Bäckman, Erngrund, Olofsson, and Nilsson (1996) who examined age differences in episodic memory, semantic memory, and priming in a sample of 1000 adults between 35 and 80 years of age. When differences in demographic, intellectual, and biological factors had been taken into account, age proved to be unrelated to performance in semantic memory and priming, whereas age was still a significant contributor to the variation observed in episodic memory. Similarly, there is evidence of an age-related deterioration in working-memory capacity (Baddeley, 1992; Hultsch, Herzog, & Dixon, 1990). In contrast to episodic and working memory, age differences tend to be slight or non-existent in tasks tapping procedural memory, priming, and semantic memory (e.g., Bäckman & Nilsson, 1996; Mitchell, 1989; Nyberg et al., 1996). It is of interest to note that age differences seem to occur primarily for the forms of memory that evolved last, that is, in working memory and episodic memory, whereas age differences tend to be small or negligible in the varieties of memories developed earlier (Tulving, 1993).

EPISODIC MEMORY AND AGING

Explaining Age-Related Memory Deficits

As noted, age-related deficits in episodic memory are well documented (see Kausler, 1994; Light, 1991; Salthouse, 1991, for reviews). Consistently, younger adults perform better in episodic memory tasks than do older adults. This deterioration is observed regardless of whether seemingly artificial and ecologically irrelevant memory materials are used (e.g., lists of words, paired associates), or when the memory task is designed to be more ecologically relevant, such as recall of conversations or television programs (Cavanaugh, 1983; Hultsch & Dixon, 1990; Kausler & Hakami, 1983). The basis for this age-related deterioration is still not well understood (Light, 1991), but neuronal changes in the aging brain are most likely an important factor (Bäckman et al., in press; Cabeza et al., in press; Creasey & Rapoport, 1985; Grady et al., 1995; Schacter, Savage, Alpert, Rauch, & Albert, 1996).

As a consequence of neuronal changes, it has been proposed that older adults have fewer processing resources available in order to learn and retrieve new information (e.g., Craik, 1983; Craik & Byrd, 1982; Craik & Jennings, 1992; Salthouse, 1991). A number of hypothetical factors related to the concept of processing resources have been identified, and have proved to account for age-related variation in memory performance. Specifically, it has been argued that age deficits in memory arise because of changes in fundamental processing mechanisms such as cognitive slowing (e.g., Hultsch et al., 1990; Salthouse, 1991), reduced working-memory capacity (e.g., Salthouse & Meinz, 1995; Salthouse, Mitchell, Skovronek, & Babcock, 1989), and reduced inhibitory functions (Hartley, 1993; Hasher & Zacks, 1988).

It is well documented that the aging process is accompanied by changes in speed of processing. Response latencies are longer in older than in younger adults (Salthouse 1980). Greater noise in the nervous system has been proposed as being responsible for this age-related slowing (Salthouse & Lichty, 1985), as have broken, weakened, or attenuated neural connections (Cerella, 1990; MacKay & Burke, 1990). Empirical findings indicate that age differences in various cognitive tasks are markedly reduced when speed of processing has been statistically controlled, which suggest that age-related slowing may underlie a great proportion of the observed age-related variation in cognitive tasks (Hultsch et al., 1990; Bryan & Luszcz, 1996).

In general, there is good evidence that older adults perform more poorly on tasks tapping working memory, and that these deficits underlie a variety of age-related deficits in cognitive performance (Light & Anderson, 1985; Morrell & Park, 1993). Working memory requires simultaneous storage and processing of information and is involved in many aspects of cognition such as learning, memory, text comprehension, and reasoning (Baddeley, 1986, 1992). An important question is whether the structural or operational aspects of working memory are the most affected by aging. Salthouse and his colleagues examined this issue by distributing tasks which varied in the demands put on storage and processing capacity. No evidence of any interaction between age and task difficulty was found. It was concluded that age differences in working memory seem to be determined at least as much by differences in storage capacity as by differences in the efficiency of processing (Babcock & Salthouse, 1990; Salthouse & Babcock, 1991; Salthouse, Babcock, & Shaw, 1991).

A related notion is that older adults have a reduced ability to inhibit irrelevant information in working memory (Hasher & Zacks, 1988). Inefficient inhibition allows entrance of information into working memory, which may not be directly relevant to the task in question. As a consequence, older adults will become more prone to entertain thoughts that are off-track, such as thinking of personal concerns or daydreaming. This may be experienced as a difficulty in concentration which is certainly a common complaint in the elderly population (Hartley, 1993; Plude & Hoyer, 1985). Faulty inhibitory functioning as a contributor to age differences in memory has received some empirical support (Hartman & Hasher, 1991; Hasher & Zacks, 1988; McDowd & Filion, 1992), but the topic needs further empirical exploration.

One hypothetical consequence of diminished processing resources is that older adults will have greater difficulties in memory tasks that require higher amounts of self-initiated processing (Craik, 1983). Obviously, various memory tasks pose different retrieval demands with respect to the amount of self-initiated processing involved. For example, to explicitly recall a certain piece of information requires more processing resources than does recognition of an item's previous exposure. Because older adults have a smaller pool of available resources, age differences may therefore be particularly exacerbated in recall tasks relative to recognition tasks (Craik & McDowd, 1987).

A related notion is that older adults are less likely to engage in efficient elaborative rehearsal (e.g., Rankin & Collins, 1985, 1986). The elaboration deficit hypothesis states that elderly adults are less likely than younger adults to construct or activate a network of semantic relationships related to the information to-be-remembered (TBR). To efficiently elaborate the TBR information (e.g., to generate images or associations), would seem to tax basic processing resources that are adversely affected by aging. In a related vein, Rabinowitz and Ackerman (1982) suggested that older adults produce less distinctive encodings resulting in less accessible memory traces relative to younger adults. Specifically, these authors claimed that the semantic encodings of older individuals are more general and prototypical in nature compared with those of young adults. This is because the encoding of general semantic characteristics can be performed relatively automatically, with a minimum of cognitive resources required (Hasher & Zacks, 1979). More global features are encoded at the expense of specific features present in the immediate context, which are crucial in order to differentiate the event from other similar events. Younger individuals, however, are more efficient in their encodings such that more specific and contextual information are integrated with the target.

This hypothesis received support in two early studies performed by Rankin and Kausler (1979) and Smith (1975) in which young and old individuals were compared in recognition memory tasks where the nature of the distractors was varied (i.e., semantically related vs. unrelated to targets). Older people made more false alarms to semantically related distractors than did the younger adults. There was no age difference in the attributions for unrelated distractors. These results indicate that elderly adults do encode semantic information, but that this semantic information may not be specific enough to differentiate the target event from other similar events. More recent research examining (a) the consistency with which young and older adults produce associations to words (Mäntylä & Bäckman, 1990), and (b) memory for expected and unexpected objects in an office setting (Mäntylä & Bäckman, 1992), have also provided results consistent with the view that older adults may encode information in a more schematic and less distinctive fashion compared with young adults.

Characteristics of the Rememberer and Memory Performance

Research has indicated that many of the effects of aging reported in the cognitive literature may result from factors other than the primary aging process (e.g., Houx, Vreeling, & Jolles, 1991; Lindenberger & Baltes, 1994). Consequently, research oriented toward age-related cognitive changes should exclude (or statistically control for) potential internal and external factors that may confound the results. For example, with regard to the role of sensory functioning for age differences in intelligence, Lindenberger and Baltes (1994) recently showed that visual and auditory acuity accounted for most of the observed age variation in intellectual functioning. In a similar vein, Houx et al. (1991) showed that existence of risk factors for brain dysfunction (e.g., head trauma, system disease, alcohol abuse) aggravated the effects of aging in memory scanning even for subjects younger than 65 years. A rigorous screening for health substantially reduced the size of age differences in performance.

There is also ample evidence indicating that individual differences in various demographic and psychometric factors covary with episodic memory functioning. One well-known demographic factor which is positively related to episodic memory functioning is level of formal education (e.g., Craik, Byrd, &

Swanson, 1987; Hill, Wahlin, Winblad, & Bäckman, 1995; Inouye, Albert, Mohs, Sun, & Berkman, 1993). The influence of education on memory is presumably related to that level of schooling is associated with verbal ability and strategy knowledge, both of which are important prerequisites for proficient memory functioning in various situations.

Gender is another demographic factor that has been proven to be related to episodic memory. A number of studies have indicated that women outperform men in episodic tests of memory across the adult life span (Herlitz, Nilsson, & Bäckman, in press; Wahlin et al., 1993; West, Crook, & Barron, 1992), but with no evidence of significant age x gender interactions. To account for these findings, both social (McKelvie, Standing, St. Jean, & Law, 1993) and biological (Gur et al., 1991) explanations have been offered.

As noted by way of introduction, age-related differences tend to be small or negligible in tasks assessing semantic memory (e.g., Bäckman & Nilsson, 1996; Kausler, 1994). Relatedly, psychometric tests assessing retrieval of generic information (often subsumed under the heading of crystallized intelligence), have been shown to reveal only minor age-related changes, indicating that the ability to retrieve context-free overlearned information is only little affected by the process of aging. Note, however, that semantic tasks posing heavier demands on mental tempo, like tests of verbal fluency, typically find evidence for an age-related deterioration in performance (Kausler, 1994; Salthouse, 1991). Importantly, proficiency in both crystallized and fluid intelligence have been shown to be positively related to performance in a number of episodic memory tests (Gillund & Perlmutter, 1988; Hultsch, et al., 1990; Hultsch, Nesselroade, & Plemons, 1976; West, et al., 1992).

Taken together, there are a number of characteristics of the rememberer other than chronological age per se, that are related to proficiency in episodic memory. These factors need to be taken into account when assessments of age differences in memory are made.

THE MODIFIABILITY OF EPISODIC MEMORY PERFORMANCE

As proposed by Craik and Jennings (1992), cognitive processing may be conceptualized as an interaction between external stimulation and subject-related internal processes. These latter processes are heavily mediated by available processing resources and may consequently decrease in effectiveness as a person gets older. Despite age-related losses in episodic memory, much research has indicated that older adults may benefit from different kinds of cognitive support in order to improve memory (see Bäckman, 1989, 1995; Bäckman, Mäntylä, & Herlitz, 1990; Craik & Jennings, 1992, for reviews). Cognitive support may be viewed as information present in the memory situation that serves as compensation for limited processing resources. A typical finding is that older adults perform better in conditions involving some form of cognitive support as contrasted with conditions in which little support is provided. Supportive conditions may be present at encoding and/or retrieval, be inherent in the information to-be-remembered, or may be internally generated and activated in the form of an individual's prior knowledge of the TBR information (Bäckman, 1995; Herlitz, Lipinska, Bäckman, 1992).

There are several theoretical and practical reasons as to why the study of cognitive support in episodic memory is important. First, many of the forms of support provided draw on basic structures in semantic memory (e.g., organizability of the TBR information, activation of prior knowledge). Evidence concerning the influence of cognitive support on memory in young and old age may thus shed further light on the interactive relationship of semantic memory functions and episodic memory across the life span. Second, it may provide valuable information with regard to potential sources of memory impairments in aging. For example, Craik and McDowd (1987) reported that age differences in episodic memory were eliminated when memory was tested by means of recognition rather than by recall. This outcome suggests that retrieval problems to a large extent underlied the observed age difference in episodic recall. Third, knowledge about whether a certain group of persons can benefit from cognitive support has obvious implications with regard to strategies for cognitive intervention.

In the following sections, I will provide a brief review of supportive conditions which may influence the size of the age-related variation in episodic memory. A schematic overview of the forms of cognitive support provided across Studies I-V is provided in Table 1. The types of support discussed below are relevant to the five studies that form the empirical basis of the thesis.

Insert Table 1 about here

Encoding and Retrieval Support

As noted above, it has been suggested that age differences in episodic memory are at least partially due to age-related deficiences in self-initiated processing. As a result, age differences may be particularly pronounced in memory tasks that pose heavy demands on self-initiated processing such as recall tasks (Craik, 1986; Craik et al., 1987). These demands may be lessened by providing the subject with appropriate retrieval cues, or by assessing memory retrieval by means of recognition rather than recall. Indeed, there is evidence that age differences are attenuated when category cues or copy cues are provided at retrieval (Craik & McDowd, 1987; White & Cunningham, 1982). The boost in memory performance usually observed in cued recall relative to free recall, is presumably related to an activation of the items initially studied, which in turn reduces the amount of self-initiated processing needed for successful retrieval. Similarly, to explicitly recall a certain piece of information is more effortful than is recognition because of the demands of active and self-initiated search in the former case. In the recognition task such a search procedure is, at least partially, bypassed, because the target is re-presented at test, and the decision could be made on the basis of the target's previous exposure. Thus, given that the cognitive demands are higher in recall than in recognition, and that older adults' cognitive resources are reduced, it is not surprising that age differences generally are smaller in recognition than in recall (Craik & McDowd, 1987; White & Cunningham, 1982).

