ROBERT JAMES FRANCIS ELSNER
The Effects Of Age, Mood, Environment, Pharmacology, And Cognitive Status On Lifespan Olfactorial Memory.
(Under the Direction of GAIL WILLIAMSON)

This project was designed to address the basic question of sources of age-associated change in olfactory memory. These changes have historically been reported as declines in abilities, examinations have concentrated on losses and their impact on the individual. As olfactory memory is not yet well established as a sensory modality in the literature, this dissertation reviews the relevant literature, followed by three studies. The first study addressed olfactory changes in the superlative aging of centenarians, and found olfactory performance and memory better than anticipated for much younger adults. The second study examined environmental and pharmacological factors contributing to declines in olfactory sensitivity and memory, and found these two factors contribute more to loss than does age. The final study considered the components of age, medication use, and environment, but also addresses the endogenous factor of mood state on memorial abilities. The third study found that there are interactions between all of these issues that are more important than any single variable itself. Findings of these studies reveal that chronological age is more an indicator of potential for loss than of loss itself.

INDEX WORDS: Lifespan developmental psychology, Olfaction, Aging, Cognition, Mood, Environment, Pharmaceuticals

THE EFFECTS OF AGE, MOOD, ENVIRONMENT, PHARMACOLOGY, AND COGNITIVE STATUS ON LIFESPAN OLFACTORIAL MEMORY.

by

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2001

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DEDICATION

This dissertation is dedicated to my wife, Elizabeth.

Words cannot convey the love and gratitude for the support and extraordinary measures she has gone to in assisting me with this project.

“Et qu'à vos yeux si beaux l'humble présent soit doux.”

ACKNOWEDGEMENTS

I would like to thank my committee, Adam Davey, Dorothy Fragaszy, Philip Holmes, L. Stephen Miller, and Gail Williamson, for the support ant encouragement they have provided me during this process. I can never thank Dr. Williamson enough for taking me and other “waifs and strays” in over the years. Her faith in me and in my abilities made all the difference, as it has to many other students over the years. Without her support, I would not have been able to finish this doctorate.

I wish to express my deepest thanks to Professor Joe Hammock and the late Professor Roger Dancz for their invaluable assistance in recruiting volunteers for these studies from among their friends and acquaintances. Special acknowledgement and thanks are due to Dr. Susan Schiffman of Duke University for extensive assistance with the design of the research protocols for the olfaction tests. My thanks also to Louise Seagraves and Barbara Dial for assistance in keeping me on track and encouraged, as well as facilitating the completion of this dissertation while on another continent.

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Several researchers have demonstrated the high level of accuracy with which infants can recognize the odors of their mothers breasts and milk (e.g., MacFarlane, 1975; Porter, Cernoch, & McLaughlin, 1983; Schleidt & Genzel, 1990). By four or five days, an infant is able to differentiate between the milk of its mother and that from another human or cow (Schaal, 1988a). This odor recognition becomes a motivating factor and increases, to a degree, during the developmental trajectory across the lifespan (Schaal, 1988b). Thus begins the deep relationship between odor and emotion that has been celebrated in great works such as *Swann's Way* by Marcel Proust (1934, orig. 1913).

On the other end of the spectrum, research indicates that during the adult lifespan, numerous losses occur in abilities to sense and perceive odors as well as other sensory stimuli. The majority of this research has looked at static moments in the lives of these people and typically has not accounted for the various life-course influences on these changes, much less momentary influences such as dehydration or pharmaceutical usage.

Humans are not static, isolated beings but, rather, dynamic individuals who grow and change constantly in an environment that also changes. To address changes in humans, one must take care to maintain the specificity of the population being addressed, as humans are an extremely heterogeneous group. The predominance of research on growth and development typically deals with the formative stages of youth, yet a

significant body of literature exists on changes that occur throughout the adult lifespan. This dissertation examines the adult lifespan with special attention to old age.

Old age can bring on a multitude of sensory changes, both in the central nervous system and the peripheral nervous system. Changes in peripheral function, such as trauma to receptors, change the way that we sense the world. Changes in central function, such as neuropathologies, change the way that we interpret sensation. This can have a profound impact on the lives of older adults stretching beyond psychological factors to physical status and quality of life.

If researchers in vision or audition found that their research participants demonstrated a drastic decline in ability with age, they would most likely begin to identify the precise declines, and what precipitated them. Unfortunately, much of the research in olfaction has neglected to do just this.

Most olfaction research in aging concentrates on loss of function or physiological degradation of the olfactory bulb and epithelium. Few studies explore specific psychological components, and fewer still explore these components within the context of functional loss. These psychological components, such as memory of odors, might be a component of age-associated declines in ability when there is no detectable physiological cause. It is important to note that memory for odors is not unidimensional but, rather, like all other sensory systems, has multiple aspects integrated into a larger system. For accurate understanding, the integration of sensory systems and cognitive function must take into account issues of both the endogenous and exogenous variables of influence.

Three major research questions are under investigation here. First, of the factors of age, environment, pharmacology, cognitive status, and mood state, which are dominant

forces in the declines in olfactorial abilities typically observed across the adult life span? The second major research question asks to what degree the different memory systems are influenced by age when considered through the sensory modality of olfaction? The final question asks how large a role do lexicality effects play in the decrease in odor recognition and identification abilities so often reported for older adults? These questions have been addressed by systematically exploring these various factors in relation to a research method developed herein. First, to provide a background for the proposed research, extant studies on age-associated change in olfaction and memory are reviewed in Chapter II, and findings from research on age-associated deficits in olfaction are outlined to consider methodological constraints. Major factors influencing olfactorial abilities are taken into account in order to assess the relative contributions of each factor to declines reported in subsequent chapters. It is from this review of literature that the main components of potential olfactorial loss are collected and analyzed.

To begin the systematic, experimental investigation into this topic, an endpoint is necessary. We typically define aging humans in relative terms, so some basis for what can be considered a final or extreme age is needed. Appendix A contains the report of a study on Centenarians evaluated for their olfactorial abilities that was completed in preparation for this dissertation. This investigation first examines the physiological manifestations of olfactorial aging in terms of detection thresholds, then explores the memorial abilities of these individuals for odors.

The next step in the investigation, also before the formal dissertation process began, Appendix B, includes expanding the age range and including factors most strongly indicated by the literature as having a significant effect on olfactory declines. Adult age

for this study was a broad collection of older adults aged 50 to 90+. The influences examined included risk of environmental olfactorial insult or injury and the potential for pharmacological interference.

The systematic development of the projects reported in appendices one and two are culminated in Chapter III. This study, while still including the considerations of lifespan development in terms of environmental risk and pharmacological mediators, addresses another major area of significant potential contribution to age-associated decline that can be non-invasively tested, that of mood state.

It is important to understand that the memorial abilities of older adults have been studied in other modalities. The research on abilities of older adults in olfaction has been plagued by limitations of controls and methodological difficulties. The methodology employed herein for the testing of olfactorial abilities was developed to negate the major limiting factors for testing, but not without some cost. Much of the extant information on age-associated change in cognition has been assessed using reaction time variables. As the chemical senses do not lend themselves to timed testing, all components of the testing are not restricted by time but, rather, by veridicality of response. Thus the respondents are addressing ecologically valid issues, not artificial constructs.

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CHAPTER II

ODOR MEMORY AND AGING: A REVIEW OF LITERATURE [1]

[1] Elsner, R.J.F. 2001. Accepted by Aging, Neuropsychology, and Cognition.
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Abstract

Although odor memory is considered to be impervious to time, an unfortunate reality is that many older people lose some olfactorial abilities across the adult life span. This review examines the unique features of odor memory and detection in perspective of the aging adult. Memory for odors does not inherently diminish with age, but neither is it impervious to the effects of time. Many, if not most of the declines typically associated with age are the result of insult and injury, neuropathologies, pharmacological and nutritional imbalance, cognitive slowing, and diminished memorial capacity. Extant research has typically ignored major facets of efficient memory encoding and recall, especially context and experience. Among the most salient experimental factors in need of more research are lexicality effects, in which some stimuli are more easily remembered because of the ability to label or name them, either overtly or covertly. Another important experimental factor is context, typically relied on more by older persons to aid in both encoding and recall. Specific suggestions for research are discussed.

Introduction

In his book on odor sensation and memory, Trygg Engen (1991) states that the "most prominent feature of odor memory is its imperviousness to time. It is actually better to think of this ability in terms of not forgetting than remembering" (p. 81). He states that part of this retentiveness is due to a limited amount of interference with learned connections between items that characterize other sensory modalities. In vision and audition, for example, what is learned most recently can dominate other memory

traces. Contrary to Engen, olfactorial retention is not impervious to interference and is not always retrievable through old age.

Old age can bring on a multitude of changes to sensory systems, both in the central nervous system and the peripheral nervous system. Changes in peripheral function, such as trauma to receptors, change the way that we sense the world. Changes in central function, such as neuropathologies, change the way that we interpret sensation. If a researcher in vision or audition found that their research participants demonstrated a drastic decline in ability with age, that researcher would most likely begin to investigate what the precise declines were, and what precipitated them. Unfortunately, much olfaction research has neglected to do just this. Most olfaction research in aging concentrates on the loss or physiological degradation of the olfactory bulb and epithelium. Relatively recently an integrated approach has begun to examine the specific psychological components, such as memory of odors, which might be a component of age-associated declines in ability when there is no detectable physiological cause. It is important to note that memory for odors is not unidimensional, but rather like all other sensory systems has multiple aspects integrated into a larger system.

Memory for odors has not been a hot topic for research for a variety of reasons. First and foremost is that although it is very important to quality of life and safety, it is typically viewed as less important than vision and hearing. Olfaction also has more limitations than these two other sensory systems, which has made inquiry more difficult than other sensory modalities. These limitations include more difficult delivery of stimuli, an overall slower response time, requirements of serial presentation of stimuli, concerns about rapid adaptation to stimuli and fatigue from stimuli, and penchant for

disturbances of airflow from illness, allergies, etc. Unlike other sensory modalities, there is relatively little in the way of consensus-driven terminology and standards of practice. All of these issues have been viewed as major constraints on olfaction research.

Vision and hearing have their own constraints that olfaction does not have that are advantageous in aging research. The olfactory bulb contains the only neurons in the human body which continue to be replaced throughout the lifespan. The limbic nature of the olfactory system also allows less mediation by other structures than the other senses. Perhaps related to the limbic nature, odors can overrule other stimuli in decisions about acceptability and safety of foods. These are among the issues that have attracted many researchers to this field.

Almost ten years ago, Frank Schab (1991) wrote an integrated review of odor memory from a general perspective. Considering current demographic trends and new information on olfaction and its role in age-associated pathologies, such as Alzheimer's Disease, an updated review is needed. The purpose of this review is to integrate the current literature on odor memory and aging, with some attention to implications of pathologies. This paper is divided into five substantive areas for this purpose. First, the olfactorial implications of age-associated pathologies such as Alzheimer's Disease are addressed. Next, the role of odors as memory cues is presented in regard to age-related changes in cueing. Forms of odor memory are then discussed in terms of current theories of memory. Odor identification is examined using the knowledge base constructed in the preceding sections. Finally, odor recognition is examined in terms of theoretical issues, short-term odor memory, and long-term odor memory. It should be remembered that the concentration is on aging and odor memory, not odor memory and related pathologies.

Pathological States and Olfaction

One of the seminal research projects on lifespan olfactorial abilities was reported by Doty, Shaman, Applebaum, Giberson, Sikorsky, and Rosenberg (1984). They tested a total of 1,955 people attending a state fair using the University of Pennsylvania Smell Identification Test (UPSIT; Doty, Shaman, & Dann, 1984). The UPSIT is among the most widely used tests of olfaction, and are referred to throughout this paper. Scores on this test at that state fair reached an optimal level of ability between twenty- and fifty-years of age. By age eighty, scores for three-quarters of the individuals tested plummeted to nearly chance performance.

As with most papers that report on age-associated change in olfaction, this was a naturalistic inquiry with no control for dementia or pathologies, and should be considered as such. The findings of Doty and colleagues should not be taken as a statement of absolute aging research, as it has been, but rather as an important snapshot of the abilities of a specific sub-section of the population. Just as it is important to understand what happens in a group within the population, it is important to understand why, an issue they did not attempt to address.

The precipitous drop in abilities that Doty, Shaman, Applebaum, et al. (1984) reported accompanying age is an important consideration for the daily activities of older individuals. The findings that showed a drop in abilities with age coincide with the current understanding of the prevalence in older adults of pathological states that affect olfaction, including disease, dementia, nutritional deficiencies, and insults and injuries. Among these, dementia is most often considered relative to aging.

Epidemiological studies have indicated that dementia effects 6-10% of the North American population over age 65. Two-thirds of these people are Alzheimer's sufferers (Hendrie, 1997). Over the past few decades it has become clear that Alzheimer's Disease (AD) and Parkinson's Disease (PD) compromise olfactory functions (Doty, 1991). Doty (1997) reviews the olfactorial indicators and contributions to detection of a variety of pathologies and physiological states, including neurodegenerative diseases like AD, PD, amyotrophic lateral sclerosis, Down's syndrome, Huntington's disease, and others. Common among these are that they result in olfactorial deficits, and are developmentally associated. It is necessary to briefly discuss the most important of these points at this time.