Age differences in episodic memory may also be attenuated by guiding the encoding activities. Because semantic memory is known to show only slight changes in normal aging, older adults may compensate their deficits in episodic memory by activating the semantic memory network. An activation of the semantic network permits the older individual to elaborate further on the TBR information, an activity which may not have been initiated spontaneously due to limitations in self-initiated processing. For example, studies have indicated that provision of explicit instructions to organize the TBR information yields better memory in older adults, as compared with situations in which no such information is given (Hultsch, 1969, 1971; Treat, Poon, & Fozard, 1981). Providing the information blocked and clustered by semantic category lessens the demands of self-initiation further. A blocked presentation of items provide the subject with both temporal and semantic information which may be useful as cues at the time of retrieval (e.g., you may remember "that the fork was presented in the beginning of the list together with all the other kitchen utensils"; Puff, 1970; Tversky, 1973).

The studies cited above have in common that they are concerned with the effects of contextual variables on memory performance. However, when evaluating episodic memory performance also subject-related variables are important to take into account. One subject-related variable that has received considerable attention during recent years is that of prior knowledge (see Dixon & Bäckman, 1993, for a review). There is ample evidence that the availability of task-relevant prior knowledge may increase the level of recall of older adults and sometimes result in the elimination of age differences in memory performance. One popular way of manipulating this variable is to select TBR information for which age groups (i.e., young vs. old) differ in terms of level of pre-experimental knowledge. This may be accomplished by varying the datedness of the information (i.e., dated vs. contemporary). The typical finding in these studies is that younger subjects remember more contemporary information, whereas older subjects remember more of the dated information (Bäckman, 1991; Bäckman & Herlitz, 1990). To the extent that older adults are more knowledgable of dated than of contemporary information, whereas the reverse is true for young adults (e.g., Bäckman & Karlsson, 1985; Hultsch & Dixon, 1983), these results suggest proficient utilization of prior knowledge in episodic memory for young and old adults alike.

Item Richness

It is well known that memory performance vary as a function of the nature of the materials to remember. Episodic memory performance is related to stimulus dimensions such as richness in features, modality, and organizability. Surprisingly few studies in the literature have focused explicitly on memory for information encoded across several sensory systems. Our knowledge of memory functioning in general is primarily based on work using materials which have been encoded through the auditory or visual sensory systems. This research has indicated that stimuli rich in features are easier to recollect than are stimuli low in detail. This is so because richer materials may lead to more elaborated encodings and representations and, therefore, be easier to reactivate at retrieval.

One example of the dependency between the number of stimulus features and proficiency in episodic memory is the picture superiority effect (e.g., Nelson, Metzler, & Reed, 1974; Paivio & Csapo, 1973), which states that pictures are more easily remembered than their corresponding words. It has been suggested that this effect is related to that pictures drive a rich and elaborate encoding rather automatically (Craik & Jennings, 1992). In a similar vein, Spoehr and Lehmkule (1982) showed that actual objects were remembered better than were their pictures, which in turn were better recalled than their corresponding words.

In two experiments involving young subjects, Gollin and Sharps (1988) demonstrated that recall of actual objects was better than recall for the printed names of those objects. They also found that items presented blocked by semantic category were more memorable than items presented unblocked. Of more interest, however, was the finding that the blocking effect varied as a function of the nature of stimuli. That is, verbal memory performance was higher following a blocked presentation format, whereas object recall was unaffected by encoding condition. In one of the experiments, four types of materials were included which were presented either blocked or unblocked: objects, color photographs of the objects, line drawings of the objects, and printed names of the objects. Again, the results indicated that recall decreased as a function of decreasing visual detail, whereas the effect of blocking decreased as a function of increasing visual detail in the materials. This likely reflects that a blocked input format adds relatively little to the quantity of encoding, once the materials is rich in terms of features.

In related work, Arenberg (1968) and Bäckman (1986) found that age differences in recall were ameliorated when items were presented bimodally (visually and auditorily), whereas age differences were exacerbated for unimodally (visually or auditorily) presented items. Also, some investigators have demonstrated that the usual superiority of young over older adults in episodic remembering may be eliminated or less pronounced in so called subject-performed tasks or SPTs (Bäckman, 1985; Bäckman & Nilsson, 1984, 1985; Nyberg, Nilsson, & Bäckman, 1992). In this task, subjects are instructed to perform a series of real-life action events (e.g., hug the doll, bounce the ball) for purposes of later recall. The absence or reduction of the age effect in this task, relative to verbal control tasks, has been attributed to the encoding of SPTs being multimodal in the sense that several sensory systems are involved at encoding, which may promote an elaborate encoding. In explanations of the SPT effect, strong emphasis has been put on the motor component and the activation of the tactual modality as well as other features present in the task, such as color, texture and shape (Bäckman, 1985; Bäckman & Nilsson, 1985; Bäckman, Nilsson, & Chalom, 1986; Cohen, 1989). However, it is important to note that other investigations have failed to replicate attenuated age differences or age equivalence in SPT memory (Cohen, Sandler, & Schroeder, 1987; Nilsson & Craik, 1990; Guttentag & Hunt, 1988).

As noted, not many studies have paid attention to memory as related to information encoded across several sensory modalities. Little is known as to memory for olfactory and tactile information as compared with memory for auditory and visual materials in relation to age. However, using a sample of young adults, Lawless (1978) reported that recognition memory for complex figures was higher than memory for odors and abstract stimuli. In two studies, age-related deficits in recognition memory have been proved to be considerably larger for odors than for visual stimuli using symbols and faces as materials: Young adults recognized odors much like they remembered visual stimuli, immediately, two weeks, and 6.5 months after inspection. Odor memory in the older adults, on the other hand, was at chance after the first testing occasion (Cain & Murphy, 1987; Murphy, Cain, Gilmore, & Skinner, 1991). How to best explain these selective age-related deficits in olfactory memory is still an unresolved issue that needs further exploration.

Utilization of Cognitive Support in Aging

Few would probably disagree with the general view that episodic memory is a context-dependent phenomenon related to encoding/retrieval factors, the nature of the TBR information, subject-related factors, and to the multiple interactions among these factors. As a result, we should perhaps not be surprised by the fact that there is no systematic relationship between adult age and the degree of memory improvement from the provision of cognitive support. In some situations, older people benefit more from supportive conditions than their younger counterparts (Bäckman, 1986; Craik & McDowd, 1987); in other situations old and young subjects benefit to the same extent from support (Park, Cherry, Smith, & Lafronza, 1990; Rabinowitz & Craik, 1986); and in still other situations, younger adults benefit more than older adults from cognitive support (Kliegl, Smith, & Baltes, 1989; Puglisi & Park, 1987). Thus, the relationship among age, cognitive support, and episodic memory performance is not straightforward (Bäckman, 1989, 1995; Jenkins, 1979). Furthermore, as recently pointed out by Bäckman (1995), the discussion of aging and cognitive support may benefit from taking two additional dimensions into account; namely, the subject's need for support and the ability to utilize the support provided. With regard to optimization of episodic remembering, there is evidence that the requirement of supportive conditions increases as a function of age, whereas the ability to utilize this support may decrease as a function of age.

The ability to utilize cognitive support is further dependent on a number of subject-related and task-related factors in addition to age. Some recent research has indicated that not all individuals of the same age benefit equally much from the provision of cognitive support. Specifically, these data indicate that the most able individuals (as reflected in educational background, level of social activity, and indices of health) are better equipped to make effective use of cognitive support as compared with their less able counterparts (Bäckman, Hill, & Forsell, 1996; Craik et al., 1987; Hill et al., 1995).

In sum, there are no simple and general laws of memory performance as related to the aging process. Rather, episodic memory may be conceived of as a context-sensitive phenomenon which involves consideration of acquisition factors, test factors, the nature of the materials, characteristics unique to the rememberer, and to the multiple interactions among these factors. The lack of a simple relationship among the variables involved is perhaps particularly notable with respect to the interplay among adult age, level of cognitive support, and memory performance.

SOURCE MEMORY

The general definition given to episodic memory (i.e., recollection of information acquired in a particular place at a particular time) matches the demands that are posed in a source memory task (Johnson, Hashtroudi, & Lindsay, 1993; Tulving, 1993). In other words, for successful recollection of source, subjects must be able to encode critical contextual features in order to be able to discriminate one memory representation from another. In general, episodic memory is assessed by asking a subject to retrieve items from a previous presentation of a study list (e.g., words, objects, or odors). No requirements of recollecting contextual details are posed. Thus, although source recollection would seem to be at the heart of episodic memory, traditional testing of episodic memory emphasizes item information.

It has been suggested that age deficits in episodic memory may be due to an age-related failure to encode contextual information and to integrate events with their contexts (e.g., Craik & Jennings, 1992; Light, 1991; Rabinowitz & Ackerman, 1982). Having insufficent information about the context that surrounds an event or item may deprive the older adult of the environmental support necessary for retrieval of the event or item (Craik & Jennings, 1992). If older adults do encode events less richly and fail to integrate items with their context, then age effects may be especially pronounced in source memory tasks.

Trying to remember who told us something or in which newspaper we read a news item are examples of source memory tasks. Our memories originate from many different sources, and to function efficiently in everyday life, we need to be able to remember these sources correctly. Some of our memories are externally derived, that is, experienced and encoded by our senses and may include information that we have heard other people say, events that we have witnessed, or acts we have performed. Other memories originate from internal sources and may be generated from our imagination, dreams, plans etc. (Johnson et al., 1993; Johnson & Raye, 1981). Thus, in current conceptualizations of source memory, the term source refers to the specific conditions that were present when a certain memory was acquired (e.g., the temporal, spatial, and social context of the event; the modalities through which it was perceived). In the laboratory, source memory is typically assessed by instructing subjects not only to recollect target information, but also to specify how this information was acquired.

The process of identifying a source is dependent on the characteristic features of memories in combination with decision processes. Principally, three types of source monitoring discriminations can be made (Johnson et al., 1993; Raye & Johnson, 1980). First, the process of distinguishing between internally generated and externally derived information in memory (e.g., to discriminate between fantasy and perceived experiences) has been referred to as reality monitoring. The second type of source monitoring is related to discriminations between internally generated memories (internal source monitoring; e.g., discriminating one's thoughts from what one says), and the third type is related to discriminations between externally derived sources (external source monitoring; e.g., discriminating between statements made by one person from statements made by another person). A number of memory characteristics on which source-monitoring decisions rely have been identified: perceptual information (e.g., sound, color), contextual information (e.g., spatial, temporal), semantic detail, affective information, and cognitive operations (e.g., records of elaborating, organizing, and identifying) that were established when the memory was formed. Typically, externally derived memories are richer in sensory attributes and involve more perceptual, contextual, semantic, and affective information than do internally generated memories. Internal memories are more schematic, often lack contextual details, but include traces of the cognitive operations (e.g., imaging, organizing) that generated them. A breakdown in source monitoring may be related to a disruption in any or several of these memory characteristics.

External Source Monitoring in Aging

Generally, older adults are less able than younger adults to specify the sources of events (e.g., Cohen & Faulkner, 1989; Hashtroudi, Johnson, & Chrosniak, 1989, 1990; McIntyre & Craik, 1987; Spencer & Raz, 1994), but there is some evidence suggesting that the magnitude of the age deficit depends on the type of source monitoring task a person confronts. Hashtroudi et al. (1989) showed that older adults were particularly impaired in external and internal source monitoring decisions, but performed as well as the younger subjects in reality monitoring decisions. However, although this finding is supported by some other work (Degl'Innocenti & Bäckman, in press; Guttentag & Hunt, 1988; Mitchell, Hunt, & Schmitt, 1986), there are situations in which age differences in reality monitoring have been observed (Cohen & Faulkner, 1989; Hashtroudi et al., 1990; Rabinowitz, 1989). The observed discrepancies in reality monitoring may be related to the use of different kinds of TBR information, and that different test procedures have been applied. Further work is needed in order to understand the mixed results regarding age differences in reality monitoring.