Alzheimer's

Early neuropathological changes in Alzheimer's Disease are found in areas of the brain associated with olfactory information processing. The physiological processes of the pathology begin in the olfactory bulb and can severely limit the abilities of that sense. One of the most important questions facing researchers in olfaction and AD is where losses in olfactorial ability occur in either central or peripheral systems, and why.

Lehrner, Brucke, Dal-Bianco, Gatterer, and Kryspin-Exner (1997) have helped to forward the answering of this question, positing that the decrements are primarily in central processing deficits of the central nervous system. They examined olfactorial abilities of 22 AD patients (2 males, 20 females; mean age =77.4 years ±8.8), 21 PD patients (13 males, 8 females; mean age = 67.9 ± 10.2), and 19 healthy, non-demented adults (4 males, 15 females, mean age = 67.8 ±15.1). They found that odor memory and identification was very poor for AD patients. Curiously, odor memory was intact for non-

demented PD patients, although they had poor identification abilities. They concluded that these findings supported the notion that the olfactory system is capable of odor memory processes without adequate verbal labeling (Lehrner, 1993), and also that olfactorial memory testing was an effective aid to AD diagnosis when used with other tests.

Improved AD diagnosis is an important aspect of this body of work. The impact of lexical functioning and detection sensitivity on the deficit of odor identification in AD was studied in persons diagnosed with probable and questionable AD by Morgan, Nordin, and Murphy (1995). Tests consisted of lexical-based odor identification (UPSIT), lexical-based picture identification (PIT; Vollmecke & Doty, 1985), picture-based odor identification (Child-odor-identification test; Anderson, Maxwell, & Murphy, 1992), and odor-detection thresholds of 18 probable AD and six questionable AD adults and matched groups of normal adults. Their results suggest four specific conclusions. First, odor identification is poorer than picture identification in probable and questionable AD. Second, odor identification continues to be poor even when lexical demands are eliminated. Third, odor detection does contribute to the odor-identification deficit, but does not account for it completely. Finally, they concluded that odor identification tests have a correct AD classification rate of 83-100%. This was superior to the 25% and 58% rates provided by color naming and color association tasks. This multimodal approach to AD testing is a compelling reason to examine further the integration of sensory modalities both in health and disease states.

As important as diagnosis is, it is best when it is as early in the disease course as possible. With this in mind, Bacon, Bondi, Salmon, and Murphy (1998) explored very

early changes in olfactorial thresholds to butanol in those individuals with the highest probability of developing the disease. They examined individuals with and without the apolipoprotein E ε4 allele, and found that the presence of the allele decreased odor sensitivity regardless of cognitive status. Their findings indicate preclinical changes in olfaction for those individuals who later developed the disease, up to one year before onset of classic AD symptoms.

Parkinson's

Parkinson's Disease (PD) has been shown to be related to decreased olfactory threshold and impaired discrimination ability (Ansari & Johnson, 1975; Quinn et al., 1987). Olfaction has also been found to be impaired in the PD population independent of age, disease duration, disease severity, anti-Parkinson medication, and neuropsychological measures (Doty, 1992; Doty, Deems, & Stellar, 1988; Wenning, Shephard, Hawkes, Petuchevitch, Lees, & Quinn, 1995). Although olfactory deficit is a classic feature of PD (Quinn, 1997), the level of deficit does not correlate well with other diagnostic measures (Ahlskog, Waring, Peterson, et al., 1998).

To examine the effect of PD and other neurological diseases on olfaction, Hawkes and Shephard (1998) used the UPSIT and olfactory evoked potential responses (OEPs) to test four groups of patients. These groups included individuals with Multiple Sclerosis, idiopathic Parkinson's Disease, motor neuron disease, and Alzheimer's Disease. They posited that olfactory tests are effective measures to differentiate between PD and "lookalike" pathologies, such as progressive supranuclear palsy or multisystem atrophy. Two important distinctions were made: that there were specific odors which the PD patients misidentified regularly (pizza and wintergreen), and that AD patients who were

able to be tested had normal OEPs. These two findings indicate that AD effects the nervous system more centrally than peripherally, and that PD shows deficits at least as severe peripherally as centrally, both important for the discussion of uses of olfaction testing in an aging population. Their position that the central nervous system shows the preponderance of deficit is strengthened by the deficiencies in ability to identify wintergreen, as wintergreen stimulates not only olfaction but trigeminal reception as well.

Environmental anosmia and hyposmia

Anosmia and hyposmia, which are complete and partial losses of the sense of smell, can be brought on by a number of environmental influences. One avenue of inquiry that has not received sufficient attention in the literature is the cumulative effects of insult and injury to the olfactory system coming from the environment. These environmental factors include viral assault (Doty & Snow, 1988; Murphy 1985), head trauma (Costanzo, Ward, & Young, 1992; Murphy & Davidson, 1992), and exposure to toxic substances (Naus, 1976; Schiffman, 1983).

It is common knowledge that upper respiratory infections such as the common cold or influenza can decrease the ability to smell by constricting airflow to the region of the olfactory epithelium. Numerous studies (e.g., Deems, Doty, Settle, Moore-Gillon, Shaman, et al., 1991; Feldman, Wright, & Leopold, 1986; Schiffman, 1983a&b) have demonstrated that upper respiratory infection is the single most common cause of anosmia or hyposmia, particularly in older individuals. Underrepresented in the literature are other potential sources of disturbance, such as dehydration and vitamin deficiencies, both of which are elevated among older members of the population.

The only comprehensive study detailing the amalgamated effects of environmental influences on older adults came from the National Geographic Smell Survey (Corwin, Loury, & Gilbert, 1995). This study reported data from 712,000 respondents who took the scratch-and-sniff test of six odorants. The findings show differential abilities for specific odors, thus bringing up the question of why some odorants are more adversely affected than others. Although there were numerous methodological issues of concern with this study, overall the results indicated that the workplace might determine the olfactorial abilities of individuals as they age more than other factors. Workplaces, especially factory work, determine not only exposure to toxic or caustic substances, but also potential for increased head injury. The selective declines also lend credence to the central processing deficit hypothesis previously discussed.

The importance in any discussion of various environmental effects on age-associated changes in olfaction was brought into question by the work of Rawson, Gomez, Cowart, and Restrepo (1998). They used biopsies of olfactory receptor neurons (ORNs) to examine physiological changes in the olfactory system that accompany aging. Biopsies were taken from nine healthy older adults (66-84 years old), three AD patients (77-79 years old), and one multi-infarct patient (73 years old). They were compared against biopsies from a subset of younger participants matched for gender as well as date and number of biopsies. The results indicated no decrease in ORN responsivity for older participants, indicating that decrement may occur primarily in other elements of signal transduction pathways or in cognition. While there is little dispute as to the physiological changes that accompany aging (e.g., changes in glomeruli and mitral cells; see Meisami,

Mikhail, Baim, & Bhatnagar, 1998), cognitive factors should be examined as to the efficacy of odors as memory cues.

Odors as Memory Cues

According to Herz (1998), "odors are the best cues to memory" (p. 673, italics in original). Her emphatic statement is based on a multimodal study of memory cues from odors, words, music, visual, and tactile stimuli rated by accuracy and emotional response to the target stimuli. Until studies such as this one, it had been assumed that when paired with other modalities, odors had only modest associative abilities.

Paired associates tasks are among the most commonly used methods of testing memory in olfaction research as well as aging research. Unfortunately, there are methodological concerns that can be overlooked in aging research, such as ceiling effects in younger cohorts, acquisition time confounds, and attention allocation (Park, Smith, Morrell, Puglisi, & Dudley, 1990).

A recent multimodal study of sensory thresholds by Stevens, Cruz, Marks, and Lakatos (1998) demonstrated that aging has a detrimental effect on sensation, however substantially different levels of decline for each sensory modality. Their study is one of the few in the literature that explores olfaction as related to other sensory systems and serves as a reminder of how little is known about olfaction compared with other modalities of sensation.

Schab (1991) states that one way to conceptualize a hypothesized deficit of odor memory as compared to visual memory is to consider it from two different sources. The first source is poor or nonexistent odor imagery abilities. The second is a relatively low ability of odors to cue the retrieval of odor names. According to Engen (1991), odors tend

to be named with reference to certain contexts in which they occur or are used and with associations at the same level of abstraction. Odor studies are rarely contextual, so inherently have bias under Schab's paradigm. Disparate contextual cues are analogous to the "cross talk" between concurrent streams of information which can complicate encoding in the working memory paradigm expressed by Stoltzfus, Hasher, and Zacks (1996). If information is out of context, attention is divided at encoding, resulting in less successful comprehension and retrieval.

A study by Kliegl, Mayr, and Krampe (1994) demonstrated increased difficulties of older individuals in encoding higher order tasks such as figural reasoning and cued recognition, but not tasks that focused on figural and verbal scanning. Thus, different tasks using the same modalities, and possibly even the same stimuli, can evoke different age-associated changes in performance, depending on the level of cognitive processing necessary for the specific task.

One classic index used in the study of olfactory functioning is the ease with which participants can name familiar odors, given a sniff, out of context (Doty, Shaman, & Dann, 1984; Douek, 1974). Regardless of population being studied, this is always a difficult proposition, resulting in an 80% veridicality rate at best, even among healthy younger participants. Context plays a key role in memory performance and, so, should be considered in any discussion of the ecological validity of any experiment. Context can contribute to age related differences, especially as older adults are thought to have more dependence on environmental cueing than younger people (Craik & Jennings, 1992). More about contextual identification are discussed in the section on odor identification.

For now, however, it is important to note that this process occurs and can impugn the efficacy of olfactorial stimuli.

One way that has been proposed to circumvent this difficulty is the study of odor as ambient stimuli. It is important to note that ambient cues could be taken as contextual if not carefully controlled for by minimizing other references to the odor in the testing environment. Herz (1997) evaluated the utilization of odors as an ambient environmental cue and found that the replication of the encoding environment significantly improved recall. Recall under all odor ambient conditions was superior to the control in which no odors were present. The increases in recall ability were only significant when odors were present at both encoding and retrieval, supporting Tulving's (1983) encoding specificity principle. Thus, the use of odors as an ambient recall cue for education, purchasing, and other decision-making experiences should be explored, especially as affected by changes in other sensory systems such as vision and hearing.

These olfactory memory cues are vital to the discussion at hand, but it is important to understand that not all memory cues are the same, as not all memories are the same. Just as physiologic changes in the human body are affected differently by age, the different forms of memory can be differentially affected, and it is important to understand the differences between these various forms of memory.

Forms of Odor Memory

Theoretical Issues

Memory is not a unidimensional measure of psychological function. There are different levels of effort between trying to remember if we have ever experienced a stimulus and naming that stimulus. Unfortunately, much early odor research treated all

forms of memory as being the same. Although there is single best descriptor of the various components of memory, there are some very good models. These models help us understand the distinctions between the forms of memory so that we can determine validity of tests.

One of the most influential views of human memory posits that there are five interrelated memory systems (Nyberg & Tulving, 1996; Tulving, 1983, 1985, 1993; Tulving & Schacter, 1990). The decomposition of memory according to this perspective is divided into 5 parts: a) procedural memory, which is expressed through skilled behavioral and cognitive procedures; b) perceptual representation system (PRS), which is primarily concerned with improving identification of perceptual objects; c) semantic memory, which is concerned with acquisition and use of factual knowledge; d) working memory, which requires simultaneous storage and processing of information for a relatively short period of time; and e) episodic memory, which involves memory of personally experienced events. This ordering of systems corresponds to a presumed epigenetic sequence. Procedural memory is conceived of as the earliest developmentally, and episodic memory as the last. It should be noted that other researchers (e.g., Rovee-Collier, 1997) have disputed this epigenetic sequence and posited that development is simultaneous, but at different relative rates of expression, not different rates of development.

Tulving (1985, 1991) proposed this memory system as a hierarchical structure such that episodic memory is the last to develop fully in childhood, because it is the most specialized system and requires experiences as specific data to process. Procedural memory and the perceptual representation system (PRS) are placed at the top of the

hierarchy and seen as immune to most effects of aging (Tulving, 1991). This developmental structure is one of the reasons that much of the extant odor memory work has concentrated on the semantic, working, and episodic segments of this continuum.

Tulving (1985, 1991) states that this hierarchical organization should not be seen as comprehensive, because “primitive” forms of learning, such as sensitization, habituation, and sensory memory (iconic and echoic) are not yet well enough understood in their relationships to other forms of short-term memory in humans. These forms tend to rely on lexical experimentation and, thus, have some inherent methodological concerns, such as fluency and ability to describe the stimulus within experiential confines. The lack of information or descriptors in a personal lexicon may not impede the memorial processes, but it would be a detriment to the assessment of their memory performance. It is unfortunate that no literature on the examination of PRS and olfaction is to be found, as the existence of such research would potentiate developmental, non-lexical experimentation on memory.

Tulving's is a systems view of memory, which typically addresses abnormalities or deficiencies (Cohen & Squire, 1980; Gabrieli, 1995; Tulving & Schacter, 1990), and differs from the process view (e.g., Blaxton, 1995; Roediger, 1990). According to the process view, memory performance is influenced by the degree to which the type of processing engaged in while studying is utilized when being tested. The more similarity between study and test processing, the better the memory performance. This transfer-appropriate processing, as Jacoby (1983) called it, can be conceptually-driven (conceptual) or data-driven (perceptual). Small, Hultsch, and Masson (1995) suggested that performance may be affected by aging on different implicit tasks, with a greater

sensitivity toward age for perceptual (data-driven) rather than conceptual (conceptually-driven) tasks. This suggestion was based on their study of fact completion in younger and older individuals. The majority of work on odor memory has focused on two areas predominantly influenced by the systems view of memory: explicit and implicit memory, and semantic and episodic memory.