The results are more straightforward concerning external source monitoring. A number of studies have indicated that older adults have more difficulties than younger adults in discriminating between sources of externally derived information (e.g., Hashtroudi et al., 1989; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991). One explanation that has been put forward to account for this deficit is that older adults have difficulties to encode sensory and perceptual aspects of the target information (e.g., Cohen & Faulkner, 1989). Direct evidence that elderly persons have greater problems to recollect perceptual information was reported by Hashtroudi et al. (1990). In this study, memory for perceived and imagined everyday situations (e.g., packing a picnic basket) was examined. A main question was whether some memory characteristics (e.g., perceptual and contextual) were affected more by aging than others. Responses were evaluated for mention of colors, objects, spatial references, and thoughts and feelings. The results indicated that older adults reported less perceptual and contextual (spatial) information, but reported more thoughts and feelings than did younger adults.

In a similar vein, older adults exhibit greater difficulties than younger adults in recollecting externally derived sources such as the sex of the presenter (Kausler & Puckett, 1981), the case format of the information (Kausler & Puckett, 1980), the color of the materials (Park & Puglisi, 1985), or the presenter of information (Schacter, et al., 1991). Relatedly, McIntyre and Craik, (1987) taught young and older persons real and made-up facts and later asked the subjects to remember the sources of these facts. Older adults exhibited larger deficits in remembering the presentation modality (experimenter vs. overhead projector) than younger adults. Also, elderly adults had greater difficulties in remembering whether a a fact was learned in the experiment or whether it came from another source. Most interesting, Ferguson, Hashtroudi, and Johnson (1992) showed that that the rate of source confusions in elderly subjects increased as a function of perceptual similarity. In that study, older adults had difficulty with source monitoring when perceptual cues were similar, that is, when the source was one of two women. However, this age difference was overcome when perceptual cues were made more distinctive, in this case when the information was presented by a man and a woman. This outcome not only indicates that older adults have more difficulties than younger adults to encode perceptual cues to discriminate between sources, but also that age-related differences can be ameliorated or enhanced by varying the similarity between sources.

Taken together, these results suggest that older adults have problems in situations in which it is of particular importance to encode, integrate, and reconstruct sensory and perceptual aspects of target information, in order to identify the source of the memory representation.

Item Memory and Source Monitoring

In current research, it is widely acknowledged that recognition memory is not a unitary phenomenon and that target recognition can be based on both perceptual representations and explicit memory for the target's previous presentation (Johnston, Dark, & Jacoby, 1985; Parkin & Walter, 1992). Gardiner and his colleagues have investigated different forms of recollective experience following recognition (Gardiner & Java, 1990; Gardiner & Parkin, 1990). On the basis of a framework developed by Tulving (1985), subjects in these studies were required to classify each recognized item into two categories; "remember" (R) or "know" (K). An R response is a recognition response where the subject has some specific contextual recollection of the specific stimulus (e.g., an image or an association). In contrast, a K response indicates that the subject knows that the item was presented at study, but has no explicit recollection or any contextual information available of that item's prior presentation. The latter component is thought of as being related to relatively automatic processes with no conscious recollection, whereas the former entails intentional processes and conscious recollection of the information TBR. R responses may be considered as a form of contextual memory similar to that involved in source discriminations (Hashtroudi et al., 1990; Parkin & Walter, 1992). Research has indicated that there is a marked difference in the quality of recognition responses in young and old subjects. Younger adults' recognition memory is associated with greater contextual recollection as indicated by a more frequent use of R responses. Older adults, on the other hand, show a far less amount of explicit recollection and tend to produce more K responses (Mäntylä, 1993; Parkin & Walter, 1992). Because recognition memory is reported to decline little with age (e.g., Craik & McDowd, 1987), this outcome suggests that the implicit contribution to recognition (i.e., the "know" items) may serve a compensatory purpose in the presence of age-related deficits in recollecting contextual detail.

At a general level, the processes of recognition and source monitoring may not be fundamentally different. In a recognition task, both new and old items are familiar from extraexperimental sources. Thus, the process of recognizing an old item involves some degree of source monitoring in that subjects must discriminate studied items from nonstudied items. However, the two tasks do differ in that they require different degrees of differentiation which may explain why age differences tend to be more pronounced in source memory than in item memory (Erngrund, Mäntylä, & Nilsson, 1996; Schacter et al., 1991). To specify the source of a given event requires a higher degree of differentiation than does a recognition task. For example, you may remember that you read about a doctoral student who shot three of the committee members when defending his thesis (item memory), but not from which newspaper you acquired this information (source memory). To be able to recollect the source of events, the memory needs to be distinct enough to discriminate it from other potential sources. These demands are typically somewhat lower in item recognition. This is not to say that performance in item recognition does not benefit from a more differentiated and elaborated input, but rather that decisions can be performed at a lower level.

Naturally, different stimuli give rise to different levels of activation. For example, over time a complex object may become more differentiated and evoke more specific and meaningful attributes in memory. Consequently, the activation becomes more elaborated and the memory of the object will be richer in the sense that it involves more information such as perceptual, contextual, and semantic details. A memory representation that includes high amounts of contextual detail will not only be easier to identify by means of recognition, but also easier detected in a source memory task. Thus, stimuli that differ in degree of salience and perceptual features will activate different kinds and degrees of attributes in memory. For example, stimuli that are low in contextual detail, will evoke less activation, compared with stimuli with higher amounts of detail and will therefore be more susceptible to source forgetting. In line with the stronger levels of processing effects for words than for faces, it has been suggested that pictures drive a rich and elaborate encoding automatically (Craik & Jennings, 1992). If older adults have a tendency to encode information with less elaboration and distinctiveness than younger adults (Rabinowitz & Ackerman, 1982; Rankin & Collins, 1985, 1986), this deficit might be compensated for by using items rich in features.

A further issue of interest is whether proficiency in source memory may be dissociated from item memory performance (Schacter, Osowiecki, Kaszniak, Kihlstrom, & Valdiserri, 1994; Schacter, Harbluk, & McLachlan, 1984). Experimental evidence clearly indicates that old adults exhibit source memory deficits, and raises the possibility that memory for source may be selectively disrupted by aging. In other words, is the age difference in remembering source separate from the age difference in remembering items and is source memory affected more by aging than is item memory? A finding of age-related source memory deficits together with impairments in item recognition may suggest that poor source memory is simply an expression of a generalized episodic memory impairment. Evidence for both positions has been obtained. Several studies have indicated parallell deficits in item and source memory on the part of older adults (Cohen & Faulkner, 1989; Hashtroudi, et al., 1989; Rabinowitz, 1989), whereas other studies indicate that elderly adults may exhibit source memory deficits that are disproportionate to their item memory performance (Erngrund et al., 1996; Ferguson et al., 1992; Schacter et al., 1991; Schacter et al., 1994). To understand why older adults in some situations, but not in others, exhibit selective source memory impairments is a topic that needs further exploration.

LONG-TERM OLFACTORY MEMORY

The Olfactory Sensory System

The olfactory pathways constitute a rather small part of the human brain, and olfaction is undoubtedly of less clinical significance than vision and hearing. Nevertheless, the olfactory sensory system is of great importance in our everyday lifes. It plays a critical role in food intake, because, together with taste, it determines the flavor or aroma of the food. The use of perfumes, cosmetics and the disguise of unpleasant body odors reflect the social implications of odors. The olfactory system also plays an important role as a warning system for certain toxic gases and contaminated food.

The portions of the brain that process olfactory information are among the brain's oldest structures. In fact, it has been shown that the structures that once subserved olfaction later evolved into the limbic system which mediates emotions and other aspects of human behavior (Guyton, 1991). Further evidence of the antiquity of the olfactory system is its structural simplicity (Stoddart, 1984). Only two synapses separate the olfactory nerve from the amygdala, which is critical for the expression of emotion and human emotional memory (Aggleton & Mishkin, 1986; Cahill, Babinsky, Markowitsch, & McGaugh, 1995). Three synapses separate the olfactory nerve from the hippocampus, which is heavily involved in various memory functions (e.g., working memory, long-term memory). No other sensory system has this direct connection with the basic neural substrates of emotion and memory; this may explain why autobiographical odor-evoked memories often are emotionally loaded.

The exact manner of the operation of the smell-processing system is still poorly understood. The general picture of its functioning is, however, more clear. Odorous molecules are detected when they reach the olfactory membrane, or epithelium, which lies in the superior part of each nostril. The axons of the receptor cells collect into small bundles and enter the brain cavity through the fine holes in the cribiform plate which separates the nasal cavity from the brain cavity. The bundles of axons enter the olfactory bulb, which is also called cranial nerve I, and are conveyed to a number of cortical structures which may be referred to as the olfactory cortex (Berglund & Lindvall, 1982; Guyton, 1991). Unlike other neurons of the adult central nervous system, olfactory neurons are replaced normally and following injury. This neural plasticity, with regeneration and degeneration of olfactory neurons, follows a periodicity of just about 30 days. The regenerated nerve cells not only form anatomical connections but also reestablish function (Graziadei & Monti Graziadei, 1978). The constant regeneration of nerve cells in the olfactory system has therefore been considered as an ideal model system for studies of neurogenesis, development, and regeneration in the vertebrate central nervous system (Morrison & Costanzo, 1992).

In addition to the olfactory neurons, the nasal mucosa is also innervated by free nerve endings of the trigeminal receptors connected to the fifth cranial nerve. Trigeminal receptors respond to potentially harmful chemicals, such as ammonia. Whether or not trigeminal stimulation is annoying depends on the strength of and prior exposure to the odorant. In low or moderate concentrations, trigeminal stimulation may not be experienced as unpleasant (Engen, 1982). The primary function of the trigeminal system is to elicit avoidance reactions because of certain odor's irritating qualities. This makes good adaptive sense, because such odors are often highly toxic. Although a person may have lost his or her sense of smell, the trigeminal system remains, but olfactory perceptions will be altered and unfamiliar (Engen, 1991).

Other examples of the singularity of the olfactory system is that the olfactory receptors are the only CNS neurons directly exposed to the environment, and that the neurons are unmyelinated. The neurons are also among the smallest in the body, which may underlie the fact that the olfactory system is our slowest sense. Visual detection takes about 45 msec (Robinson, 1968), whereas odor detection takes 400 msec and recognition about 600-800 msec (Herz & Engen, 1996; Laing & MacLeod, 1992).

In the next sections, I will provide a brief review of the scientific knowledge available on human long-term olfactory memory. I will highlight the relationship to current memory theory, and finally review the age-related cognitive changes that do occur in the olfactory sensory system.

Episodic and Semantic Memory in Olfaction

Tulving's (1972, 1993) distinction between episodic and semantic memory has proved to be a useful tool in understanding olfactory cognition. The two main tasks used in the study of odor memory are odor recognition and odor identification. The former task is related to episodic memory, whereas the latter taps semantic memory functions.

In a typical odor recognition memory experiment, the subject is exposed (with incidental or intentional instructions) to a number of odors, and later asked to recognize the target odors in the context of new odors (distractors).

Semantic memory in this context refers to a subject's general knowledge or experience with a specific odorant, and is exemplified in odor identification and familiarity ratings. The concept of olfactory knowledge may be viewed as a continuum of informational specificity (Schab, 1991). At the most primitive level, olfactory experiences are subject to ratings of hedonic qualities (e.g., I like this smell) or of familiarity (e.g., I have smelled this before). At the next higher level, the smeller is able to describe the odor in general and adjective terms (e.g., spicy and dark). The next step involves even more specific knowledge but without being able to produce the odors' name (e.g., christmas attribute), which is followed by the highest degree of informational specificity where the subject is able to retrieve the name of the odor (e.g., cloves).

Odor Identification

It is widely accepted that naming odors spontaneously is a difficult task. In normal subjects, it is common to smell an odor and to recognize that it is familiar and belongs to a general class or category, but still being unable to produce a specific label. Lawless and Engen (1977) described this as the "tip-of-the-nose" phenomenon, that is, as the olfactory analog to the tip-of-the-tongue state (Brown, 1991; Brown & McNeill, 1966). However, in contrast to the latter, persons in the tip-of-the-nose state typically cannot answer any questions about the name of the odor, such as the initial letter, the number of syllables, or the general configuration of the word. Subjects can, however, answer questions about the odor's quality, such as its taxonomic category or say something about objects associated with it (Lawless & Engen, 1977).

Although humans in general are sensitive in detecting odors, and can discriminate among hundreds of odors in side-by-side comparisons (Doty, 1992), our ability to identify an odor verbally is extremly limited. Reviews indicate that unaided free identification of odors by young laypersons varies between 22-57%, with set sizes ranging from 7 - 80 items (e.g., Cain, 1979; Chobor, 1992; Richardson & Zucco, 1989). Even everyday odors, which are highly overlearned (e.g., chocolate), may prove extremely difficult to name.

Odor identification abilities are also assessed through multiple-choice test procedures (e.g., Doty, Shaman, & Dann, 1984; Doty, Frye, Agrawal, 1989). In these tests, response alternatives are presented verbally, one target in conjunction with a number of foils. Not surprisingly, subjects perform better in multiple-choice tasks than in free odor identification. This superiority is presumably related to lessened cognitive demands. The provision of label alternatives reduces the effort an individual has to invest in searching for an appropriate label, and thus, a multiple choice test may be regarded as more supportive. However, it is important to note that identification performance will vary as a function of foil selection. Engen (1987) showed that with highly dissimilar foils (e. g., pizza, turpentine, clove for the target grape), performance reached 93% correct identification. However, if the foils were selected as highly similar to the target (e. g., melon, strawberry, plum), identification dropped to about 50% correct. This outcome suggests that poor odor identification may stem from problems in selecting the correct label from a number of related alternative labels.

As stated above, young healthy subjects can typically name about half of a set of odors with precision in free identification. For the other half, subjects may emit labels that are reasonably good approximations to the target label (e.g., lemon for orange), surprisingly poor labels (soap for tuna fish), or simply fail to emit any verbal description of the odor. Although it may seem like a minor error to call the odor of orange for lemon, such an error, if presented with an orange visually, would seem large indeed (Schab & Cain, 1991).

Two major factors have been proposed to account for the difficulty in retrieving the association between an odor and its lexical representation. In an experiment performed by Cain (1979), it was shown that subjects' identification performance was highly sensitive to feedback of the odor names. Across three trials perfomance improved from 45% to approximately 90%. This outcome suggests that given a supportive environment, subjects are able to efficiently utilize their semantic knowledge, and that proficiency in odor identification is highly modifiable. Engen (1987) proposed that an inherently weak connection between language and olfactory processes causes the temporary blockage of retrieval of well-learned olfactory information. Findings of fast re-learning once a veridical label is offered, and that people have little difficulty in retrieving the names of corresponding objects to odors, suggest a weakness specifically related to odor-name associations.

A second factor that may explain the impoverished ability in odor identification has been proposed by Cain and his colleagues (Cain, 1979, Cain & Potts, 1996; Schab & Cain, 1991). These investigators argued that misidentification may be related to misperception. Specifically, the claim is that odor identification is heavily dependent upon odor discrimination ability. Thus, errors in identification may arise from failures in discrimination. For example, if a person calls the odor of orange lemon, was the odor then really perceived as lemon? The important point here is that poor identification could have a perceptual origin. This is an important point, because most studies focused on odor identification have neglected the potential influence of the discriminative dimension in odor perception, and its relationship with performance in identification.

Odor Familiarity

Another aspect of semantic knowledge of odors is exemplified by the perceived familiarity of the olfactory experience. In contrast to identification measures, this parameter makes no demand of explicit verbal characterizations. Typically, familiarity is assessed using scales in which subjects are instructed to rate the perceived familiarity (from low to high) of a given odor.

Both familiarity and identification tap reservoirs of prior knowledge about odors. However, whereas the identification task requires the subject to emit a verbal descriptor of the odor as a means of assessing the presence of semantic processing, familiarity ratings only require the smeller to mark the corresponding perceived familiarity. In this sense, level of familiarity may be regarded as a continuum covering the subject's implicit level of odor knowledge. A low familiarity rating may reflect an extremely vague perception, with no distinct semantic cues elicited by the olfactory experience. A medium rating may involve moderately meaningful associations, whereas a high familiarity rating presumably reflects the experience of having access to more specific knowledge about the odor. Occasionally, a high familiarity rating may simply reflect the knowledge of the odor name, which would make this measure equivalent to identification. This is presumably true in some cases, but considering the high amount of tip-of-the-nose states for olfactory stimuli, an item rated as highly familiar may truly reflect access to a more general or idiosyncratic knowledge of the odor, such as belonging to a specific food category (e. g., the spice you find in pizzas), or referred to as an odor that "I felt in Paris in that specific corner."

Episodic Odor Recognition

Earlier work on olfactory memory indicated that odors that were successfully encoded showed relatively slow forgetting, possibly because of a negligible impact of retroactive interference (e.g., Engen, 1987; Engen & Ross, 1973; Lawless & Cain, 1975). Based on the rather flat forgetting function, it was assumed that odors are encoded as unitary perceptual events. Typical findings in these studies were imperfect initial encoding, little subsequent forgetting, and no effects of familiarity and identifiability. Engen and Ross (1973) showed that subjects recognized only 75% of the studied odors in immediate recognition. However, performance only dropped to 65% after 1 month and remained above chance even after 1 year. A similarly flat forgetting function was obtained by Lawless and Cain (1975), who reported an immediate recognition performance of 85% which declined to 75% over a span of 28 days. Over a 6-month period, Murphy et al. (1991) reported that odor memory declined only slightly in a group of young adults, but this study also indicated that the retention for faces and symbols remained about the same over the same time period.

However, more recent data are at variance with the view of odors as impervious to forgetting, in showing significant odor forgetting for odors across relatively brief retention intervals (Cain & Murphy, 1987; Perkins & Cook, 1990). Also, significant forgetting has been shown to occur with verbal suppression techniques, which suggests that odors may not be represented as holistic, unitary percepts in memory which are resistant to interference and forgetting (Perkins & Cook, 1990).

As noted in the introduction, not many studies have focused on memory for odors as compared with stimuli encoded through our other senses. As a result, it is largely unknown whether episodic memory of odors operates according to the same principles as episodic memory for information acquired via other modalities.

The Relationship Between Olfactory Knowledge and Episodic Odor Recognition

The dominant assumption made in earlier work has been that odors are encoded perceptually as relative featureless stimuli and that semantic or verbal factors play little or no role in episodic odor recognition (Engen & Ross, 1973; Larjola & Wright, 1976; Lawless & Cain, 1975; Lawless & Engen, 1977). Engen and Ross (1973) provided subjects with correct labels of the odors during encoding and found no evidence of better subsequent recognition performance as compared with odors presented without labels. Likewise, Lawless and Cain (1975) instructed their subjects to name odor stimuli with personally meaningful descriptors at study, and found no benefit of this instruction in recognition memory. Taken together, these experiments suggest that the representations of odors in memory do not involve semantic information.

However, this view has been challenged in more recent work showing that familiar and identifiable odors are better remembered than are unfamiliar and less identifiable odors (see Schab & Crowder, 1995, for a review). For example, Rabin and Cain (1984) demonstrated a strong relationship between a subject's knowledge about an odor and the ability to recognize it in a subsequent recognition memory task. Specifically, these authors found that rated familiarity and label quality were positively related to recognition performance. Memory performance increased as a function of the quality of the label emitted for the odorants, that is, memory was poorest for odors to which far misses had been generated, slightly better for identifications defined as near misses, and highest for odors that had been correctly named. Furthermore, Walk and Johns (1984) reported that interference from interpolated events may occur in odor memory. In this study, recognition performance was poorest when subjects free associated to an additional odorant during the retention interval, whereas recognition was highest when subjects free associated to the name of the target odorant during the retention interval. In another study, the effects of visual suppression, verbal suppression, and combined suppression were examined in retention of olfactory information (Perkins & Cook, 1990). Overall, the results indicated that performance was lower in the suppression groups relative to control groups. The verbal and the combined visual-plus-verbal suppressions were most detrimental to recognition performance, whereas visual suppression showed no effect on memory relative to a control condition.

Two important studies by Lyman and McDaniel (1986, 1990) provided evidence of the role of semantic activities at encoding in odor recognition performance. In their first study, subjects were instructed to generate (a) a visual image, (b) a name, and (c) a life episode, when smelling a set of common odors. As compared with a control condition, in which subjects were instructed to simply remember the presented odors, odorants that were named and associated with a significant life episode were shown to be best remembered after a 7-day retention period. In a follow-up study (Lyman & McDaniel, 1990), a similar pattern of results emerged. Here, odors were encoded with (a) a visual representation (photographs), (b) odor names, or (c) both. As compared with a control condition, performance after a 1-week interval was higher for elaborated odors, and combined visual and verbal elaboration produced the highest recognition performance. To summarize, these studies indicate that episodic recognition for common odors may be mediated by semantic factors.

Aging and the Olfactory Sensory System

It is well established that aging is accompanied by a decline in smell functioning (see Murphy, 1995; Schiffman, 1992 for reviews). A distorted sense of smell alters adversely the flavor of foods and beverages, with increased nutritional risks in the elderly (Ferris & Duffy, 1989; Griep et al., 1995). It may also increase the chance of accidental poisoning from toxic fumes and spoiled food (Chalke & Dewhurst, 1957). The underlying causes of the age-related smell loss are multifactorial and several candidates have been proposed (see Schiffmann, 1992, for a review). Unfortunately, the extent to which age-related changes in olfactory abilities is related to the aging process per se, or to changes brought about by other factors correlated with age, is unknown.

A number of extrinsic and intrinsic factors related to aging-related olfactory dysfunction have been identified. It is well established that viral infections affect the sense of smell negatively. A culmination of repeated viral insults collected during the life span and/or an age-related lack of resistance to viral insult may cause damage to the olfactory epithelium (Doty & Snow, 1988; Murphy, 1985). A diminished sense of smell may also be related to calcification of the cribiform plate (Krmpotic-Nemanic, 1969). Apposition of bone around the cribiform plate openings in which the olfactory neurons pass, may result in degeneration of the primary olfactory neurons. Other factors that may contribute to smell losses are head trauma (Costanzo, Ward, & Young, 1992; Murphy & Davidson, 1992; Potters & Butters, 1980; Sumner, 1964), drugs (see Schiffmann for a review, 1992), neurological diseases (Nordin, Paulsen, & Murphy, 1995; Ohm & Braak, 1987; Reyes, Deems, & Suarez, 1993), and exposure to toxic substances (Naus, 1976; Schiffmann, 1983). In addition to the factors noted above, anatomical and neurophysiological changes associated with the normal aging process may produce structural alterations in the olfactory epithelium and morphological alterations in the olfactory bulb (Dodson & Bannister, 1980; Hinds & McNelly, 1981).

Aging and Odor Memory

Age-related impairments in various sensory and cognitive aspects of olfactory functioning have been observed. Older adults exhibit a lower sensitivity for odors, as reflected in absolute threshold measurements (Kimbrell & Furchtgott, 1963; Murphy, Nunez, Withee, & Jalowayski, 1985; Van Toller, Dodd, & Billing, 1985), and in intensity measures of suprathreshold odors (Stevens, Plantinga & Cain, 1985; Stevens & Cain, 1985). Likewise, older adults' recognition memory for odors is poorer than that observed in young subjects (Cain & Murphy, 1987; Murphy et al., 1991). There is evidence that age differences in recognition memory for odors may be influenced by the passage of time, such that olfactory forgetting is faster in old relative to young age (Murphy et al., 1991). However, other research demonstrates similar odor forgetting rates for young and older adults (Stevens, Cain, & Demarque, 1990). The ability to name or identify odors also deteriorates with advancing age. This is true for both free identification measures (Schemper, Voss, & Cain, 1981; Stevens & Cain, 1987), and in tasks where multiple choices of possible odor names are available, like the University of Pennsylvania Smell Identification Test (UPSIT; Doty et al., 1984; Ship, Pearson, Cruise, Brant, & Metter, 1996).

The National Geographic Smell Survey, which included 6 common odorants, and was conducted on a highly selected sample (i.e., those readers of the National Geographic Magazine who chose to return the survey) replicated earlier findings of age-related deficits in olfactory functioning. People over 60 years of age exhibited more difficulties in detecting the odor samples and particularly in identifying the odors relative to younger cohorts. Moreover, strong effects of gender were found, such that women outperformed men across all age groups (Wysocki & Gilbert, 1989).

Whereas age-related increments in thresholds and lower ratings in suprathreshold intensity for older adults most likely reflect a sensory impairment, age decrements in recognition memory and identification of odors may have both sensory and cognitive origins. A person who exhibits lower olfactory sensitivity will perceive an odor as weaker and consequently find it harder to identify and recognize. An important research issue has therefore been to establish whether the observed age-related deficits in odor recognition and identification are caused by elevated detection thresholds (Cain & Gent, 1991; Van Toller et al., 1985) and/or cognitive changes (Murphy et al., 1991; Schemper et al., 1981). Recent research suggests that age-related deficits in odor recognition and odor identification may largely be attributable to cognitive limitations.