Explicit and implicit memory

Implicit and explicit memory are differentiated by the deliberacy of attempted retrieval. Explicit recall is an effortful process, whereas those who implicitly remember do not attempt, they simply remember. Tulving (1991) defines implicit memory as designating “the expression of stored information without awareness of its acquisition coordinates in space and time—that is, expression of what the individual knows without necessarily remembering how, when, or where the knowledge was acquired” (p. 12, italics in original). He further defines explicit memory as referring to the “expression of short-term and episodic memory, expression of what the person consciously remembers as a personal experience” (p. 12, italics in original).

Schab and Crowder (1995) presented the first specific exploration of implicit memory for odors. In a series of four experiments, they used odor identification, detection thresholds, identification thresholds, and suprathreshold latency measures to determine implicit memory for odors. From the contradictory evidence elicited from these experiments they concluded that "under experimental conditions where priming generally is found for visual or lexical stimuli, little or none is found for odors" (p. 87). They further state that implicit memory for odors has been elusive and inconsistent in their experiments but that it should not be taken that it does not exist.

The conclusions of Schab and Crowder (1995) were the impetus for a study by Degel and Köster (1998). Rather than using the repetition priming effects employed by Schab and Crowder, they chose a variation of subliminal tachioscopic exposure from Feustel, Schiffrin, and Salasoo (1983) and Jacoby and Dallas (1981) to avoid the direct conscious or explicit confrontation with the odors and their names.

In Degel and Köster's (1998) experiment, series of pictures served as contextual cues for series of odors. Each picture was shown, then the odors smelled, and participants were asked to rate the fit of the odor to the picture. They admittedly had confounds within the experimental structure. One example was a picture/odor pair in which coffee odor was used, and coffee cups in a picture, providing visual cues to the odor. Most of the methodological difficulties they encountered could have been avoided through use of olfactorial components of the odors, rather than the odors themselves. An example would be weak blends of typical components of coffee (e.g., 2-ethylfuran & 2,6-dimethylpyrazine; Shimoda & Shibamoto, 1990) which are familiar, but not recognizable enough to force the name to be elicited. Degel and Köster avert much criticism by emphasizing that their experiment is merely a component of the systematic development needed for the exploration and understanding of implicit memory for odors.

In a following research project, Degel and Köster (1999) attempted to assess the implicit memory for ambient odors and the effects of these odors on performance of 108 participants. These participants were given a series of creativity, letter counting, and mathematical tests under two ambient conditions or a control. The first ambient odor, Jasmine, was chosen because of its reported effects as a stimulating odor, while the second, lavender, was chosen as a reportedly sedative odor. In this experiment, Degel and

Köster compensated for their earlier confounds and incorporated the visual stimuli in to appropriate settings where they add to, instead of detract from, validity of the results. They concluded that specific odors, or lack thereof, can differentially affect the rate of errors made in mathematical and letter counting tests. In keeping with Tulving's (1991) commentary on lack of awareness of the source of the expressed memory, this project does further the scientific stance that there is a specific implicit memory for odors.

As implicit odor memory is still in research infancy, there has not yet been time to realistically examine any potential changes across the lifespan, but some speculation is possible. Studies of other sensory modalities have demonstrated that both implicit and explicit memory are significantly affected by age. For example, Cherry and St. Pierre (1998) examined the effects of perceptual and conceptual encoding procedures on implicit and explicit memory for pictures in younger ($\underline{M}$ = 20.8 years) and older ($\underline{M}$ = 69.9 years) adults. These 64 people were shown line drawings, first a complete acquisition set, then a test set of fragmented drawings. Participants were asked to write down specific information about the drawings, based on the picture or its name. Cherry and St. Pierre found comparable priming effects in picture-fragment completion for younger and older participants following a conceptually-driven task, but the young outperformed older participants on data-driven tasks. This agreed with the commentary by Small, Hultsch, and Masson (1995) discussed earlier. Cherry and St. Pierre, however, suggested that characteristics of the retrieval context play an important role in producing or eliminating the effects of priming regardless of the task-encoding processing operations. We could therefore assume that in a contextually appropriate examination of

odor memory, the experiential advantages of aging provide equivalent performance between the groups.

In a review of lifespan changes in implicit and explicit memory, Graf (1990) questioned the impact of age differences in terms of application and experimental control. Graf found that age differences were negligible and that these differences might be confounded due to the extent to which younger and older people use explicit memory to facilitate implicit performance.

Age-related studies use almost exclusively verbal learning paradigms such as repetition priming and primed word completion tasks. This is most likely due to the difficulties in constructing implicit memory tasks that are purely implicit in nature, receiving no benefit from explicit memory in task performance. Through tests of homophone spelling, word completion, and word associations, Howard (1988) concludes that age effects are minimal on implicit memory, except where initial acquisition conditions are very cognitively effortful.

Semantic and episodic memory

As mentioned before, semantic memory is the acquisition and use of factual knowledge, whereas episodic memory is concerned with personally experienced events. This is an important distinction in research in both aging and olfaction. Each individual has collected experiences that make them unique. Different factors of personality, preference, or even chance may allow for individuals in the same environment learn to remember and attend to different stimuli. Thus, two individuals may have equivalent semantic abilities and stores, but vastly different episodic abilities and stores. One of the best examples of this distinction is from Marcel Proust (1934, orig. 1913). In his classic

novel Swann's Way, Proust gives an excellent description of the evocative episodic recall of his life by the odors of dunking a madeline into tea. That this simple act brought on a deluge of memories and emotions is not unrealistic, and it serves to remind researchers of the powerful nature of experience that should not be overlooked in the interpretation of test results.

Age-related deficits in episodic memory have been well documented (for reviews, see Kausler, 1994; Light, 1991; Salthouse, 1991). This form of memory requires conscious recollection of previously experienced events acquired in a particular place at a particular time. Younger adults consistently perform better in episodic memory tasks than do older adults. This deterioration is observed regardless of memory materials used (e.g., lists of words, paired associates). Older adults have been theorized to have fewer processing resources available in order to learn and retrieve new information (Craik & Jennings, 1992; Salthouse, 1991).

In an examination of age-related differences in episodic memory, Nyberg et al. (1997) asked 1000 healthy adults aged 35-80 (100 per 5-year cohort) to perform word recall tasks alone and concurrent with a card-sorting task. Nyberg and colleagues concluded that their results did not support the hypothesis that reduced attentional capacity in old age underlies age differences in episodic memory. In their methodology, participants were presented with 48 nouns to remember. Four groups were used: those individuals who gave full attention at encoding and recall; those people who had divided attention at both; one group full attention at encoding and divided attention at recall; and the last group of people with divided attention at encoding but full attention at recall. Memory was impaired when attention was divided at encoding, but was worst when

divided at encoding and retrieval. The most important differences in their results were that the variation between cohorts was similar for the four conditions. Thus, as with other studies, division of attention during encoding had a substantial effect, whereas division during recall has a minor effect, indicating that the most precisely recalled memories were those which were best encoded. The methodological considerations of this study are noteworthy here, not only for the encoding levels, as the visual tasks used have elevated automaticity effects over those of olfactorial tasks. We are socialized to explore even subtle changes to visual stimuli, whereas olfactorial stimuli are typically ignored unless contextually inappropriate or unusual. Thus, in examination of olfaction, the encoding of the stimuli needs special attention.

Several studies (e.g., Larrson & Bäckman, 1993; Murphy, Nordin, & Acosta, 1997) demonstrated that there is a reduction in odor recognition memory and odor identification in older individuals, though not without some methodological concerns (e.g., Cain & Gent, 1986; Cain & Krause, 1979; Murphy, Nordin, & Acosta, 1997). Murphy, Nordin, and Acosta (1997) comment on age-associated differences in encoding and retrieval and warn that some tasks may purport to examine recall but are not controlling for encoding due to individual variations in labeling.

Doty (1997) warns that a number of nominally distinct olfactory tests, to a large degree, measure the same component of variance in normal subjects. Thus, as his example went, if an odor memory test is given to a person who has experienced cumulative damage to the olfactory neuroepethilium, the low scores may have nothing to do with neural circuits per se, but the interpretation would typically be dysfunction on the cognitive level. This idea supports the basic findings of Baltes and Lindenberger (1997)

that brain structure and function in aging may be a common cause for both sensory and cognitive changes. Baltes and Lindenberger examined 687 individuals aged 25 to 101 years using hearing, vision, and a battery of intelligence tests. The link that they found between sensory and intellectual functioning increased substantially from adulthood to old age. They suggest that much of the age-associated decline in sensory performance typically observed in older people is caused by the same set of factors as those which bring about declines in complex cognition. Thus sensory tasks that are more easily understood than complex tasks, both in terms of the cognitive processing of the individual tested and the psychometric tests being employed.

Performance decreases in a wide variety of tests of speeded performance during the aging process (Cerella, Poon, & Williams, 1980; Davies, Taylor, & Dorn, 1992; Salthouse, 1991). Salthouse (1991) posited that performance decreases are the consequence of cognitive speed decreases. Performance decrements have been observed in tests of intelligence (Hertzog, 1989; Schaie, 1989), attention (Giambra, 1993; Madden & Plude, 1993), and memory (Howard & Wiggs, 1993).

Lawless (1978) reported that recognition performance for complex figures was uniformly higher across time as compared with memory for common odors and abstract visual stimuli in a sample of young adults. Using unfamiliar symbols, faces, and common odors as test materials, two studies have indicated that aging seems to take a particular toll on odor memory (Cain & Murphy, 1987; Murphy, Cain, Gilmore, & Skinner, 1991). In these studies, age-related deficits in recognition memory were considerably larger for odors. Younger participants remembered the odors much like they remembered the other

materials, immediately, two weeks, and 6.5 months after inspection. Odor memory of the older adults was at chance performance levels after the first test.

As memory can be greatly affected by changes in signal input, significant considerations for tests of olfaction among older individuals are olfactory adaptation and recovery. In an examination of these phenomena, Stevens, Cain, and Oatley (1989) found that older individuals adapt more quickly and recover more slowly than do younger people. They staged a series of experiments along this theme. As this is a consideration that influences all age-associated studies of olfaction, it is vital that it be discussed here.

First, Stevens, Cain, and Oatley examined thresholds of 13 young (18- to 30-years-old) and 13 older (64- to 84-years-old) people to n-butanol, then exposed them to a 30 second saturation (27 times the strength of threshold) of the same substance. Participants were then asked to make forced-choice decisions for the presence of n-butanol. The older participants demonstrated a longer recovery period but then were able to perform well after the initial dip toward chance performance.

In the second experiment, 63 young and 77 older participants first were screened for thresholds to pyradine, a warning agent for argon used in industrial settings. Although the mean threshold for the older participants was 10 times higher than their younger counterparts, 23 of them matched the performance of 25 younger participants exactly and were selected for participation in the experimental procedure. For three sessions, they were placed in a chamber which was infused with pyradine gas at high, low, or no volume (sham). During the following fifteen minutes, they rated the perceived intensity of the odor present. The older individuals in the low-volume condition were not able to recover from adaptation as well as the younger people. Thus, with impairment of the

sensory input system, it would not be logical to assume maintenance of the efficacy of the affected memory systems.

All of these differences in the forms of odor memory aid in explaining the differences in the results of previous research on memory for odors, as well as beg for reexamination of conclusions drawn by some past work. It is through this critical perspective that other issues of experimentation should be examined. The various forms of odor memory are experimentally evaluated in two most common task categories, odor identification and odor recognition.

Odor Identification

Theoretical Issues

Odor identification is an explicit, semantic task. In this task, odors are presented to a research participant who then retrieves an appropriate verbal label for the odor. This labeling typically comes from spontaneous identification (participant arrives at name without cueing, context, or prompting), multiple choice, or forced choice examinations. Cain (1982) found that most people are very confident of their abilities to identify common objects by their odors, although he has found that less than 50% correct identification in most circumstances of spontaneous identification (Cain, 1979).

The study by Doty, Shaman, Applebaum, Giberson, Sikorsky, and Rosenberg (1984) discussed at the beginning of this paper is an example of an odor identification task using a multiple-choice system. The University of Pennsylvania Smell Identification Test (UPSIT; Doty, Shaman, & Dann, 1984) that they employed is a scratch and sniff test of forty items, each of which is given four possible names. Considering the results of the UPSIT in light of the findings of Cain (1979) that spontaneous identification is so poor,

we are alerted to the differences in processing and recall of these types of testing doe to the needs of verbal naming.

Semantic Processing in Identification

There are limitations to the verbal naming of stimuli, and ability to identify items decreases with lack of familiarity. Rabin and Cain (1989) suggest that semantic processing is critical to odor identification based on their findings that familiar odors are more easily identified than unfamiliar odors when both are in mixtures. To allow for the limitations of familiarity, categorization is sometimes used. In an examination of semantic categorization using word groups (not odors), Brosseau and Cohen (1996) found that the 90 older and 90 younger participants in their study differed in the associations of category names presented. Although there were many similarities in most common responses, thirteen of the thirty categories presented had significantly different response profiles in relation to these most common responses. These differences lead Brosseau and Cohen to claim more than simple cohort effects to explain these. They conclude that the representations of semantic categories are different in young and old people, possibly caused by developmental differences affecting the quality of experience and knowledge.