Murphy et al. (1991) compared young and elderly adults in recognition memory for graphic stimuli (i.e., presidents, engineering symbols, free forms) and common odors. Performance was assessed 15 min., 2 weeks, and 6 months after inspection. The results indicated that elderly adults' memory for odors were selectively impaired relative to the other stimuli and fell to chance level after the first test, although their memory for graphic information remained well above chance across all measurement points. By contrast, the young subjects forgot both olfactory and graphic information progressively, although their performance stayed above chance over the 6-month period for both types of materials. As expected, odor thresholds were negatively affected by age. Specifically, threshold and age together explained 44% of the variation in the dependent measure, suggesting that poorer olfactory sensitivity in the elderly underlies some proportion of the age decline in recognition memory performance. Besides the influence of sensory acuity, subjects' task-relevant prior knowledge, as assessed by means of familiarity ratings and the ability to name the odors, were positively related to odor memory performance. Unfortunately, the semantic memory data were not analyzed with regression techniques, and thus, the explanatory power of these variables as compared with the contribution from sensory acuity and chronological age is unknown. In sum, these results suggest that age-related differences in odor recognition are related to decrements in olfactory sensitivity, but may also be related to the amount of prior knowledge possessed of the odorants.

With the exception of a recent study by Ship et al. (1996), there are no published longitudinal data assessing olfaction in adulthood. Ship et al. examined the influence of age and gender on smell identification over a 3-year period in a group of generally healthy men and women. The study group (n=161) ranged between 19 and 95 years of age, and were tested on their ability to identify a set of common odors using the UPSIT test. The findings confirmed and extended earlier results from cross-sectional studies: The ability to identify common odorants deteriorated with increasing age also in the absence of overt medical problems. Of further interest is that the longitudinal findings suggest that men experience a more precipitous and earlier decline in smell identification than do women. More specifically, males declined significantly in identification performance already at the age of 55 years, whereas this decrement was not evident in women until the age of 75 years. This finding suggests that the pattern of smell deterioration varies as a function of gender, and that olfactory dysfunction is delayed by approximately 20 years in women. Moreover, women outperformed men in nearly all age groups, indicating a general female superiority in olfactory functioning across the human life span. This result fits nicely with results obtained in cross-sectional studies (e.g., Doty, Shaman, Applebaum et al., 1984; Ship & Weiffenbach, 1993), and in different cultural groups (Doty et al., 1985).

RESEARCH OBJECTIVES

Based on the foregoing review, I examined potential age-related differences in episodic memory performance and the ability to make use of cognitive support in young and old adults in five separate studies. The main focus of interest was put on olfactory memory and source memory. Manipulations of the degree of cognitive support involved experimenter-provided guidance at encoding (i.e., organizational instructions, a blocked presentation format, activation of prior knowledge), provision of information varying in degree of salience (e.g., words, objects), and cues provided at the time of retrieval (e.g., category cues, copy cues). Furthermore, the importance of various subject-related factors as related to performance in episodic memory tasks were taken into account (i.e., proficiency in semantic memory). The main objectives in the studies that form the basis of this doctoral thesis were to examine:

(1) Recall performance as a function of age, item richness, and experimenter-provided support at encoding and retrieval (Study I)

(2) Source memory for externally derived information differing in degree of salience and modalities engaged at acquisition. Of further interest was to investigate whether elderly adults are selectively penalized in source memory tasks relative to item memory tasks (Study II and III);

(3) Episodic recognition memory for common odors as a function of age and time of testing (Study III, IV, and V);

(4) The relationship between various semantic memory functions and episodic recognition of odors (Study V); and

(5) Older adults ability to utilize cognitive support in order to improve memory. Encoding support was provided in the form of organizational instructions (Study I), blocking (Study II), and activation of prior knowledge (Study IV). Retrieval support was provided in terms of semantic category cues (Study I) and copy cues in recognition (Study II, III, IV, and V). Furthermore,

episodic memory performance as related to the richness of the materials and age was examined (Study I, II, and III).

STUDY SAMPLES

The results in the present thesis are based on studies using a cross-sectional design. The participants were recruited through advertisements in daily newspapers, senior citizens organizations, and adult education centers.

All subjects were interviewed as to their perceived state of health, and background data concerning history of critical conditions and medications that might have adverse effects on cognitive and memory functioning were collected. Individuals with health problems that could potentially interfere with cognitive performance were excluded. This included the presence (or reported recent history) of stroke, psychiatric illness, neurological disease, and sensory disabilities (hearing and eyesight problems). In Study III, IV, and V, subjects presenting with hyposmia (decreased olfactory sensitivity) or anosmia (inability to detect any odor sensation) were excluded.

As noted earlier, factors other than chronological age may influence performance in episodic memory tasks. For example, level of formal education and proficiency in vocabulary have shown to be positively related to episodic memory performance (e.g., Bäckman & Wahlin, 1995; Inouye et al., 1993; Nyberg et al., 1996; West et al., 1992). Consequently, participants in Studies I-IV were matched on these variables.

In all studies, with the exception of Study II, females served as participants. In Study I, this resulted from problems in recruiting large enough groups of men in the oldest cohort. Furthermore, pilot testing in Study IV indicated that males, in general, and older males in particular, exhibited extreme difficulties in naming the set of odors used. Beside the expected outcome of a female superiority in odor identification, I discovered that some males were unable to identify the odors, because of true lack of knowledge of the odor names. By natural reasons, most of the test items could be found in the kitchen area. In older age cohorts, males may not have had equal experience of these items as have males in younger age cohorts. Therefore, in order to avoid a potential gender x age cohort effect in odor identification due to selection of the test items, I decided to exclude males in the studies involving olfactory stimuli (i.e., Study III, IV, and V).

OVERVIEW OF STUDIES

STUDY I

(Bäckman & Larsson, 1992)

The purpose of this study was to further our knowledge of the relationships between different forms of cognitive support and episodic memory performance across the adult life span (Bäckman, 1989, 1995; Craik, 1985; Craik & Jennings, 1992). Three groups of normally aged women: young-old (mean age = 66 years), old (mean age = 75 years), and old-old (mean age = 84 years) adults together with a young control group (mean age = 27 years) studied lists of organizable words and objects. The materials were encoded with either standard instructions (SI) or organizational instructions (OI). Three types of memory tests were used: immediate free recall, delayed free recall, and delayed cued recall. Hence, the level of cognitive support provided varied in terms of the materials (objects are richer in terms of features than are words), encoding activities (OI involve more learning support than SI), and testing conditions (cued recall involves more retrieval support than free recall). The delayed free recall test was included in order to evaluate possible effects of passage on time on performance in the various conditions.

Perhaps the most important finding in this study was the triple interaction found among age, the nature of materials, and the level of retrieval support. In word recall, cue benefits were equal across age groups, whereas cue benefits increased gradually with increasing age in object recall. Stated somewhat differently; for all older age groups, performance gains from the provision of retrieval cues were greater for objects than for words, although this was not true for young adults. This suggests that younger adults' encoding of the words may have been more elaborate than that of the older age groups, which is consistent with the notion of age-related deficits in self-initiated recoding operations (e.g., Bäckman, 1985; Craik & McDowd, 1987). As a result, the need of cognitive support at encoding and retrieval increased with increasing age.

The effects of the manipulation of learning instructions also indicated an age-related increase in the level of support required in order to improve memory. The young and young-old age groups did not show any improvement following OI as compared with SI; the old adults showed a tendency of an improvement, whereas the old-old adults performed reliably better with OI than SI. This indicates that guidance at encoding, at least in the form of organizational instructions, was rather redundant in all age groups studied, except the oldest. The drop in performance from immediate free recall to delayed free recall for both materials was less pronounced for young adults relative to the three older age groups, suggesting age-related increases in forgetting rate (Giambra & Arenberg, 1993).

Objects were better remembered than were their corresponding words. In a study involving young subjects, Gollin and Sharps (1988) found that blocking affected word recall but not object recall. Although the present study used a weaker encoding manipulation (instruction to organize the items in terms of semantic categories), this manipulation affected word recall, but not object recall. These findings may be interpreted such that objects are sufficiently rich and elaborated in themselves for instructions to give any additional memory advantage. Words on the other hand, involve less visual detail and are therefore more susceptible to the memory advantage afforded by organizational instructions.

Taken together, this research indicated that with increasing age there seems to be an increase in the level of support required in order to improve episodic memory functioning.

STUDY II

(Larsson & Bäckman 1994)

The main aim of Study II was to examine item memory and source memory for externally derived information. A number of studies focusing on external source monitoring have indicated that older adults exhibit greater difficulties than younger adults to specify the origins of memory representations (e.g., Hashtroudi et al., 1989; Schacter et al., 1991). Explanations given to the observed age-related deficits in external source monitoring are that older adults fail to engage in a distinctive encoding (Kausler & Puckett, 1981; McIntyre & Craik, 1987) and have trouble utilizing organizational processing efficiently (Dywan & Jacoby, 1990).

Groups of young (mean age = 25 years), young-old (mean age = 66 years), and old (mean age = 75 years) adults learned three types of organizable materials differing in degree of salience and modalities engaged at acquisition; words, objects, and subject-performed tasks or SPTs. The TBR information was presented randomly or blocked by semantic category. Item memory and source memory were assessed. In the source memory test, subjects were presented with targets and distractors which were selected such that they belonged to the same semantic categories as the targets. On a verbal response sheet, subjects were instructed to cross one of four alternatives; word, object, SPT, or new.

Item memory (d') decreased gradually as a function of age. Young adults recognized more items than did the young-old adults, who in turn recognized more items than did the oldest adults. Replicating the finding in Study I of better retention for more elaborated materials, the present results indicated that the materials high in visual detail (objects and SPTs) were better remembered than were words (Gollin & Sharps, 1988; Spoehr & Lehmkule, 1982). In agreement with the notion that older persons' have greater difficulties to elaborate on materials low in features (Bäckman, 1985), younger adults proved to remember more of the word items than did both groups of older subjects. In a similar vein, false alarms were more often attributed to words than to objects and SPTs and this response pattern was most pronounced among the oldest participants. The richer and more distinctive traces produced by objects and SPTs relative to words may be an important reason for that false alarms were more often attributed to words than to the other materials.

As expected, there was a gradual increment in source error rate with increasing age (e.g., Ferguson et al., 1992; Hashtroudi et al., 1989). Irrespective of age, confusions were more frequent for SPTs than for objects and words. The number of confusions related to words and objects did not differ. Source confusions were predictable from the degree of structural similarity among materials. Words, which were visually and orally presented, were most often confused with objects, which involve a higher degree of visual detail, but lack the extra motor component present in the SPT task. For all age groups, objects were most often confused with SPTs than with words. This may be related to that the shared features for objects and SPTs (e.g., color, shape) are more difficult to differentiate, than those shared between objects and words (verbal descriptions). Finally, source errors for learned SPTs were more often attributed to objects than to words and, interestingly, the oldest persons proved to be selectively penalized with this materials as reflected in a disproportionally high source error rate to objects for SPTs.

In accordance with the results obtained in Study I, and as reported by Gollin and Sharps (1988), the hit rates indicated that words were more easily recognized following a blocked compared with a random presentation, whereas recognition of objects and SPTs did not benefit from this manipulation. This finding again indicates that guided encoding activities, such as organizational instructions and blocking, are less important for information which in itself is rich in features, whereas less detailed information benefit from these types of supportive encoding conditions.

Replicating the data reported by Schacter at al. (1991), the present study indicated no beneficial effects on source memory from presenting the TBR information blocked by semantic category and subsequent performance in any age group. This result questions the notion of an organizational deficit underlying age decrements in external source monitoring. Furthermore, this research indicated similar patterns of results in both item memory and source memory. For all age groups, the ability to recognize an item's previous exposure determined largely the ability to specify and differentiate between different external sources of information. This finding suggests that the mechanisms underlying proficiency in item memory and source memory may not be qualitatively different.

STUDY III

(Larsson & Bäckman, in press)

This study was designed to gain further knowledge regarding age differences in item and source memory as related to input modality. Information was presented in four modalities. Auditory information was presented in all four conditions. In one condition the information was presented auditorily only; in the remaining three conditions, visual, olfactory, and tactile information, respectively, were added to the auditory input. Based on some earlier findings indicating that processing of olfactory information may be more age sensitive than processing of visual and tactile information (Lawless, 1978; Murphy et al., 1991), we sought to generalize these findings across item and source memory. A further aim was to examine whether older adults would exhibit selective source memory deficits relative to item memory performance. Groups of young (mean age = 25 years), young-old (mean age = 66 years), and old (mean age = 75 years) adults were presented with a mixed-modality list of items, and were later asked to verbally recognize these items and to specify the modality in which they were perceived. Memory was assessed immediately after and 48 hours after study. In this way we could evaluate potential effects of time on memory for these materials and whether these effects varied across the age groups.