Some researchers have attempted to compensate for differences in experience and knowledge, though to a minor degree, by ensuring that all stimuli used were experienced and named for the participants at the beginning of the study. In one such study, Larsson and Bäckman (1998) examined the source memory deficits in item memory as varied across modality. They utilized a strongly word-associated group of stimuli across the modalities of olfaction, audition, vision, and touch. Hearing was used as a control so that

all of the stimuli could be presented and named. The 66 participants in three groups (22 each) of young (M = 25.0 years), young-old (M = 65.9 years), and old (M = 75.0 years) were presented 40 items via the four modalities (hearing, hearing and olfaction, hearing and vision, and hearing and touch). Modality-mixed lists were used immediately after presentation, and again at a 48 hour interval. Vision, olfaction, and haptic (touch) presentation resulted in higher source-memory scores than audition due to the strength of lexicality of the items. There was higher source confusion for the items for both of the older groups, but the level of confusion was low among all participants. They concluded that memory for source information is selectively disrupted by aging and that age-related differences in source memory are not solely an expression of general impairment of episodic memory. These conclusions were corroborated by findings of Stadtlander, Murdoch, and Heiser (1998), although that study only encompassed vision and haptics.

One of the most important considerations for the Larsson and Bäckman (1998) study is the importance of context in memory. How odors are represented contextually is a key element to understanding identification, especially in light of the development of experience and knowledge described by Brosseau and Cohen (1996).

Context and Identification

Craik and Jennings (1992) suggest that the more closely associated an item to be remembered is to the context under which it is encoded, the larger the facilitation effects of the contextual cues as an aid in retrieval, especially for older individuals. These issues of cueing and contextualization have support from other modalities. In order to examine the impact of environmental cues and contextualization on memory for line drawings, Earles, Smith, and Park (1996) staged a two-experiment study. In the first experiment, 48

younger and 48 older individuals were placed in one of two rooms and asked to remember 50 pictures. They were then distracted by being moved to a waiting area to fill out questionnaires. Half of each group returned to the original room, the other half went to the opposite room. No environmental context effects were found between a plain room and a cluttered office.

In the second experiment, the participants (32 each, young and old) flipped 25 picture cards while hearing a sentence about the picture related to an item either within the room (item-integrated) or not (item-isolated). Again, they were distracted with clerical tasks, and half of each group brought was back to their original room. Those who were in the item-integrated conditions had markedly superior performance to those who were in the item-isolated group. The item-isolated group had no difference in contextual condition, whereas the item-integrated group benefited from the same contextual setting. This study demonstrated that people can use environmental cues to facilitate memory, but only when participants were forced to use environmental cues. These findings contrasted with previous findings (Park, Smith, Morrell, Puglisi, & Dudley, 1990) that older individuals integrated intratask content better than young people did. If we were to apply these findings to odor memory paradigms similar to Degel and Köster (1999), we would expect that the contextualization of olfactorial discrepancies that are appropriate within general classifications would not be encoded by older individuals, or that their memory token traces would have diminished retrieval potential. This would imply that older individuals perform less well on some tests because they are not encoding information they deem as contextually irrelevant. If this is the case, than most extant research has

taught us more about perceptions of relevancy for these stimuli than for memorial abilities of the older participants.

From this we can see that the most difficult component of the odor identification tasks is the access to appropriate names for the odors presented. These tasks assume that there is enough experience with the odors to have a reference for the research participants, whether prior to or during the testing. Regardless of sensory modality, older individuals perform less well than their younger counterparts on these tasks, but the effect can be lessened through contextual information provided to the participants. Not all odor memory tasks require naming the odor. Another of the most common tasks is the odor recognition, which may not explicitly require names or labels, but rather a more definite recollection of the stimuli as compared with other, similar stimuli.

Odor Recognition

Theoretical issues

Odor recognition is an explicit, episodic task in which odors are presented in a variety of sequences, and the participant must judge whether or not the particular odor has been presented before. This test of previous experience in the short-term memory stores does not inherently require verbal labeling, but covert labeling may occur, potentially either increasing or decreasing performance. Odor memory, like memory for other sensory modalities, tends to undergo labeling during encoding, whether overt or covert. This phenomenon was reported by Engen, Kuisma, and Eimas (1973), whose experiment employed spoken backward counting as a disrupter of odor memory. Their results were verified in a series of experiments reported by Murphy (1995).

Murphy's (1995) experiments investigated age-associated odor recognition memory with short delays (15 minutes and one hour), long delays (15 minutes, 2 weeks, and 6 months), short-term recognition memory (26 second delay), and short-term recognition memory with verbal distraction (backward counting). At all tasks, older participants performed below the levels of their younger counterparts. Her conclusions reinforced the basic proposition by Walk and Johns (1984) that odors are encoded through both semantic and perceptual means. Murphy's tasks could have been strengthened had she employed an olfactorial distractor as well as the verbal distractor, thus allowing an understanding of the relative strength of the two distractors. This would have allowed for further investigation into the basic question of the uniqueness, or lack thereof, of odor memory and its systems. This distinction would be very useful in understanding differences in accurate short-term versus long-term memory for odors. The question that would be asked is if unintentional distractors (i.e., normal sensory input from everyday occurrences) decrease appropriate recall from the various sensory systems.

From her work with face recognition, Maylor (1998) concluded that repetition priming may be relatively unaffected by aging over short retention intervals (40 minutes, including the repetitions) but not over a very long retention interval (22 months). As this is contrary to the basic propositions of Engen (1991) that the limited interference from other modalities accounts for the retention of longer-term memory traces, it is an excellent choice for further investigation that may lead to a deeper understanding of the multimodal nature of cognition and memory.

Contextualization of odors may also prove a useful avenue of research in the realm of recognition. The work of Doty, Shaman, and Dann (1984) and Douek (1974) could be expanded to examine the appropriateness of environmental cues in more naturalistic settings. A basic suitable paradigm would be that which Biederman (1987) used for his contextualization and categorization experiments on human vision. If olfactory identification was demonstrably facilitated by context-appropriate cues, then some of the unknowns of human olfactory memory encoding could be explained in terms that the prevalent vision-oriented research could support.

Short-term odor memory

In his commentary on short-term memory for odors, Engen (1991) illustrated short-term memory with the example of looking up and dialing a telephone number. After discussing classic experiments on memory using trigrams (sets of three consonants, such as GKB or MRQ), he stated that:

> …remembering odors and verbal codes are quite different tasks. Unlike trigrams and names, odors are affected less by the passage of time. On the one hand, keeping an odor in mind is simpler because it does not require verbal monitoring, but on the other hand, odor memory does not have the advantage afforded by verbal encoding and thus is not as accurate as the memory of a trigram or telephone number (p. 34).

Thus, the simplicity of non-semantically aided olfactory imagery makes the image harder to encode but more permanent. According to the short-term/long-term dual system view of memory, a memory trace begins to decay as it moves from short-term to long-term

memory, assuming it is successful in that transition. This means that the perceptual details should be more difficult to maintain as working memory reaches capacity. In an experiment on visual contrast, Hitch, Brandimonte, and Walker (1995) found that the passage from short-to long-term retention intervals reduces the probability that a visual trace maintains sensory features. These sensory features are critical in perception but are not necessary for long-term memory. Thus the basic categorization of a stimulus would be remembered, but the ancillary components that make it unique will probably be lost in transition. This proposition would allow us to accept that during rapidly ordered olfaction testing, some of the more subtle qualities of the odorants would be lost to long-term memory, thus increasing the probability of misidentification into broader categories with similar structural composition.

Engen's (1991) work has allowed for the formation of a question of whether odor memory is a separate and distinct memorial system or if it relies predominantly on common and open memory systems, as in the model proposed by Baddeley (1986). A recent study on short-term memory for odors compared the content and order of stimuli (White & Treisman, 1998). Their series of three experiments were designed to discern cross-modal retention using words and odors. In the first experiment, they examined the reaction times for item recognition and order recognition of names of odors. The second experiment repeated the procedure, but with random consonants instead of odor names. The third experiment used odors in the procedure, but with a decreased number of stimuli (5 instead of 10 or 20, respectively). White and Treisman contended that there is an olfactory short-term memory but without the primacy that arises from differential rehearsal that occurs in verbal memory. They further argued that this odor memory is

capable of incorporating verbal labels but is not dependent on such and, thus, is a separate system.

There are many avenues of future research that are needed on odor memory and many aspects of odor memory that could aid in the solution of questions in other areas. The independence of odor memory is realistically a minor issue but could aid in determining the relative contributions of each sensory modality to memory. This information would then allow for more precise investigations of influences of age-related changes. One pragmatic question affecting numerous older individuals is whether there are changes in behavior due to loss of short-term odor memory. Decrements to this modality would impact nutritional intake, for better or worse, as well as danger signals, such as gas leaks.

For example, Pelchat (1994, 1997) hypothesized that decreases in olfaction and age-related changes in cognition can bring about decreased aversions to specific foods, thus resulting in changes in older individuals' eating behavior. Schiffman and Warwick (1989, 1993) found the same phenomenon yet with opposing results due to differing context. In their studies, some instances of geriatric anorexia could be reversed by amplification of the olfactorial components in foods. Whether this is due to the sheer strength of the odor or the aid it provides individuals in identification of the odor is not known. If we knew that various pathologies or injuries have limited the abilities for short-term memory for odors, then this understanding would aid in explaining the variability of interventions to aid in overcoming physical sensorial abilities.

Long-term odor memory

Studies of long-term memory typically involve learning a list or sequence of target odors, then after a period of time, deciding if a presented odor was part of that list or sequence. Studies by Engen and Ross (1973) and Lawless and Cain (1975) found that initial memory for odors was 75 and 85%. This veridicality rate may not be impressive to scientists studying vision and audition, but it should be noted that after one month, recognition for odors was still 65% and 75% respectively and above chance after one year. Lawless and Engen (1977) compared 12 sets of pictures and odors to investigate interference in odor memory. Their results indicated only proactive interference, and they concluded that memory has a narrow but strong associative structure. This narrow throughput of sensation may be partly due to the slow physical structure of the olfactory bulb compared to other sensory systems. This would become more difficult a proposition to examine with age, as there are age-associations speeding olfactory adaptation to odors and slowing of recovery (Stevens, Cain, & Oatley, 1989).

In Murphy's (1995) experiment on recognition memory with long-term delay, familiarity greatly increased the abilities of older participants to remember odors and faces after 15 minutes, two weeks, and six months. She posited that the increased efficiency of those individuals who performed better on the tasks were those who self-initiated semantic encoding of the odors. Under a timed paradigm, however, this task would prove very difficult for older individuals due to limitations of and declines in cognitive processing speed and the capacity of working memory.

Although these tasks have not yet been performed with olfaction, we can examine the results from studies on other sensory modalities. In research into mediators of long-

term memory across the life span, Park et al (1996) documented the decreases in long-term memory that accompany aging. These decreases were attributed to the inter-relations of cognitive processing speed and the capacity of working memory, both of which tend to decrease during aging. Although their study examined spatial, cued, and free recall of words and numbers across a three-day period, some of the same cognitive processes utilized in their tasks would impact the abilities to remember odors, as discussed earlier.

Future work on long-term odor memory should explore changes in efficiency and strategies of encoding odors into memory stores. Schab (1991) suggested that the longevity of odor memory may be related to the holistic nature of odor memory encoding and the resultant resistance to interference but does not address the relatively low efficiency of encoding among older adults. One of the most likely interpretations that could come from the interference reported in the literature (e.g., Murphy, 1991) is aligned with the "failure to inhibit" scenario described by Stoltzfus, Hasher, and Zacks (1996). Murphy (1991) provided anecdotal evidence of this inhibition failure with her descriptions of the odors bringing forth Proustian memory episodes (see discussion of Marcel Proust earlier), in which the odors elicited such strong memorial and emotional responses that testing was disrupted.

Questions of ecological validity need to be addressed in olfaction research. These include questions of odor memory in various living conditions (e.g., institutionalized vs. community dwelling elders), pathologies, medical interactions, and cognitive status of the participants in the research. From this, we can determine the most appropriate strategies for remembering and identifying odors and other sensory stimuli. For example, Lyman

and McDaniel (1986) instructed participants to use specific strategies to remember odors over a seven-day period and found the different strategies to be successful under specific circumstances. This is important for full comprehension of the mechanisms involved. However, we must investigate what the natural strategies are that individuals employ and might use despite instructions to do otherwise. This might aid in the understanding of the vast heterogeneity of abilities among older participants.

Summary and Conclusions

The goal of this review has been to discuss recent advances in the understanding of age-associated changes in olfaction in view of work in pathologies that affect the olfactory nerve and perception. The decreases in olfactorial abilities often accompanying these age-associated pathologies require additional research on not only the similarities of various conditions, but of their relationship to declines in nonpathological aging populations.

From the data presented, it is clear that there is common to find loss of olfactorial abilities with aging. Previous reports have often dismissed these losses as a normal part of aging without questioning the causes or examining more than single dimensions of change. Many studies examining olfaction and age have failed to consider the most common causes of these decreases, including physiological factors like trauma or chemical imbalances as well as cognitive deficits and instead attribute all losses to aging. Within the realm of cognitive deficits, a variety of memorial systems may need to be examined to explore issues of precisely what the deficits may be and what is causing them.