The results indicated an age-related impairment in both item memory and modality memory (e.g., Hashtroudi et al., 1989). The pattern was consistent across both measures: young-old and old adults did not differ in any of the measures, whereas young adults generally outperformed both older age groups. Auditory items were less well remembered than were olfactory items, which in turn proved more difficult to recognize than visual and tactile items. In addition, forgetting rates from immediate to delayed testing were more pronounced for auditorily and olfactorily presented items, as compared with visual and tactile items. These findings are consistent with the view of a positive relationship between the degree of richness of the stimulus input and memory performance (Paivio, 1986; Park, Puglisi, & Smith, 1986).

Inspection of the source memory data yielded a somewhat different picture with regard to the effects of age and modality. Two significant triple interactions among age, modality, and time of testing indicated that both groups of elderly adults were especially penalized with auditory and olfactory information. Overall, subjects most often confused auditory items with olfactory items, but the number of confusions attributed to odors was higher in older than in young adults, and this age difference was exacerbated at delayed testing. A similar pattern of results was obtained for odors which were most often confused with auditory items, and both groups of elderly adults were more likely to attribute olfactory inputs to the auditorily modality at delayed testing. These findings indicate that distinctive and reconstructive processes related to auditory and olfactory information may be particularly difficult for older adults.

In agreement with some earlier findings, the present study also indicated that older adults were more impaired in source memory than in item memory (Ferguson et al., 1992; Schacter et al., 1991, 1994). It is important to note that older subjects were not selectively impaired for any materials in item memory. However, when recollection of source was required, both groups of elderly generated a disproportionate amount of errors for auditory and olfactory information. This outcome suggests that aging takes a particular toll in the processing of olfactory information and that such age deficits may be especially likely to occur when recollection of source is required.

STUDY IV

(Larsson & Bäckman, 1993)

This study specifically addressed episodic recognition for common odors in young (mean age = 25 years), young-old (mean age = 67 years) and old (mean age = 74 years) age. As noted, some early research in olfaction indicates that odors are encoded and stored as unique, nonlinguistic whole percepts, resistant to interference and forgetting (Engen, 1987; Engen & Ross, 1973). This view has been questioned in more recent research, indicating that verbal and visual elaboration techniques contribute additively to odor recognition performance (Lyman & McDaniel, 1986, 1990). The present study was designed in order to further examine whether semantic activation of odor names enhances subsequent recognition of the odors at the time of retrieval. Of interest was also to investigate whether older adults could compensate for their expected deficits in odor memory by activating their prior knowledge of the odors. The activation of semantic knowledge consisted of providing the corresponding names of the odors at study. Two control conditions were included: a name-only condition in which only the names of the odors were presented, and an odor-only condition in which the odors alone were presented.

In order to determine whether the degree of previous exposure was related to memory, subjects made familiarity ratings for all items at study. Due to possible age-related deficits in sensory acuity which may confound the memory data, all subjects were tested for intact olfactory sensitivity. Recognition memory was assessed immediately after and 48 hours after inspection. In the delayed recognition test, subjects were instructed to name all odors presented.

The results indicated that the young adults outperformed both groups of elderly adults in both odor recognition and odor naming, whereas the young-old and old adults did not differ in performance (Murphy et al., 1991; Schemper et al., 1981). These findings indicate that the ability to recognize common odors is rather stable from the seventh to the eighth decade in life, given that olfactory sensitivity is intact. In contrast to earlier findings that odors should be resistant to forgetting, this study indicated significant forgetting over a 48 hours interval (Lawless & Cain, 1975; Walk & Johns, 1984). The magnitude of decline across time was unrelated to age.

Providing the subject with the name of the odor at encoding, fostering a semantic elaboration of the olfactory information, resulted in better recognition compared with items encoded as names only or as odors only. For all age groups, recognition performance did not differ following name-only and odor-only presentation formats. An odor-name presentation, however, facilitated recognition to the same extent in all age groups. Lyman and McDaniel (1986, 1990) showed that the retention for olfactory information was higher following verbal referential processing at encoding in young adults. Our findings extend these results in demonstrating sizable performance gains when providing verbal labels also in young-old and old adults. These results also suggest that odor memory may show a similar plasticity as does memory for information encoded in other sensory modalities.

The most important finding in this study was perhaps that semantic knowledge of the presented odors was strongly related to performance in episodic odor recognition. Perceived familiarity of an odor bore a strong and positive relationship to subsequent performance in both immediate and delayed testing. This relationship was seen in all age groups. Furthermore, when controlling statistically for the age-related difference in odor naming, age differences in odor recognition were eliminated. This suggests that an important factor which underlies the observed age differences in episodic odor recognition may be the efficiency with which verbal representations of odors are accessed.

STUDY V

(Larsson & Bäckman, in press)

A number of studies focusing on verbal and visual materials have shown that episodic memory performance increases when the TBR information is semantically elaborated (e.g., Bäckman, 1991; Craik & Lockhart, 1972). These findings where generalized to olfactory information in Study IV which indicated beneficial retention effects with verbal-referential processing at encoding in all age groups. In related work, research has indicated that performance on tasks that may be subsumed under the concept of semantic memory, such as vocabulary and verbal fluency, are important predictors of episodic memory performance for verbal information in young and old adults (Craik et al., 1987; Zelinski, Gilewski, & Schaie, 1993).

An important finding in Study IV was that age differences in odor memory were eliminated when the ability to name the odors was controlled for. Therefore, a chief objective in Study V was to replicate and extend these findings. Specifically, we examined whether age-related differences in episodic recognition of common odors are related to general access problems in old age, or to more specific problems related to the accessibility of odor names. Tests of general access (fluency, vocabulary) were administered along with tests of access to specific semantic odor information (odor familiarity, odor naming). Also, we sought to replicate the findings of significant forgetting for olfactory information found in Study IV.

Young (mean age = 26 years), young-old (mean age = 66 years), and old (mean age = 74 years) women, screened for potential sensory losses, were presented with a series of common odors at encoding. Recognition memory was assessed immediately after and 48 hours after study. In conjunction with the presentation of odors at study, subjects rated their perceived familiarity of the odor sensation, and at delayed testing subjects were instructed to name the odors.

The results replicated nicely those obtained in Study IV. Both groups of elderly adults exhibited greater difficulties to remember the presented odors than did the younger adults. The young-old and old adults did not differ in performance. Significant forgetting of olfactory information was again observed, forgetting rates being equal across age groups. Interestingly, individual differences in fluency and vocabulary did not predict performance in odor recognition. Instead, odor memory was related to the subjects' specific semantic knowledge of the odors. Level of perceived familiarity of the odor and the accuracy in labeling the odors were strongly and positively related to episodic odor recognition. Extending the results from Study IV, regression analyses indicated that age and odor naming were the most potent variables in predicting both immediate and delayed odor memory. Again, controlling for odor naming resulted in the elimination of age effects, indicating the pivotal role of accessibility of odor names for successful odor recognition, and for age-related differences in odor recognition.

GENERAL DISCUSSION

The overall aim of this doctoral thesis was to investigate episodic memory in early and late adulthood. Of particular interest was to examine whether older adults could make use of different forms of cognitive support in order to improve episodic memory performance. In addition to item memory, memory for source and olfactory information were assessed. Manipulations of the degree of cognitive support included experimenter-provided guidance at encoding (i.e., organizational instructions, a blocked presentation format, activation of prior knowledge), the degree of salience in the materials (e.g., words, objects), and the presence of cues provided at retrieval (e.g., category cues, copy cues). Furthermore, the importance of various subject-related factors (i.e., proficiency in semantic memory) as related to episodic odor recognition was examined.

In this section, the main findings from the five studies will be discussed along some main lines of thought. First, I discuss some of the results pertaining to the observed relationships between aging, cognitive support, and episodic memory. Next follows an examination of the main results from the studies assessing source memory. Thereafter, a discussion on possible explanations of the observed age deficits in odor memory is provided along with a discussion of the impact of semantic memory on episodic recognition for common odors. Finally, some limitations in the interpretations of the obtained results are discussed, and suggestions for future research are provided.

Utilization of Cognitive Support in Episodic Memory

One of the major aims in the present thesis was to further our knowledge of the influence of various forms of cognitive support on episodic memory performance across the adult life span. Specifically, the focus of interest was to examine potential interactive relationships among age and other characteristics of the rememberer, the nature of the materials, the encoding and retrieval conditions (e.g., Craik & Jennings, 1992; Gollin & Sharps, 1988; Jenkins, 1979; Bäckman, 1991, 1996). In general, the results across Studies I-IV indicate that the ability to utilize the forms of support examined is preserved in old age. Overall, various supportive conditions at encoding (i.e., organizational instructions, a blocked presentation format, and activation of prior knowledge) yielded higher episodic memory performance, relative to conditions in which less support was provided. Also, and in line with previous findings (Bäckman & Nilsson, 1984; Gollin & Sharps, 1988; Murphy et al., 1991), the degree of richness inherent in the TBR information was positively related to memory performance: materials which were rich in features were better remembered than were materials low in detail. Furthermore, when retrieval support was provided in the form of category cues, elderly adults could use this additional information to enhance their memory performance.

The view of episodic memory as a context-dependent phenomenon was nicely illustrated in the results obtained in Study I. Here, recall performance proved to be determined by three interacting factors: age, the nature of the TBR information, and the level of retrieval support provided. Specifically, the results indicated that cue benefits were equal across age groups in word recall, whereas cue benefits increased gradually with increasing age in object recall. From a different perspective, in old age, performance gains from the provision of retrieval cues were greater for objects than for words, although this was not true for young adults. This outcome suggests that the importance of a rich stimulus input (i.e., objects) for efficient cue utilization may increase with advancing age (Bäckman, 1995). Thus, with increasing adult age, there may be an increase in the level of cognitive support required in order to optimize episodic remembering.

Further evidence of the plasticity of episodic memory was obtained in three of the studies (I, II, IV) in which the episodic information was encoded in conjunction with various forms of experimenter-provided guidance at encoding (i.e., organizational instructions, a blocked presentation format, and activation of task-relevant prior knowledge). Overall, all age groups benefited from the different types of encoding support provided. However, in Study I, the provision of explicit organization instructions at encoding yielded reliable performance increments in the old-old adults only. A slight tendency of memory improvement was observed in the old adults, although this tendency did not approach conventional significance. The young and young-old adults showed no sign of beneficial memory effects following instructions to organize, as compared with the condition in which standard instructions were provided. Thus, in the present context, instructions to organize the materials on the basis of semantic categories proved redundant in all age groups except the oldest. A likely reason thereof is that the two youngest age groups engaged in organizational processing following standard instructions to a greater extent than the two oldest age groups. Thus, this result is consistent with the notion that aging is associated with deficits in self-initiated cognitive operations (e.g., organization). This speculation is supported by the fact that the correlations between level of clustering and memory performance decreased with advancing age.

However, presenting the episodic information blocked by semantic category yielded parallell performance gains in hit rates across age groups in Study II. This indicates that subjects could utilize or were in need of this information in order to enhance their performance. A similar pattern of outcome was observed in Study IV, where activation of an odor's name yielded higher recognition performance in all age groups studied compared with a control condition involving odors only. Again, young and old persons benefited to the same extent from the provision of semantic support at encoding (cf. Bäckman, 1991; Hultsch & Dixon, 1983). Engen and Ross (1973) and Lawless and Cain (1975) showed that neither providing subjects with verbal odor labels or having the subjects generate odor names produced any advantage as to subsequent odor recognition. In contrast to these findings, the present results suggest that provision of odor names at encoding, which fosters a semantic elaboration of the odors, may result in better recognition as compared with items encoded in name-only or odor-only formats. In line with these findings, but using samples of young adults, Lyman and McDaniel (1986, 1990) reported higher recognition for odors encoded with verbal referential processing. Study IV extends these results in showing that beneficial effects from verbal labeling are present also in young-old and old adults. Based on these reports and the present findings, episodic recognition for common odors does appear to operate according to similar principles as memory for information encoded in other sensory modalities.