In an ideal experimental model of aging and olfaction, there are several salient factors to be addressed. Considerations of who participates are essential. To maintain ecological validity in a general aging study, the participants need to include a large variety of participants, including those with pathologies, pharmaceutical use, nutritional deficiencies, relevant employment histories (i.e., industrial exposure to caustic fumes, etc.), and other concerns. These concerns, however, need to be controlled for. The testing employed must consider contextual variables and lexicality effects of the stimuli without giving any cohort an advantage. The procedures used must also be attuned to the specific facet of memory that they are examining, not just addressing some ephemeral, amorphous memory variable.

Although there have been many excellent studies dealing with the topic of aging and olfaction, there are methodological issues that prevent most studies from answering important questions concerning the reasons for the diminishment of abilities that most extant research has found. For example, it is surprising that the screening procedures of few studies have included questions about pharmaceutical use of participants. Ship and Weiffenbach (1993) reported that general medication use did not statistically influence olfactory abilities, but they did not examine differences in specific drugs. Not all pharmaceutical products influence olfaction, but many broad categories do (PDR, 1997). One classification that typically influences olfactory abilities is anticholinergics. This classification of drugs affects olfaction directly by drying and decreasing mucosa (cf. Astor, Hanft, & Ciocon, 1999) as well as by causing or exacerbating cognitive impairment (Gray, Lai, & Larson, 1999). As certain anticholinergics are typically prescribed to treat conditions such as Parkinson's, research into this area must consider

these effects carefully to avoid misinterpretations (Doty, 1992; Doty, Deems, & Stellar, 1988; Wenning, Shephard, Hawkes, Petuchevitch, Lees, & Quinn, 1995). These particular drugs are a good example, as they are not only taken in PD, but a wide variety of other circumstances as well.

Blazer, Federspeil, Ray, and Schaffner (1983) reported multiple anticholinergic drugs being taken by many older people with alarming prevalence. This rate of usage is not only dangerous because of toxicity, but also because drug-drug and drug-food interactions can have negative effects on cognition and mood. Schiffman and colleagues (1997) recently reported that multiple pharmaceuticals can also cause deficits and distortions in taste. Pharmacological use and side effects may aid in explaining the uniformity of chemosensory losses (Cain & Steens, 1989). A vital facet is missing if these pharmacological interactions are among the primary influences on age-associated changes in odor memory but are not included in the study design. To assess the impact of pharmacology on aging and olfaction, it must be considered at least in screening participants. The most appropriate use of pharmacological status of research participants would be to factor in the specific drugs into the analyses, thus allowing us to distinguish between the changes caused by them and by other factors.

Beyond the questions of pharmacology, if decreases in working memory capacity and speed force older adults to prioritize sensory stimuli, then the ecological validity of much extant research on aging and odor memory may be called into question. Unless specifically controlled for with appropriate tasks and instructions, the older adult may enter a state of divided attention in which sensory encoding and retrieval would be affected (see Craik, Naveh-Benjamin, & Anderson, 1998). This control would consider,

for example, the instructions, timing, and any choice alternatives for odor names. For example, in such a divided attention scenario, the instructions could potentially be a source of such concern to the participant that more processing effort is expended on ensuring conformity than is expended on performing the task. The divided attention theory would also support the contention of Bacon, Bondi, Salmon, and Murphy (1998) that many putative normative studies of olfactory function have failed to exclude preclinical dementia cases, thus overestimating variance and effects of age while underestimating mean abilities within age groups.

To aid in preventing attentional division and wandering, Baddeley and Andrade (1998) suggested the use of verbal suppression techniques. Such techniques, usually involving the voiced repetition of a single word or sound, can mediate lexicality effects without too much effect on working memory. Thus, to assess the impact of lexicality on sensory memory, the most likely course of action would be to run a pair of tasks, one with verbal suppression, the other without. Any differences between the two tasks would then be strongly associated with lexicality. Such examinations would assist us in better understanding the degree of separation between and interdependence of the various sensory modalities and their respective memory systems. One way in which this understanding may be increased is in the creation of a model of odor encoding similar to that which exists for other sensory modalities. Without a reference, like phonemes, morphemes, geons, etc, it is difficult to discuss similarities and levels of difference between odors other than by the classification of the odors as perceived by the experimenters.

Larsson and Bäckman (1998) reported that the statistical control of odor naming resulted in the elimination of age-related odor memory deficits. They inferred that age-related failures in accessing specific semantic information largely determine age-related deficits in episodic memory. This position would agree with that of central processing deficits (commented on in the sections on pathological states) that the association between age and decreased olfactorial abilities is less a matter of physical ability to receive the sensory signals and more about decreases in ability to recognize and process those signals. Support for this notion comes from a recent meta-analysis of olfactory functioning in AD and PD (Mesholam, Moberg, Mahr, & Doty, 1998) showing similarities in olfactory disturbances among all of the neurodegenerative diseases that affect central processing abilities. By studying pathological states in aging, we have a chance of gaining insight into normative aging.

In a recent study, Larsson, Semb, Winblad, Amberla, Wahlund, and Bäckman (1999) took this basic information and tested the olfactory thresholds and identification abilities of 11 women with AD compared with 11 non-AD controls. The relation between level of dementia and ability of identification was significant, but the ability to detect odors on the threshold task was not, thus further strengthening the position of age-associated decrements as being predominantly in central processing capabilities. This information also strengthens the position that changes in olfaction across the lifespan are not inherently different from other sensory modalities. Rather, it infers that the lexical load on olfaction limits most psychometric testing more than for other sensory modalities. The lexicality effect combined with physiological limitations on adaptation and recovery limits abilities to employ automaticity on olfaction as in other senses in later

adult life. These limiting factors aid future research by tempering any hopes for some "silver bullet," a specific odor or odor category that might show deficits only in the specific disease states (e.g., AD, PD) or other conditions and circumstances. The study of other pathological states in olfaction may also aid in the discussion of how environmental influences impact the peripheral nervous system in various ways.

If we were to understand the variations of impact of trauma on these systems, we might achieve parity for olfaction research with that for other sensory modalities. To truly discern the origins of decline, the best approach is the multimodal approach, as has been taken by Razani, Chan, Robideau, and Murphy (1997), Herz (1998), Stevens, Cruz, Marks, and Lakatos (1998), and Larsson and Bäckman (1998). Such an examination would allow the detection of relative changes in each sensory system and indicate whether changes are central or peripheral in the nervous system or in central or peripheral processing. It is also imperative that the relation between olfaction and the nutritional deficiencies that commonly and severely affect older people (e.g., dehydration and vitamin deficiencies such as A, B_{12}) are investigated. Neglecting such simple, yet vital issues would negate the possibility of developing true research parity among the sensory modalities.

Parity of the research abilities achieved through such multimodal investigations would open the possibility for true comparison of the sensory systems. Once such as comparison is achieved and issues of deficiencies and pathologies have been controlled for, the issue of Baltes and Lindenberger's (1997) common cause hypothesis may be addressed in a complete and meaningful sense. It would be possible to negate the issues of differing sensory loads or lexicality effects of the various stimuli that limit true

comparisons at this point. This type of testing would allow for a settling of the debate over the common cause theory versus the aging-induced cognitive load hypothesis which considers relatively simple sensory tasks to increase in cognitive complexity and demands as participants age. By maintaining comparability of stimuli across the sensory modalities when stimuli were adjusted relative to their absolute thresholds, changes in performance across all modalities would be more indicative of the common cause stance. Specific deficits in sensory systems which the individual's experiences have developed lower automaticity effects, such as olfaction and possibly haptic sensation, would be supportive of the aging-induced cognitive load hypothesis due to the relative changes in demand characteristics for these sensory systems.

To evaluate the demand characteristics in a truly comparative fashion, an experimental procedure would need to be developed in which all of the sensory modalities tested are presented with comparable stimuli in as close a presentation method as possible to reduce confounds. The most difficult aspect of such a proposition is the assurance that the stimuli presented are actually comparable and not different levels of difficulty due to novelty and automaticity. Due to the constraint on serial presentation of stimuli, the olfactory system would need to be considered as the standard for the design of such a project. Thus, the most likely choice would be a serial recognition task, rotating modalities to avoid sensory fatigue and inuration. Such as experiment could be designed to avoid the ceiling effects of the younger participants and avoid acquisition time confounds while controlling for attentional allocation and division of attention. One of the major drawbacks from such a study, however, would be an inherent advantage for

younger individuals who do not utilize and depend upon contextual information as much as older people do.

Studies which can integrate comparable contextual information into the various sensory modalities are another example of much needed research which would contribute to the understanding of age-associated changes in cognition and memory. Such work would require cues that can have context, yet not give advantage to specific cohorts. Much of the difficulty in such a proposition is how to address cohort-neutral context and still ensure that the specific systems or processes intended are being tested.

Before such far-reaching multimodal studies could be undertaken, there are still more basic issues to be addressed. A salient point would be the examination of relative efficacy of memories under circumstances of recognition versus identification. Such inquiry would explore the relative contribution of lexicality effects on memory retrieval. One task would investigate the relative abilities of forced choice odor identification in individuals across the lifespan. By having a forced choice paradigm, some of the experiential advantages of older individuals might be lessened while not giving an advantage to younger participants for processing demands of recall of a large number of odor names for the presented stimuli. In the other task, a series of tasks involving the recognition of odors that are difficult to label could be employed to contrast the identification tasks with their rich lexical information. It would be essential that a broad spectrum of ages were represented in such an experiment. The stimuli chosen would need to be cohort-neutral and selected to avoid ceiling effects in all participants.

In summary, there are typically declines in olfactorial ability with aging, but these declines are not uniform in type or severity. Little is known about the causes of these

declines, but they can interfere with encoding and recall of memory traces. However, evidence is beginning to demonstrate that the preponderance of deficits are cognitively based. Further, across the lifespan, people compile a fluency of odors that can be named along with stimuli for other sensory modalities. As with the other modalities, as olfactorial sensation declines, so does access to appropriate lexical tags for the stimuli. The questions that must be asked include the sources of loss, how to prevent these losses, and what possible remediation might exist when losses have already occurred. The studies that will answer these questions have yet to be performed, but the technology necessary to perform them does exist.

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CHAPTER III

INFLUENCE OF MOOD STATE ON OLFACTORIAL MEMORY ACROSS THE ADULT LIFESPAN[2]

[2] Elsner, R.J.F. 2001. Submitted to Food Choice and Acceptability, 4/19/2001

Abstract

This study explored the influence of mood on various types of odor memory. All participants were assessed for baseline depression using the CES-D, cognitive status using the MMSE, and olfactory thresholds using ascending staircase procedures with phenethyl alcohol and menthol (separately). Ninety-eight participants in three age groups (Young, M = 41.29 years, SD = 5.04; Middle, M = 59.05, SD = 6.52; Older, M = 76.83, SD = 4.84) were randomized into three mood manipulation conditions (positive, neutral, and negative). Mood manipulation was accomplished using an extended Velten technique. Odor discrimination, identification, and recognition memory tasks were performed. Recognition memory was most affected by mood state, with positive affect increasing olfactory ability and negative affect decreasing ability.

Introduction

Several researchers have demonstrated the high level of accuracy with which infants can recognize the odors of their mothers' breasts and milk (e.g., MacFarlane, 1975; Porter, Cernoch, & McLaughlin, 1983; Schleidt & Genzel, 1990). This remarkable ability has been demonstrated in infants as young as four or five days who can differentiate between the milk of their mothers and that from a cow or another human (Schaal, 1988a). Likewise, olfaction can be used by mothers to recognize their neonates (Porter, Cernoch, & McLaughlin, 1983). According to Schaal (1988b), odor recognition becomes a facet of motivation that changes and develops through the entire lifespan.

In the well-known *Swann's Way* by Marcel Proust (1934, orig. 1913), this association between odor and emotion is explored in a way that is understandable to most

people and is widely cited in describing the powerful emotive potential possessed by odors. Proust is also an excellent demonstration of the retrospective elicitation of memories by olfaction and the depth of emotional processing that accompanies this sensory modality. The basic behavioral-cognitive relationship described in this literary work as pertaining to the adult lifespan is supported by empirical work on the stability of olfactory sensitivity through the lifespan (Rovee, Cohen, & Shlapack, 1975).

Affect and memory have been intimately linked to odors by research as well as literature and anecdotes. Vernet-Maury, Alaoui-Ismaïli, Dittmar, Delhomme, and Chanel (1999) measured autonomic nervous system parameters and indices for basic emotions as participants were presented with odors. They concluded that odors have the ability to elicit basic emotions of varying intensities, although these may be mediated by experiential factors. Ehrlichman and Halpern (1988) demonstrated the use of odorants as a mood induction tool in order to minimize the potential cognitive involvement that accompanies most mood-induction procedures. Thoughts and reflections can vary with mood state, potentially interfering with other possibly more relevant thoughts typically examined in empirical investigations (Ellis & Ashbrook, 1988; Ellis, Thomas, McFarland, & Lane, 1985; Seibert & Ellis, 1991). Pliner and Steverango (1994) found that mood had a significant effect on memory for flavors, which has the potential to be a nutritional risk factor in the general population if the changes affect food acceptability.