A popular notion with regard to olfaction is the durable nature of odor memory, and that odor memory, relative to memory for other types of information (e.g., visual) is so "good." It may be of interest to discuss the meaning of this notion. For instance, as illustrated in the recognition scores in Studies IV and V, d' values tend to be relatively low as compared with memory for other types of information. In a study by Bäckman (1991), recognition memory for contemporary and dated famous faces was examined in one group of young adults and three groups of older adults. Collapsing the d'scores over datedness and comparing these data with the d' scores obtained in Study IV (odor-only condition), it is obvious that odor recognition is substantially poorer relative to face recognition performance in young and old age ($young_{face}/young_{odor}$ = 2.84/2.14; $young\text{-}old_{face}/young\text{-}old_{odor}$ = 3.08/1.57; old_{face}/old_{odor} = 2.25/1.60. The same pattern is valid for the d' scores obtained in Study V, with even greater differences in the two older age groups. Of course, these studies are not completely comparable because of differences in methodological design. However, despite the facts that (a) the face memory task involved 60 items, whereas the odor memory task consisted of 32 items, and (b) the interval between study and test in face recognition was 20 min. as compared with an immediate assessment in odor recognition, retention for faces was considerable higher than for odors. These outcomes suggest that at least from a quantitative perspective, retention of olfactory information is poorer than retention of faces. Perhaps people's subjective experience of odors evoking strong memories concern recollection of single, distinct odors, or relate to that odors may trigger memories of unique events of emotional nature.

In congruence with other work (Gollin & Sharps, 1988; Paivio, 1986; Spoehr & Lehmkule, 1982), the richness of the stimulus input was positively related to memory performance. Across Studies I-III, objects were more easily remembered than were their corresponding words. Although potential effects may have been masked by ceiling effects, objects and SPTs were equally well recognized in Study II. Similarly, memory for auditory items was lower than memory for odors which, in turn, were more difficult to remember than visual and tactile items. In addition, more auditory and olfactory items, as compared with visual and tactile items, were forgotten from immediate to delayed testing. Interestingly, hit rates in Study III indicate that forgetting was less pronounced for tactually encoded items, as compared with forgetting rates observed in the other sensory modalities. This outcome suggests that tactually encoded information may be more resistent to forgetting as compared with other types of information.

It is noteworthy that instructions to organize the information by means of semantic categories affected immediate recall for words, whereas object recall proved unaffected by this manipulation (Study I). Similarly, and replicating earlier research by Gollin and Sharps (1988), a blocked presentation format in Study II affected hit rates for words, whereas this encoding manipulation was redundant for recognition of objects and SPTs. These outcomes may be interpreted such that visually detailed stimuli (e.g., objects and SPTs) are sufficiently rich and elaborate in themselves for instructions or blocking to give an additional memory advantage. Words, on the other hand, involve less visual detail and memorability, and are therefore more susceptible to the memory advantage afforded by directed encoding instructions and a blocked presentation format.

Finally, it is of interest to view the observed age patterns concerning the relationship between degree of cognitive support and episodic memory in the five studies in light of relevant prior research. As noted, the extant literature is populated with studies that show (a) a selective increase in memory performance of older adults following the provision of cognitive support (Bäckman, 1986; Craik & McDowd, 1987); (b) parallel gains in young and older adults following cognitive support (Park et al., 1990; Rabinowitz & Craik, 1986); and (c) a selective increase in memory performance of young adults from cognitive support (Kliegl et al., 1989; Puglisi & Park, 1987).

It is perhaps debatable whether the present studies bring new clarity to the complexities embedded in the relationship among aging, cognitive support, and episodic memory. However, three points are noteworthy. First, the dominant outcome in the present research was that all age groups examined benefited to the same extent from supportive conditions at encoding. Such parallel gains across age were observed with regard to the effects of (a) blocked presentation of organizable items (Study II), (b) richness of materials (i.e., objects and SPTs vs. words) concerning overall recognition accuracy (d'; Study II), (c) richness of materials (i.e., visual+auditory and tactile+auditory inputs vs. olfactory-auditory and auditory inputs) on item recognition (Study III), and (d) activation of prior knowledge (i.e., provision of odor names and perceived familiarity) and odor recognition (Study IV).

There were two exceptions to this pattern of parallel gains from cognitive support across age. First, as noted above, performance benefits from receiving cognitive support at both encoding and retrieval (i.e., a rich input+category cues) increased with age (Study I). Second, in Study II, age-related differences in recognition were more pronounced for words than for objects and SPTs as far as hit rates were concerned (Study II). However, the latter finding must be interpreted cautiously, given that this age-differential pattern was not seen with regard to the d' scores.

In general, then, the pattern of outcome from this research is consistent with the view that adult age has negligible effects on performance gains from cognitive support. Reviewing the relevant studies that have appeared in the literature in recent years this, indeed, seems to be the most common outcome. Thus, the present research provides only limited evidence for the notion that older adults are capable of compensating for deficits in episodic memory through the provision of cognitive support, and no evidence whatsoever that normal aging would be associated with deficits in utilizing cognitive support for improving episodic memory.

External Source Monitoring and Aging

Although both studies addressing source memory in this thesis (Study II and III) suffer from severe ceiling effects with restricted ranges of variation, many of the experimental manipulations were still reliable. In agreement with earlier findings, the results from both studies indicate that both memory for items and external sources deteriorate as a function of age (e.g., Hashtroudi et al., 1989, 1990; Spencer & Raz, 1994).

In Study III, elderly adults were not selectively impaired for any type of materials in item memory. However, when recollection of source was required, a different pattern emerged. Overall, olfactory items were most often confused with auditory items, but the number of confusions attributed to auditory items was higher in young-old and old adults than in young adults, and this age difference was exacerbated at delayed testing. The reverse was true for auditory items which were most often confused with odors, and both groups of elderly adults were particularly likely to attribute olfactory inputs to the olfactory modality at delayed testing. These deficits may be related to a failure in older adults to integrate specific cognitive and semantic aspects present in perceptual odor information (Murphy et al., 1991). In sum, the outcome of Study III suggests that aging may take a particular toll in the processing of olfactory information, and that such age deficits may be especially likely to occur when recollection of source is required.

Irrespective of whether or not subjects were presented with the information blocked by semantic category, proficiency in source memory remained at the same level. This was true for all types of materials and across age groups. This outcome is in agreement with data reported by Schacter et al. (1991) and questions the importance of an organizational deficit as a factor underlying age decrements in source monitoring.

Evidence is mixed regarding whether source memory is selectively impaired in aging relative to item memory. Some studies indicate parallel age deficits in item memory and source recollection (Hashtroudi et al., 1989; Rabinowitz, 1989), whereas others report exacerbated age differences when recollection of source is required (Erngrund et al., 1996; Ferguson et al., 1992). In Study II, strong positive correlations between item memory and source memory performance were obtained, indicating that, for all age groups, the ability to recognize item information determined largely the ability to specify and differentiate between different sources of information. This finding suggests that similar mechanisms may underlie the observed age deficits in item memory and source memory. Likewise, a gradual deterioration in both item and source memory across age groups was observed in Study III and, in congruence with some other work (e.g., Erngrund et al., 1996), source memory was selectively disrupted by aging. That is, older subjects had a higher tendency to forget the source of information even when the item itself was retained.

It is important to note that although source memory showed greater age effects as compared with item memory in Study III, it may not necessarily imply that the two types of memory draw on qualitatively different processes. Old-new recognition and source memory tasks require different degrees of differentiation, such that source monitoring processes incorporate and require more complete and differentiated information than does item recognition (Johnson et al., 1993). Relatedly, McIntyre and Craik (1987) proposed that encoded information may be viewed as being processed over a continuum of informational specificity, going from specific knowledge of the event itself (i.e., source memory) through remembering that the event happened although you cannot tell when or where (i.e., item memory), to knowing the fact without no recollection of contextual detail (i.e., the information has been transformed into semantic knowledge). Thus, the finding that older adults in the present research were selectively penalized in specifying the origin of items may suggest that elderly persons have greater problems than the young to integrate perceptual features with target information at encoding, and to reconstruct this source information and its association with target information at retrieval (Schacter et al., 1994).

Explaining Age Deficits in Long-Term Olfactory Memory

In agreement with earlier findings, Study IV and V demonstrated age-related deficits in episodic recognition of common odors and odor naming (e.g., Murphy et al., 1991; Schemper et al., 1981). Moreover, the results in Study III suggest that olfactory memory may be especially vulnerable in aging, relative to memory for stimuli encoded in other sensory modalities. The pattern of the age-related impairments in odor recognition, odor naming, and source memory for olfactory stimuli was consistent across studies: young-old and old women did not differ reliably in performance for any measure, whereas young women consistently outperformed both groups of elderly women. In olfactory research, most studies have included one group of elderly subjects as contrasted with a group of younger subjects. Other research focusing on recognition memory for verbal and visual recognition memory has yielded mixed evidence with regard to decrements in performance among subjects in their 60s and 70s. Some studies indicate a gradual performance deterioration with increasing age (e.g., Bäckman, 1991; Crook & Larrabee, 1992), and others show age equivalence comparing older cohorts of varying ages (e.g., Cohen & Faulkner, 1989; Schonfield & Robertson, 1966). Given that the subjects exhibit similar olfactory sensitivity, the present work suggests that odor memory is rather stable from the seventh to the eighth decade of life.

Many studies have reported significant losses in olfactory sensory acuity with increasing age (e.g., Murphy et al., 1985; Van Toller et al., 1985). Sensory deficits have also been thought of as an important causative factor for age-related deficits in odor memory. One parameter that relates to olfactory sensitivity is the perceived intensity of olfactory stimuli. Intensity ratings for suprathreshold odors have proved to be lower in older subjects than in younger subjects (Stevens & Cain, 1986, 1987), which in turn may have adverse effects on odor memory performance. The role of threshold sensitivity for age differences in odor recognition could be evaluated by varying the intensity degree of odorous stimuli. This issue was addressed by Stevens et al. (1990). Specifically, the role of intensity in odorous stimuli on odor memory and identifiability was examined. The main issue of interest was to examine whether older adults could compensate for their deficits in episodic odor recognition and odor identification by increasing the intensity levels in the olfactory information. If so, then observed age deficits may be attributed to losses in suprathreshold strength (Stevens & Cain, 1986, 1987). The results indicated that retention of odors was unrelated to the degree of intensity, in both young and older adults. With regard to odor identification, intensity degree was weakly related to performance, but there was no interactive relationship with age.

In the present work, one measure of sensitivity was included: absolute threshold sensitivity for n-butyl alcohol, which has been recommended for use as a standard in olfactory threshold research (Moskowitz, Dravniek, Cain, & Turk, 1976). No information concerning the subjects' perceived intensity of the olfactory stimuli and its potential relationship to performance in odor memory is thus available. However, two circumstances should be noted, which together suggest that intensity may not have been of crucial importance with regard to the observed age deficits in odor memory. First, all subjects were screened for potential sensory losses, indicating that all subjects had intact sensory abilities. Second, efforts were made in making each of the test odors as distinct as possible. If subjects in the odor identification test were unable to emit any verbal description of the odor, they were always interviewed as to whether they could perceive that an odor was present. My personal experience in testing these persons is that very few complained of not perceiving anything from the odors presented.

Furthermore, in order to examine whether olfactory sensitivity (absolute thresholds) bore any relationship to the identifiability of the test odors, correlations were performed. In Study IV, identifications following name-only and odor-name formats were excluded, yielding a correlation of $r = .15$ ($df = 34$; $r_{\text{krit}}\ p < .05 = .32$). In Study V, the correlation reached an r of .18 ($df = 70$; $r_{\text{krit}}\ p < .05 = .23$), which indicates that sensory acuity was unrelated to identifiability in both of the studies. Although it is not possible to fully explore the impact of intensity on the results in this work, these findings along with the results reported by Stevens et al. (1990), suggest that intensity most likely play a negligible role in explaining age deficits in olfactory memory.

Ship et al. (1996) reported that the pattern of age deterioration in odor identification is similar in males and females, but delayed by approximately 20 years in women. These results were obtained using the UPSIT test which has been identified as a reliable test of smell function, with high test-retest reliability coefficients, and with a strong correlation to odor detection thresholds (Doty, Newhouse, & Azzalina, 1985; Doty, Shaman, & Dann, 1984). With reference to the reliable relationship between sensory acuity and performance in the UPSIT test, it is of interest to note that in Study III-V, only one older women had to be excluded due to olfactory sensory deficits. This low exclusion rate may be understood in view of the findings reported by Ship et al. (1996) of relatively intact sensory functioning in females up to 75 years of age. However, a close inspection of the threshold levels indicates that a slight decrement in sensory acuity is present across the age groups in the current research. Therefore, and in line with the Ship et al. (1996) results, inclusion of an additional group of older subjects (> 80 years of age) would likely have yielded reliable age deficits in sensory acuity.