One of the most immediate nutritional risks associated with mood is weight loss in depression. Russ and Ackerman (1988) discuss the mechanisms of weight loss during depression and conversely, weight gain during antidepressant use. They describe scenarios in the neurologic pathways of olfaction and affect that tie together to influence

appetitive mechanisms that require further investigation. Settle and Amsterdam (1991) provide an extensive review of depression and its deleterious effects on the chemical senses.

Although there are numerous instruments for assessing levels of depression, few have been validated across age cohorts and cultures. The Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977) has been validated for use with a number of diverse age and cultural groups. These groups include older adults (Arean & Miranda, 1997; Gatz & Hurwicz, 1990), adolescent mothers (Wilcox, Field, Prodromidis, & Scafidi, 1998), American Indians (Dick, Beals, Keane, & Manson, 1994), Caucasians, Blacks, and Hispanic populations (Arean & Miranda, 1997), in rural communities (Husaini, Neff, Harrington, Hughes, & Stone, 1980), and in many other groups. Versions have also been translated and validated in France (Paterniti, Dufouil, Bisserbe, & Alperovitch, 1999), China (Cheung & Bagley, 1998), Indonesia, North Korea, Myanmar, Sri Lanka, and Thailand (Mackinnon, McCallum, Andrews, & Anderson, 1998).

Gatz and Hurwicz (1990), using the CES-D, found that although older individuals may not be more depressed than the general population, they lack many of the positive feelings that their younger counterparts express. This finding is a key consideration when discussing the environmental validity of research on depression and memory. Burt, Zembar, and Niederehe (1995) employed meta-analytic procedures to examine depression and memory impairment. Their results showed that depression and memory are clearly related, although the causal mechanisms underlying this relationship are not known. One counterintuitive finding was an inverse age association and severity of

impairment. “For both recognition and recall, significant age effects indicated a greater association of impairment with depression in younger relative to older patients” (p. 295).

Burt et al. suggest four possible explanations for this unexpected effect. First, type of depression (including early-onset predisposition), medication, and other moderator variables may overlap or confound the effects of age. Second, comorbid physical illness and other factors (e.g., underlying white-matter brain abnormalities, inpatient status, malnutrition) complicate late-onset depression, and depression may be accounting for a larger proportion of cognitive variance in younger patients. Third, floor effects for some indicators may be caused by other age-associated memory-impairing factors, such as declines in sensory ability, failure to inhibit, cognitive slowing, etc. Finally, they suggest that older adults may have heightened automaticity effects for strategy implementation that younger participants may not yet have developed. Thus, depression may differentially diminish performance mediated by the strategies developed over a lifetime.

Fox, Knight, and Zelinski (1998) eloquently stated that the importance of depression in the older community is well-recognized in the literature because of the number of people affected as well as the potential severity of debilitation. They contend that there are methodological issues that must be addressed in depression studies, most importantly the lack of random assignment to groups. Without random assignment, too many other variables are left uncontrolled that may account for any observed changes in performance on various measures.

A method to control for these confounds and utilize random assignment was developed by Velten (1968). In the Velten technique, participants read statements silently, then out loud, for a total of 60 sentences read by each participant. These

statements fall into three categories: elation ("This is great—I really do feel good—I *am* elated about things"), depression ("I have too many bad things in my life"), or neutral ("Utah is the Beehive State"). Velten determined the effectiveness of the mood manipulation using the Multiple Affect Adjective Check List (MAACL; Zuckerman & Lubin, 1965) and found it to be effective. Although the efficacy of this procedure has been criticized (e.g., Buchwald, Strack, & Coyne, 1981), and questions about the depth of processing of such non-significant affective manipulation have been raised (e.g., Costanzo & Hasher, 1989), this procedure is generally considered to be efficacious (cf. Finegan & Seligman, 1995). Fox et al. (1998) evaluated the efficacy of mood induction techniques such as the Velten technique in older adults using the CES-D and concluded that there was clear support for their effectiveness.

In the current study, the issue of age-associated changes in olfactorial ability as mediated by emotional mood state was examined in perspective with other lifespan accumulations of experience, such as environment, disease, and medications. The original hypothesis was that these mood state differences may be larger than those accounted for by age group, especially in the depressed state. Younger participants typically show superior performance in positive mood states across episodic memory tasks but not across semantic tasks. Participants in the negative affect state usually exhibit the worst memory performance for both episodic and semantic tasks, and the hypothesis for olfactory ability maintained this relationship. As memory is not a single factor, several memorial tasks were included to view specific changes in odor memory across the adult lifespan.

Method

Participants. A total of 98 healthy, community-dwelling adults volunteered to participate. Participants were recruited by word of mouth from several social groups and retired faculty. Each participant was assigned a randomly determined three-digit identification number to maintain confidentiality of information and results. Information about the participants appears in Table 1. There were no marked differences between the groups, although the younger participants had a higher index for depression according to the CES-D, the predominant score was well below clinical thresholds for depression.

As these participants were recruited in a college town, the educational levels were extremely high. For the 98 participants, there were 33 doctorates, two specialists, 26 masters, 33 bachelors, and two professional nursing degrees (associate level). The level of education was distributed across the age groups.

Design. This experiment was a 3 (age: young, middle, and older) x 3 (mood state: positive, neutral, and negative) x 3 (memory task: recognition, identification, and discrimination) factorial design. Other factors indicated by previous research as being vital components were assessed, including environment, pharmacological use, and cognitive status. These factors were evaluated in independent analyses to validate previous research (i.e., Appendices A & B) as well as ensure appropriate interpretation of the current primary variables.

Procedure. All participants were tested individually in the meeting house of a local church. Participants were given time to acclimate to any odors in the house before olfactory testing commenced.

Age, environmental history, and pharmacological use were evaluated in a structured interview prior to olfactorial testing. This structure for this interview appears in Appendix C. Cognitive status was assessed with the Mini Mental State Exam (Folstein, Folstein, & McHugh, 1975). To assess verbal proficiency and examine possible lexicality effects, the WAIS Vocabulary test (Wechsler, 1944) was administered. Since mood was manipulated in this experiment, a baseline measure of depression was established using the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). These instruments appear in Appendix D.

Olfactory thresholds were then evaluated using phenethyl alcohol, a pure odorant, and menthol, an odorant that stimulates the trigeminal nerve as well. Baseline assessment of olfactory abilities before mood manipulation allows for assurance against confounds of ability.

After these tests were administered, the participants were given 60 Velten statements to read, once silently, then aloud, to place them into the appropriate temporary mood state. Participants were then randomized into the recognition, discrimination, or identification tasks. As the olfactory battery requires a significant amount of time to complete, participants were asked to read an additional 24 statements at two regular intervals during the olfactory tasks to reinforce the appropriate mood state. Pilot testing had demonstrated no advantages of unilateral contraction of hand muscles (cf. Schiff & Lamon, 1994) or face muscles (cf. Schiff, Guirguis, Kenwood, & Herman, 1998). Unilateral breathing as a mood modifier (cf. Schiff & Rump, 1995) possessed too many confounds for an olfaction study, especially in light of previous work on laterality effects in odor memory (Bromley & Doty, 1995). .

Olfactorial stimuli. All stimuli were placed into separate sealed, opaque 20ml polyethylene bottles, thus assuring a consistent amount of headspace relative to the desired level of aromatic concentration. Bottles were labeled with three-digit numbers in order to assist in making this a double-blind procedure.

For each task, five ml of each stimuli were presented inside gauze-wrapped cotton balls within opaque polyethylene jars with odor-tight lids. The gauze and cotton balls allow for obstruction of visual cues from the stimuli without obstructing airflow. All samples were presented at nose level after instructions to take a "natural" sniffs (i.e., not “strong” or “weak” sniffs; Mozell, Hornung, Sheehe, & Kurtz., 1986) of the stimuli. Olfactory instruments for all tasks appear in Appendix E.

Tasks. A total of four olfactory tasks were employed. First, all participants were given an odor detection threshold task, then were randomly assigned into one of three tasks. The three memory tasks were odor recognition, discrimination, and identification.

Detection Threshold. The odor detection threshold task used was a two alternative (test stimulus and control) forced-choice ascending concentration single series procedure. The stimuli presented during this task were menthol dissolved in light odorless mineral oil and phenethyl alcohol (PEA) dissolved in deionized water. A placebo of de-ionized, distilled water or light odorless mineral oil was used. This task evaluates the physical abilities to detect an odor, as well as cognitive resources for perceiving the odor.

Ten concentrations of each odorant were offered in a dilution series from neat (undiluted), with a dilution factor of 3 for both odorants in their respective solutions. Participants were asked to determine which of the two samples (test and placebo) presented in each pair had a stronger odor and to describe the odor (if possible). The

assumed level of ability was the lowest of any three consecutive correct responses. Scoring of the thresholds was on a ten point scale, with one indicating detection at the lowest concentration and ten indicating detection at the strongest concentration in the series.

Odor Recognition. This task examined ability to recall a difficult to name odor that is from three forced-choice alternatives. Odor recognition is an episodic test of memory and, thus, may be the most likely to show declines associated with aging (Kausler, 1994; Light, 1991; Salthouse, 1991). This form of memory requires the conscious recollection of previously experienced events or stimuli acquired at a particular place at a particular time.

Engen, Kuisma, and Eimas (1973) employed spoken backward counting as a disrupter of odor memory. Their results were verified in a series of experiments reported by Murphy (1995). For this reason, as well as to clear the air in the nasal cavity, this procedure was employed in the current project. Participants sniffed one odorant in a single bottle, counted backward aloud from ten to one, then sniffed all four of the distracter odorants in their respective separate bottles and designated which was identical to the odor they had been asked to remember. The odor recognition task was repeated a total of ten times with breaks between iterations, three of which were to read Velten cards. These breaks were included to prevent speeded age-associated olfactory adaptation and slowed recovery of the olfactory epithelium (Stevens, Cain, & Oatley, 1989) by allowing a time without direct stimulation of the olfactory epithelium. This release from time-dependent measure was intended to increase the environmental validity of the research. The odor recognition task used eight odorants. These include: geraniol (floral),

citral (lemony), citronellal (medicinal), guiacol (burnt), methyl salicylate (wintergreen), n-butanol (oily/chemical), benzaldehyde (berry/almond), and caproic acid (pungent).

Odor Discrimination. The odor discrimination task presented pairs of odors that were identical or different compounds. Participants were instructed to ignore the intensity of the odors and concentrate of the qualities of the odors to discriminate between the two as same or different. Identical pairs were composed of: benzaldehyde, caproic acid, n-butanol, citral, guiacol, phenethyl alcohol, and methyl salicylate paired with themselves. Pairs of different odors were composed of: benzaldehyde and caproic acid, n-butanol and citral, benzaldehyde and geraniol, geraniol and citral, methyl salicylate and caproic acid, and phenethyl alcohol and guiacol. Twenty trials were performed.

Odor Identification. As familiar odorants have been shown to be more easily identified than uncommon odorants (Schab, de Wijk, & Cain, 1991), the stimuli used in the identification component of this study were common odorants derived from previous research (e.g., Appendix B). The procedure is similar to that used by Schemper, Voss, and Cain (1981) in which participants were told the name of an odor, then presented with two samples and asked to judge which one was the odor that had been named. The pairs consisted of items from the following list: coffee, peanut butter, anise, mint, vanilla, cinnamon, honey, orange, fennel, almond, ginger, cloves, isopropyl alcohol, vinegar, apple, grape, garlic, lemon, coconut, rose, and molasses.

Results

Data analysis was accomplished using the SPSS system (version 10.0; SPSS, Inc, 2000). To prevent data entry errors, independent raters duplicated separate verifications of coding against the original data collection sheets.

Series of regression analyses were used to determine the between-group variability for the three odor memory measures based on age and mood state. Within group variability was also assessed. These memory tasks were then analyzed separately as dependent measures to age, environment, and pharmacological use both within and outside of the structure of the mood states. This analytic procedure allowed for further investigation into the relative influence of the mood states on the individual tasks and their underlying cognitive mechanisms. In order to assess the accumulated experiential components of environmental influence, a summative variable was constructed to assist in analyses. This summative variable enabled exploration of composite influence from environmental risk factors other than current or last employment while retaining statistical power.

Overall. Simple statistics for the participants in each experimental condition are reported in Table 2. Initial descriptive analyses showed no significant variation in demographic parameters of the participants except for military service, which was more prevalent among older adults. The overall uniformity of participants was important in this instance as to avoid educational and social confounds that can otherwise bias outcomes.

A correlation matrix for the data showed limited relationships among variables. This matrix appears in Table 3. Increased age was positively correlated with having smoked in the past ($p < .001$), more colds or other recent illness ($p < .04$), and more

medicine usage ($p < .001$). Pharmaceutical use reported by the oldest participants consisted primarily of aspirin and analgesics recommended by physicians. None of the participants used pharmaceuticals listed in the *Physician's Desk Reference* (1993) as having deleterious effects on olfaction.

A correlational relationship was found approaching significance for individuals who have had surgery in the past to have higher thresholds for menthol ($p < .06$), but not for phenethyl alcohol. As higher menthol thresholds were correlated to reporting of childhood allergies ($p < .03$), this would possibly tie into surgery for adenoids or other minor past surgeries. From the correlation matrix, older participants ($p < .02$) and those who were higher risk for environmental trauma ($p < .04$) enjoyed dining out less than did other participants. Although there was an average increase in threshold for PEA and menthol by age group, the average performance on the threshold tasks showed no significant difference between age groups. The current participants exhibited comparable performance with the results reported in Appendix B.

It was important to note that there had been no age-associated changes in thresholds for either PEA or menthol. There was, however, significant ($F = 4.91$ [1, 90]; $p < .03$) association with MMSE scores for the PEA threshold, although these only explained a small percent of the variation within that model ($R^2 = .05$, $p < .03$). As this did not hold true for the menthol thresholds, the meaning of this finding cannot be ascertained appropriately, but may be indicative of the broader pathways employed (trigeminal and olfactory) in sensing menthol.

To further delve into the question of thresholds before exploration of mood and odor memory, a regression model was tested in which age, medication, risk, CES-D, and

MMSE scores were treated as the independent variables to the dependent PEA and menthol thresholds. No significant relationship was found for either model (PEA- $\underline{F}$ = 1.73 [5, 90]; $\underline{p} < .15$; Menthol- $\underline{F}$ = .98 [5, 91]; $\underline{p} < .44$).

Memory for odors. Series of regression analyses were used to determine the between-group variability for the three odor memory measures based on age and mood state. Within group variability was also assessed. These memory tasks were then analyzed separately as dependent measures to age, environment, and pharmacological use both within and outside of the structure of the mood states. This analytic procedure allowed for further investigation into the relative influence of the mood states on the individual tasks and their underlying cognitive mechanisms. At the lowest level of analysis, it was expected that younger adults would slightly outperform older adults on memory tasks without accounting for any other variables. This, however, was limited in the findings. An important consideration for the examination of these results is the relative difficulty of the three memory tasks.

Anticipated results of the testing were that mood state would influence all olfactorial abilities exclusive of other variables and that the influence should be negative in the negative mood condition (c.f. Hertel & Hadrin, 1990). This hypothesis only held for the recognition task, wherein the negative affect state bordered on significance ($\underline{F}$ = 4.75 [2, 8]; $\underline{p} < .06$). When the baseline level of depression was considered from the CES-D, however, the relationship became clearer that there is an interaction between the age groups and adjusted affect level only in the recognition task($\underline{F}$ = 4.32 [5, 28]; $\underline{p} < .01$). As the three memory tasks are assessing different components of memory, they need to be discussed separately.

Discrimination. The discrimination task required an unfamiliar use of short-term memory for odors for many participants, thus accounting for the large variability of performance across all three age groups illustrated in Figure 1. The average efficiency was 62.64% correct responses (SD = 12.44). This figure demonstrates that while odor discrimination was statistically unimpaired by age, individual performance varied considerably, thus increasing the hypothesis that other factors besides chronological age influence this facet of memory.

An ANOVA of the factors anticipated to be of influence in this task, namely age, environmental influence, mood (adjusted for depression), medication use, MMSE score, and both detection thresholds, showed a lack of significance ($\underline{F} = 1.32$ [8, 30]; $\underline{p} < .28$). Primary regression analyses demonstrated an influence of PEA threshold on discrimination ability ($\underline{F} = 3.53$ [1, 33]; $\underline{p} < .07$) approaching significance. No relationship was found for menthol threshold and odor discrimination. Multiple analyses of variance (MANOVAs) were used to determine interaction effects in separate models. As anticipated by the research rationale, the full model examined performance as related to overall factors influencing the participants' olfactory effectiveness. The final model was selected by using backward elimination on the independent variable set containing age group, CESD, environmental impact, MMSE, PEA threshold, and risk at a 0.1 significance level. Mood was forced to remain part of the model, as this was the manipulated variable. The resulting model was:

$$\text{Discrimination}_i = \mu + \text{Mood} + \text{PEA threshold} + e_{i,}$$

where Discrimination_i is the Discrimination score for the i^{th} person, μ is the mean Discrimination, Mood is the increase or decrease in Discrimination associated with which

way a persons Mood was altered. PEA threshold is the increase in Discrimination associated with a one-unit increase in Discrimination. Values for this analysis are presented in Table 4.

We can see from Table 5 that mood approached significance, but was not a significant factor. The respective importance of the mean term Mood and PEA threshold to the model is shown by their t-values. None of the other variables was found to be significant at the 0.1 level. The full model originally accounted for 27.5% of the variability of discrimination scores as opposed to PEA threshold alone, which only accounted for 11.7%. However, after calculating the adjusted R^2, PEA threshold was found to be a better predictor of discrimination. A summary of these models appears in Table 4.

As the individual dynamics of the components are of interest in support of the hypothesis, a linear model report appears in Table 6. The t-values from the final model were then used to calculate the p-value from a corresponding t- distribution. A comparison of the full and PEA/Mood-only models appears in Table 7, showing the overall variability accounted for declined, but the significance was greatly increased.

Identification. All participants were familiar with the odors used in this study, unlike that reported in Appendix A where cohort-specific cultural issues prevented familiarity with some odorants. Although the identification task shows an age-association that was only marginally significant ($\underline{F} = 2.69$ [3, 33]; $\underline{p} < .06$), there is the highest level of veridical response among the three tasks (see Figure 2). The efficiency of responses was 79.26% correct (SD = 9.14). Unlike other identification tasks where no priming is

given, the primer of an odor name in this circumstance allows for highly efficient processing.

An ANOVA of the factors anticipated to be of influence in odor identification, namely age, environmental influence, mood (adjusted for depression), medication use, MMSE score, and both detection thresholds, showed a lack of significance ($F = 1.39$ [8, 32]; $p < .25$). As with the discrimination task, a better model had to be developed to discover the underlying influences in this task. The model was selected by using backward elimination on the independent variable set age group, CESD, environmental influence, MMSE, PEA threshold and risk at a 0.1 significance level. As in the discrimination models, mood-state was forced to remain part of the model, as this was the manipulated variable. The resulting model was:

$$\text{Identification}_i = \mu + \text{Mood} + \text{PEA threshold} + \text{Risk} + e_i$$

Where Identification_i is the Identification for the i^{th} person, μ is the mean Identification, Mood is the increase or decrease in Identification associated with which way a persons Mood was altered. PEA threshold is the increase in Identification associated with a one-unit increase in PEA detection threshold. Risk is the increase in Identification associated with someone having a high-risk job. Values for this analysis are presented in Table 8.

As the model did not show significance for the three variables of interest, only inferences can be drawn concerning the influence on identification abilities. Given the lack of significance, the relative predictive abilities of the components are muted, however, they are still presented in Table 9. Table 10 presents the linear model report of unstandardized and standardized coefficients. Table 11 presents the comparative

performance of the full model with the parsimonious model containing mood, PEA threshold, and risk as independent variables.

Although the significance is low, the models demonstrates a potential for related but unexplored factors to have predictive validity. As the difference between the full model and the most parsimonious models are minimal in regard to levels of significance, this adds to the impetus to assume other unmeasured influences are responsible for identification abilities. As lexicality effects are known to be important to identification, the WAIS vocabulary scores were also analyzed in this context. No relationship was found with WAIS vocabulary and odor identification ($\underline{F} = 2.16$ [1, 32]; $\underline{p} < .24$).

Recognition. The recognition task showed the lowest efficiency of the three, which was anticipated due to its intense nature (See Figure 3). The response efficiency was 58.33% correct (SD = 18.95). Significant differences were found with age in the recognition scores ($\underline{F} = 19.64$ [1, 29]; $\underline{p} < .001$), which is graphically represented and evident in Figure 3.

Factors anticipated to be of influence in odor recognition were analyzed by ANOVA. These factors namely age, environmental influence, mood (adjusted for depression), medication use, MMSE score, and both detection thresholds, were determined to be significant ($\underline{F} = 3.14$ [8, 26]; $\underline{p} <.02$), but with greatly varying contributions. A more detailed model was selected by using backward elimination on the independent variable set age group, CESD, environmental influence, MMSE, PEA threshold and risk at a 0.1 significance level. Mood was forced to remain part of the model, as this was the manipulated variable. The resulting model was:

$$\text{Recognition}_i = \mu + \text{Mood} + \text{Age Group} + \text{MMSE} + e_i$$

Where Recognition $_i$ is the Recognition for the i^{th} person, μ is the mean Recognition, Mood is the increase or decrease in Recognition associated with which way a persons Mood was altered. MMSE is the increase in Recognition associated with a one-unit increase in a persons MMSE score. Age Group is the decrease in Recognition associated with someone in the older age group. The output of this regression model appears in Table 12. A summary of the linear regression models appears in Table 13. As with the other tasks, individual dynamics of the components are of interest in support of the hypothesis, thus a linear model report appears in Table 14. The t-values from the final model were then used to calculate the p-value from a corresponding t- distribution. A comparison of the full and most parsimonious models appears in Table 15.

Although the effects were not directly related to the recognition scores, analyses (ANOVAs) revealed that there was a significant relationship between mood and age groups ($\underline{F} = 2.83$ [8, 29]; $\underline{p} < .03$) within this group, although not so in the other task groups. Similarly, relationships were found for mood and MMSE score ($\underline{F} = 4.20$ [5, 27]; $\underline{p} < .008$) and MMSE and CES-D scores ($\underline{F} = 9.98$ [3, 27]; $\underline{p} < .001$). Although these relationships may not show direct influence on recognition memory, they aid in the understanding of the complexity of the specific memory systems utilized in this task.

Discussion

While the narrow educational range of demographics describes this participant group as non-representative of the general population, it stands as an exemplary group of healthy, successfully aging people. Differences between the current work and epidemiological studies should be considered as a demonstration of population differences with minimal difficulties and pathologies versus truly normative studies.

In the study reported in Appendix B, environment and pharmaceutical use were demonstrated to be more powerful determinants of olfactory function and ability than age. The lack of conclusive evidence in this study is most likely due to the minimal medication use other than aspirin and other analgesics. The lack of odor-disrupting medications taken by this group may also contribute to the good performance on the threshold tests. Many of the drugs indicated in the *Physician's Desk Reference* (1993) as affecting olfaction do so through drying out the mucosal layer of the olfactory epithelium or manipulating specific neurotransmitter pathways, so the lack of these drugs in the participants' systems may indicate the importance of these points. Even the most at-risk participants in the study were not in situations as potentially detrimental to the olfactory epithelium as those who participated in the earlier study (Appendix B).

Contrary to previous findings (e.g., Appendix B) and most likely attributable to the excellent health and cognitive status of the participant group, the only direct relationship between odor thresholds and cognitive status was in the recognition task. As age groups were also predictive of ability on this task, there may be support for the need to consider indirect relationships within age-associated data sets. Indirect relationships are of special importance, as they indicate a more intricate relationship between sensation and cognition than may otherwise be considered (cf. Lindenberger & Baltes, 1995).

The interactions between MMSE and mood contributing to memory are in agreement with the capacity theories of working memory proposed by Salthouse (1991), although the lack of CES-D relationships does not. According to Salthouse, as capacity is limited (as indicated by MMSE), and resources are utilized on the cognitive, physiologic, or both levels by factors associated with depression (as indicated by CES-D), memory

should decrease. As the range of baseline depression scores indicated a very healthy population, this component could not be examined, yet allowed for this otherwise powerful confound to be removed from consideration.

Similarities between the final models for each task were not anticipated considering the different processing effort required for each of the tasks (cf. Hasher & Zacks, 1979). It would be unlikely that the results may be different than would be found in a broader population sample, although the influence of depression in a representative sample may show greater influence. The relative homogeneity of the participants who volunteered for this sample, especially in high educational attainment and good health, are not representative of the general population, but rather are exemplary of normative aging under good conditions.

Benedict, Dobraski, and Goldstein (1999) demonstrated links between mood and cognition in an older population, with negative mood being detrimental to cognitive performance. Although their work dealt with spatial processing and learning instead of olfaction, the overall effects of negative mood decreasing memorial abilities are similar. Hertel and Hadrin (1990) warned that positive mood condition may result in an increase in the memorial abilities of younger participants due to excitability instead of increased cognitive ability from mood itself. The current study cannot address the point of excitability directly, but lends some non-causal support to the basic premise in finding the converse: the oldest adults in the negative mood state condition performed worse than other participants across the three tasks, even if not to significant levels. An important difference from Hertel and Hadrin, however, is that mood did not independently impact memory performance in the current study.

Stoltzfus, Hasher, and Zacks (1996) suggest that decreases in older participants' performance are due to hyperactivation of memory traces and the failure to inhibit these effects. This would be a likely age effect based on previous research, but does not necessarily fit the current models. As only the recognition task was significantly associated with age, we cannot say that this is the case, although the differences in the three tasks do lend some inferential support to the basic premise. Recognition was the most processing-intensive of the tasks, thus would be most susceptible to the effects described by Stoltzfus, Hasher, and Zacks (1996). The current findings indicate the potential viability of further investigations of this topic, especially as through their support for the findings of other researchers in cognitive aging (cf. Kausler, 1994; Light, 1991; Salthouse, 1991), but also in affective resource allocation models (e.g., Ellis & Ashbook, 1988; Ellis, Thomas, McFarland, & Lane, 1985).