Results from earlier work in odor recognition indicated that retention for olfactory stimuli showed a virtually flat forgetting curve over a 3-month retention interval (Engen & Ross, 1973). In Study III-V, we found evidence that memory for olfactory information is not resistent to forgetting. Over a 48 hours interval, a significant drop in recognition performance was observed and the magnitude of this decline was similar across age groups. This result is in agreement with data reported by Stevens et al. (1990), who assessed odor memory immediately after, 2-3 hours after, and 1 week after study. Recognition memory decreased reliably as a function of time, but with no evidence of faster forgetting in older relative to younger subjects. Other work also questions the earlier view of only minimal losses of olfactory information across time, demonstrating that odor memory is not resistant to decay (Murphy et al., 1991; Walk & Johns, 1984). An important reason as to why common odors are prone to forgetting may be that this type of information involves episodic and semantic features in addition to sensory features (Perkins & Cook, 1990).

One factor that needs further exploration in olfactory research is the speed at which the olfactory system processes incoming information, and its relationship with other olfactory parameters. Research indicates that the olfactory system is extremely slow relative to other sensory modalities (Herz & Engen, 1996; Laing & MacLeod, 1992). This slowness of the olfactory system in combination with the aging-related cognitive slowing (Bryan & Luszcz, 1996; Salthouse & Lichty, 1985) may be one reason as to why age differences seem to be exacerbated in olfactory memory. In Study V subjects were assessed in tests of verbal fluency which reflect the speed at which an individual may retrieve verbal information. Given that odor recognition is mediated by the accessibility of odor names, it should be of interest to further explore the relationships between verbal fluency and odor naming. With regard to odor recognition performance (*d'*) only one fluency measure (i.e., occupations) showed a slight, albeit reliable, relationship to recognition memory. However, this measure exhibited no predictive power with regard to the age-related variation in episodic recognition. Inspecting the correlations between fluency and odor identification, two fluency tests showed slight, but reliable, relationships (FAS: $r = .25$, $df = 70$; supermarket fluency: $r = .30$, $df = 70$, $r_{\text{krit}}\ p < .05 = .23$). This outcome suggests that the speed of access to verbal information is related to the number of odors identified. Given that odor identification is strongly related to odor recognition, it may be that verbal fluency has a more indirect relationship (i.e., through identification) to odor memory.

The Impact of Semantic Memory in Episodic Recognition of Common Odors

It is of theoretical interest to investigate the role of verbal mediation in human olfactory memory. If olfactory memory is not dependent on linguistic or verbal factors, then olfactory processing would be fundamentally different from the cognitive processing carried out in other modalities. As noted by way of introduction, some research has indicated that verbal/semantic components are present in odor memory to a similar extent as for visual and verbal memory (Bäckman, 1991; Craik & Lockhart, 1972; Lyman & McDaniel, 1986, 1990;

Murphy et al., 1991; Walk & Johns, 1984), whereas others have shown that verbal or linguistic factors play a negligible role in olfactory memory (Engen & Ross, 1973; Lawless & Cain, 1975).

In the present thesis, two studies indicated that episodic recognition for common odors is strongly mediated by factors related to semantic memory (cf. Lyman & McDaniel, 1986, 1990). Study IV and V indicated that the crucial factor for odor recognition performance, in general, and age-related differences in odor recognition, in particular, is the subject's specific semantic knowledge of the odors presented. First, in both studies, the degree to which an odor connects with experience, as indexed by rated familiarity, was positively related to hit rates at both immediate and delayed testing. Recognition performance increased as a function of increasing familiarity, which is consistent with previous findings (Murphy et al., 1991; Rabin & Cain, 1984). Second, label quality was associated with recognition performance at both times of testing. The quality of a naming response may be seen as an overt indicator of how much explicit verbal information an individual has about an odor. In Study V, subjects' naming responses were classified into four categories; omissions, far misses, near misses, and veridical repsonses. The results indicated that memory performance increased as a function of the quality of the emitted odor label. Correctly named odors were more easily recognized than were odors that received a near-miss naming response, which in turn were related to higher recognition than odors receiving a far-miss response or no response (omissions). These results fit nicely with earlier findings indicating a dependency between the accuracy of labeling and olfactory recognition (Lyman & McDaniel, 1986; Rabin & Cain, 1984). Interestingly, despite the fact that subjects were asked to name the odors at delayed testing, a naming-recognition relationship was seen also in immediate testing. This outcome suggests that some kind of covert labeling took place at the immediate test. The fact that subjects engaged in semantic encoding of the target odors is congruent with the notion of an inherent human tendency to identify and classify incoming information into meaningful percepts (Fiske & Taylor, 1984).

In contrast to available evidence from research using verbal and visual stimuli, Study V indicated that proficiency in complex verbal intellectual abilities (Craik et al., 1987; Hultsch et al., 1990), such as vocabulary and fluency, may be of minor importance in predicting memory performance for olfactory information. However, as noted previously, fluency may be related to recognition via identification as a mediating variable. Similarly, and also in contrast with the bulk of research on verbal memory (Hill et al., 1995; Inouye et al., 1993), education proved to be unrelated to odor memory.

The finding that accessibility of veridical odor names was strongly related to episodic odor recognition and that statistical control of proficiency in odor naming eliminated the impact of age on episodic odor memory (Study IV) should be highlighted. This finding was replicated and extended in Study V using regression techniques. When age was entered before odor naming in the analyses, both predictors made sizable contributions to the variation in immediate and delayed recognition. Importantly, when changing the order of entry of these variables, odor naming made a still greater contribution to performance, although the impact of age was eliminated. Thus, these results suggest that the ability to name odors appears to be an extremely important factor not only for episodic recognition of odors in general, but also for age-related deficits in odor recognition.

It is important to note that these results are restricted to recognition memory for common odors, which likely represents overlearned information in the individual's network of semantic knowledge. An important issue to address in future research concerns the relationship between age and episodic recognition for uncommon odors. Given that older adults have greater difficulties in accessing odor names, and that this deficit underlies the age-related deterioration in episodic memory for common odors, this limitation may be overcome using a task with minimal involvement of semantic memory functions (i.e., memory for unfamiliar odors). However, this is not to say that age differences would be nonexistent in recognition memory for uncommon odors. Other age-sensitive factors (e.g., working memory, odor discrimination) that perhaps play a lesser role in memory for common odors may increase in importance when the lexical demands are low.

POINTS OF CAUTION

In Studies III, IV, and V, forgetting over a 48 hours interval was registered. However, because the same target and distractor items were used at both times of testing, discriminations may have been more difficult to perform at the delayed testing. Thus, at delayed testing, the distractors may have been more likely to be remembered as "old" items, compared with immediate testing, resulting in an increment of false alarm rates across time. Of particular concern is whether any of the age groups studied were especially affected by this state of affairs. Across studies, false alarm rates were consistently higher at delayed testing than at immediate testing. In Study IV, both groups of elderly subjects produced disproportionally more false positives at delayed testing relative to the group of young adults. Whether this effect is related to the use of the same distractors at both times of testing, or is a true effect of age-related increases in forgetting, or a combination of both, is difficult to determine. Note, however, that this age-related increase in false alarm rates across time was not observed in Study III and Study V, in which all age groups showed a similar increase in false alarms rates from immediate to delayed testing.

Another methodological concern is that effects of frequency may have affected the forgetting data. This is so because the target odors were smelled twice before delayed testing and distractors were smelled only once before delayed testing. As a result, the observed decreases in hit rate performance over time in Study III-V may underestimate the true rate of forgetting. Importantly, however, age did not interact with time of testing. In sum, it is not possible to determine the extent to which these circumstances may have confounded the observed rates of forgetting. Therefore, it is important to stress that the forgetting data must be treated with due caution.

As pointed out previously, the results in Study II and III are clouded because of ceiling effects. Thus, the interpretations of the results in these studies should also be treated cautiously. However, note that although performance was extremely high in both these studies, many of the manipulations were still reliable.

The participants in all five studies were recruited through advertisements in daily newspapers, senior citizen organizations, and adult education centers, and were all highly motivated to participate in research. Thus, the present samples are composed of a set of highly selected individuals and the results may overestimate the true population levels in the older age groups. Population-based sampling would most likely have revealed more pronounced age differences than those observed in this work. However, at the same time it is important to recognize that young and older adults were carefully matched on relevant background characteristics in Study I-IV. The use of population-based samples may have resulted in age-related differences favoring the young in various demographic and other characteristics. Thus, a potential gain in external validity from using random samples would likely have resulted in losses in internal validity.

CONCLUDING REMARKS

This doctoral thesis examined item memory and memory for sources in early and late adulthood, with special reference to information acquired through the olfactory system. Of additional interest was to examine whether older adults could make use of different types of cognitive support in order to improve these forms of memory. In this section, I will recapitulate the main findings of the five empirical studies.

(1) Episodic recall performance varied as a function of age, the nature of materials, and the level of retrieval support. Cue benefits in word recall were equal across age groups, whereas cue benefits increased gradually with increasing age in object recall. Thus, with increasing age there was an increase in the level of support required, in order to improve episodic memory functioning.

(2) Both item memory and memory for source decreased as a function of age. Item memory for information rich in features was better than memory for information low in detail, and source confusions were predictable from the degree of structural similarity shared among materials. The ability to recognize an item's previous exposure determined largely the ability to specify the source of information. Moreover, older individuals exhibited greater difficulties in specifying the source of information as compared with memory for the item itself. This was particularly true for olfactory and auditory information.

(3) Episodic recognition of common odors decreased as a function of age. However, odor memory proved stable when comparing subjects in their 60s and 70s. Odor memory decreased reliably over a 48 hours interval. This drop in performance was independent of age.

(4) Specific odor knowledge, such as perceived familiarity and identifiability was strongly and positively related to performance in episodic odor recognition. In contrast to memory for verbal and visual information, factors assessing more general aspects of semantic memory were not associated

with odor memory. Moreover, accessibility of odor names was crucial for successful episodic odor recognition, and for age-related differences in odor recognition.

(5) In general, the ability to utilize the various forms of cognitive support examined was found to be well preserved in old age. The degree of richness inherent in the information generally predicted episodic memory performance. Materials which were rich in features were better remembered than were materials low in detail. With few exceptions, performance gains from the provision of cognitive support were parallel across the adult life span.

FUTURE DIRECTIONS

It is hoped that this thesis will direct some attention at the role played by chemosensory functioning in human life. Because chemosensory functioning decreases as a function of age, it is important that persons exhibiting deficits in chemosensory functioning are thoroughly evaluated clinically, because of the intimate relationship with nutritional status (Schiffman & Warwick, 1989). One important direction of future research, therefore, is to develop more effective methods to enhance flavors of foods, which, ultimately, can help prevent malnutrition and anorexia in the elderly (Schiffman & Warwick, 1988).

It is important to note that the finding that episodic odor memories are largely mediated by semantic memory factors, is valid only for common odors. Hence, an interesting issue in future research would be to explore the relationship between age and episodic recognition for uncommon odors. Given that older adults have greater difficulties in accessing odor names, and that this deficit may determine largely the age-related deterioration in memory for common odors, this limitation may be overcome using a task with minimal involvement of semantic memory functions (i.e., memory for unfamiliar odors). Determining which factors that are related to olfactory memory, in general, and to potential age differences in olfactory memory with regard to uncommon odors, is a research issue that I would like to address in the future.

Furthermore, as observed in Study V, age-related deficits in odor memory were related to an aging-related deterioration in the production of odor names. One way of further evaluating whether age deficits in odor identification are related to lexical access problems or are due to a degradation of the semantic network, is to maximize the degree of support at encoding and retrieval. For example, subjects may be provided with the respective odor names while smelling and, at the time of identification, multiple-choice alternatives, rather than free identification, may be provided.

An important question in olfactory research is whether this sensory system should be conceptualized as similar or different from our other sensory modalities. The present thesis yielded some evidence that odor memory may be influenced in a similar fashion from activation of prior knowledge, as is memory for visual and verbal information. However, in contrast to the well established influence of educational background and general lexical retrieval on episodic memory involving verbal and visual information, these factors proved unrelated to retention of olfactory information. This outcome suggests that memory for olfactory information may operate according to different principles as compared with other types of memories. Therefore, it would be of great interest to further study the relative impact of various individual-difference factors known to be related to olfactory performance (e.g., odor discrimination, odor intensity), and factors known to have an influence on episodic memory in general (e.g., cognitive speed, working memory) for proficient odor recognition. In this way, it will be possible to obtain a more complete picture of whether odor memory should be conceptualized as a phenomenon working on its own premises, or one that largely resembles memory for episodic information acquired through our other sensory modalities.

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