The relative contribution of mood state to age-associated change was expected to be small, but significant, and to explain additional variance beyond the effects of environment and pharmaceutical use. As this relationship was not found, other possibilities must be explored. As mentioned earlier, odor has been used to elicit mood changes in mood state (e.g., Ehrlichman & Halpern, 1988; Vernet-Maury et al, 1999), but the lack of converse relationship (i.e.: mood influencing olfactory abilities) is not improbable. In all three of the final models, there is a lack of relativity effects of baseline depression, as measured by the CES-D, with the Velten mood state manipulation upon the memorial abilities. Given that there was such a narrow range of medical and environmental influences, this places more attention on overall mood from the analytic perspective. Although there was a very narrow range of baseline depression scores with

no severely depressed individuals, these results support Engen's (1991) proposition that "odor stimulation activates the limbic system and a related circuitry of emotion and motivation" (p. 58), even if limited. Engen's proposition assumes that odor perception is predominantly bottom-up, with central brain control over the effects of odor stimulation.

Engen's proposition also assumes, however, that the limbic system integrates all the effects of odor stimulation with both hormonal effects and environmental experiences with odors. "In short, the limbic system is believed to be 'the smell brain'" (Engen, 1991; p. 59). This means that the impact of emotion on olfaction is different from the impact of emotion on vision or hearing in that there is an intrinsic link between the detection and encoding of olfactory stimuli and the emotive state of the organism. Thus, unexplained variance may also be due to changes in hormone balance that could not be controlled for in the present study.

For some individuals with sub-optimal detection thresholds, average or extraordinary performance on other odor tasks would most likely be associated with compensatory strategies developed across the adult lifespan (cf. Baltes & Baltes, 1990). As only one participant had poor threshold performance, and that only for PEA, this could not be directly tested here. Conversely, however, the findings support the proposition that appropriate compensatory strategies in other avenues of life have assisted in maintaining mental health and social resources. Their strategies, once imposed on their life course trajectories, may have also served in protecting or maintaining the physiologic structure of the olfactory epithelium to the extent that they retained their abilities.

Hultsch, Hertoz, and Dixon (1984) noted that although task and material variables play an important role in accounting for adult age-associated performance, a major

portion of variance may be due to subject variables. It is essential to recognize differences within individuals cannot be explained by the exogenous factors (e.g., environment) or endogenous factors (e.g., affect) explored. The levels of intra-individual performance are based on relative level of ability, in this case olfactory thresholds, while examining differences in memory and cognitive processing.

Pliner and Steveragno's (1994) use of the Velten technique to assess recognition memory for flavors is of great importance here. Although different from the present study in that they found large mood and memory congruency, they suggest that the memorial aspects of flavors, thus their constituent odors, are salient indicators of nutritional risk. Pliner and Steveragno used a representative sample in their study, while the present experiment employed very healthy and well-educated people. As Murphy (1985, 1986) demonstrated an increased potential for serious nutritional deficiencies with decreased olfactory ability in old age, this differentiation of healthy and representative samples becomes especially important in measuring relative risk.

Walk and Johns (1984) found that recognition memory for odors was best when participants free-associated target odor names, assuming that the primary memory traces are verbal. Their findings support the basic suppositions that memory for odors are governed by the same basic principles as for other sensory modalities, even if the lexical stress is very different between these modalities. Although recognition memory has a strong lexical component, the verbal lexicality is not as inherently powerful as that in identification memory tasks. As participants in the current study were instructed not to concentrate on naming the odors in the recognition task, but rather remember the overall quality of the odor, this has importance here beyond explorations of covert labeling. The

lack of significance of verbal ability to performance on these measures supports propositions of the underlying strength of covert labeling and short-term memory that does not require a phonoarticulatory-processing component.

Schemper, Voss, and Cain (1981) found that older adults had poorer identification abilities for odors than younger adults tested under free identification circumstances. Similarly, Doty and colleagues found the same age differentiation for multiple-choice priming tests of olfactory identification (Doty, Shaman, Applebaum, Giberson, Sikorsky, & Rosenberg, 1984; Doty, Shaman, & Dann, 1984). As the current identification task limited the lexical load by providing the name of one of the odors presented, the similarities between this and other identification tasks are limited in the underlying processes involved.

Larsson and Bäckman (1997) and Murphy, Cain, Gilemore, and Skinner (1991) suggest that deficits in odor recognition and identification by older adults may be largely attributable to cognitive limitations, especially vocabulary ability. Although they did not control for environmental or pharmacological histories, both research groups posited that vocabulary would be an optimal choice for examination of concurrent decline. This assertion is based on the understanding that odor identification is a semantic memory task in that it refers to an individual's general knowledge or experience with a specific odorant (Schab, 1991; Tulving, 1993). As the current results found that this is not necessarily the case, it may lead to conclusions that there is some separation of the various memory systems in the individual lexicons for stimuli maintained by each participant. Further, this evidence might mean that these individual lexicons may be able to access each other only to a limited degree. This possibility may prove vital in using odor identification and

recognition tasks in clinical settings, especially for diagnostic purposes (cf. Cain & Gent, 199; Doty, 1991).

The results discussed here have implications beyond the overt realm of psychology and will thus provide the basis for future research in basic and applied areas, including food science and nutrition, natural gas provision, workplace regulatory agencies, and pharmaceuticals. Schiffman and Warwick (1989, 1993) have demonstrated the effect of increased olfactory abilities on the nutritional intake of older adults on a rudimentary level. Griep et al. (1995) demonstrated the relationship between nutritional status and sensory thresholds for foods, although they did not include any intervention similar to that used by Schiffman and Warwick (1989, 1993). The next logical step would be to specifically design or modify food products to meet the needs of those who have suffered differing levels of environmental, pharmacological, or physical insult, injury, or depression in order to maximize acceptability and maintain or even increase functional status based on appropriate nutrition.

As changes in pharmaceuticals and working conditions have improved over the years, humans have been exposed to fewer toxins and corrosive agents. There is a heightened likelihood that future generations may have a better chance of retaining more of their olfactorial abilities due to this more protected environment. This allows for the potential of increased quality of life, partly due to better nutritional intake, as well as from fewer accidents with natural gas, food poisoning, and other areas where olfaction plays a vital role.

It is hoped that this research will also allow for more scientific investigation of affective elicitation that may be conducive to new product development in the personal

care and alternative medicine markets. The impact of odors as a tool for actually eliciting emotional response is in need of further research (cf. Ehrlichman & Halpern, 1988). It would be a dangerous proposition for laypersons to infer that the use of specific odors could elicit specific responses to the degree that long-term care facilities (LTCFs) all begin to smell like sandalwood and lavender to sooth and comfort residents. At best, such treatment would elicit the response for a short period before inuration occurs. At worst, there could be associations of those fragrances with the less positive attributes of the LTCF that override any pleasant associations, thus precluding future therapeutic odor interventions.

Baltes and Lindenberger (1997) found that there is a link between maintenance sensory systems and cognitive function. In the studies presented here we find support for their proposition, although with minimal causal inference. Those individuals with the best sensory performance seem to retain the best cognitive function, but it is also possible that the relationship is the other direction, that those who retain the best cognitive status retain sensory capability. Harrison and Pearson (1989) note that although olfaction is the "Cinderella of the senses" (p. 822), the potential for discovery of localization of pathologies within the brain through use of olfactory testing is well worth the examination. It is hoped that the work presented here will speed these researchers on toward further discovery.

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Table 1. Mean descriptors and Standard deviations for participants.

	Youngest		Middle		Older	
Age:	41.29	(5.04)	59.05	(6.52)	76.83	(4.84)
MMSE:	29.72	(0.45)	29.56	(0.86)	28.79	(1.32)
CES-D:	7.60	(5.09)	5.83	(5.09)	6.28	(4.80)
WAIS:	59.21	(7.19)	60.39	(6.65)	57.16	(5.96)
PEA threshold	2.90	(2.29)	2.95	(2.38)	3.10	(2.69)
Menthol threshold	4.42	(2.52)	4.65	(2.20)	4.40	(2.75)
Relative memory score (%)[1]	71.61	(13.44)	70.00	(14.62)	58.83	(18.74)

[1]Percent correct across all three tasks

Table 2. Means and Standard Deviation for selected indicators by experimental condition

	Discrimination Task			Identification Task			Recognition Task		
Variable	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive
Memory Score	12.09[1] (1.64)	11.92[1] (3.11)	13.64[1] (2.24)	15.41[1] (1.62)	15.91[1] (2.39)	16.27[1] (1.42)	5.78[2] (1.86)	5.8[2] (2.35)	5.91[2] (1.64)
PEA[3]	2.27 (1.64)	3.25 (2.66)	2.45 (1.57)	2.92 (2.02)	3.73 (3.00)	1.45 (0.82)	4.66 (3.27)	3.78 (3.07)	2.72 (1.95)
Menthol [3]	5.45 (1.81)	4.83 (2.62)	3.55 (2.29)	5.17 (2.79)	3.82 (2.79)	4.64 (2.29)	3.66 (2.00)	6.20 (2.74)	3.09 (1.44)
Risk	0.36 (0.51)	0.25 (0.45)	0.36 (0.50)	0.50 (0.52)	0.18 (0.40)	0.36 (0.50)	0.56 (0.53)	0.40 (0.52)	0.27 (0.47)
Medications[4]	2.45 (1.57)	2.00 (2.34)	2.27 (1.73)	1.25 (1.43)	1.09 (1.04)	2.27 (2.37)	2.55 (2.07)	1.40 (1.89)	2.27 (2.53)
WAIS	62.50 (7.71)	57.00 (3.63)	59.80 (4.87)	57.18 (6.84)	59.60 (6.04)	55.27 (9.21)	59.89 (6.79)	60.44 (7.57)	60.44 (4.45)
CES-D	9.18 (4.35)	6.00 (5.14)	5.82 (4.42)	6.08 (5.78)	4.91 (4.39)	6.27 (6.21)	3.89 (2.09)	7.44 (4.58)	8.18 (6.14)
MMSE	29.00 (1.48)	29.70 (0.48)	29.80 (0.42)	29.50 (0.90)	29.30 (1.06)	29.45 (0.82)	29.44 (1.01)	29.11 (1.36)	29.00 (1.15)
Environment Influence[5]	5.55 (1.86)	4.08 (2.47)	4.18 (1.08)	4.33 (1.78)	3.91 (1.76)	4.45 (2.98)	5.11 (2.37)	4.20 (1.81)	3.81 (2.60)

[1]Maximum score 20

[2]Maximum score 10

[3]Threshold in log steps

[4]Number of medications taking

[5]Summative indicator based on risk, history of smoking, surgery of the nose, live near a risk source, work place risk, previous job risk, past diseases losing smell, pesticide use growing up, grow up near industrial plants, diseases, childhood allergies, still have allergies, military service, gas-mask training, loss of ability after training; for a maximum score of 15

Table 3. Correlation matrix for complete data set

	Mood	Memscore	Pthresh	Mthresh	age	risk
Mood	1.00000	0.03379	-0.16704	-0.18183	-0.04482	-0.11394
(Manipulated mood	0.7411	0.1020	0.0731	0.6612	0.2639	
State)	98	98	97	98	98	98
Memscore	0.03379	1.00000	-0.23719	-0.00819	-0.19182	-0.04246
(Overall odor memory,	0.7411	0.0193	0.9362	0.0585	0.6781	
regardless of task)	98	98	97	98	98	98
Pthresh	-0.16704	-0.23719	1.00000	0.13731	0.08155	0.01524
(PEA detection	0.1020	0.0193	0.1799	0.4271	0.8822	
threshold)	97	97	97	97	97	97
Mthresh	-0.18183	-0.00819	0.13731	1.00000	0.05428	0.08270
(Menthol detection	0.0731	0.9362	0.1799	0.5955	0.4182	
threshold)	98	98	97	98	98	98
Age	-0.04482	-0.19182	0.08155	0.05428	1.00000	-0.01232
	0.6612	0.0585	0.4271	0.5955	0.9042	
	98	98	97	98	98	98
Risk	-0.11394	-0.04246	0.01524	0.08270	-0.01232	1.00000
(Environmental	0.2639	0.6781	0.8822	0.4182	0.9042	
olfactory risk)	98	98	97	98	98	98
Smoke	-0.05297	0.06287	-0.15262	-0.02215	0.28505	-0.02154
(Current or recent	0.6044	0.5385	0.1356	0.8286	0.0044	0.8332
smoker)	98	98	97	98	98	98
Allernow	-0.04481	0.12034	0.02402	-0.13983	0.03733	0.02782
(Current allergies)	0.6613	0.2379	0.8153	0.1697	0.7151	0.7857
	98	98	97	98	98	98
cold	-0.03426	-0.01947	0.00333	0.01458	0.20692	-0.05316
(recent colds or flu)	0.7377	0.8491	0.9741	0.8867	0.0409	0.6031
	98	98	97	98	98	98
meds	0.05258	-0.09986	0.00872	-0.09988	0.52593	0.05701
(Number of	0.6071	0.3279	0.9324	0.3278	<.0001	0.5771
medications)	98	98	97	98	98	98
surg	-0.19581	-0.13978	0.14605	-0.19087	0.01130	-0.01856
(Surgery of nose)	0.0533	0.1698	0.1534	0.0598	0.9120	0.8560
	98	98	97	98	98	98

Table 3 Continued next page

Table 3 Continued

	allernow	cold	meds	surg	ohealth	well
Mood	-0.04481 0.6613 98	-0.03426 0.7377 98	0.05258 0.6071 98	-0.19581 0.0533 98	0.07707 0.4507 98	0.00127 0.9901 98
Memscore	0.12034 0.2379 98	-0.01947 0.8491 98	-0.09986 0.3279 98	-0.13978 0.1698 98	0.16184 0.1114 98	0.01401 0.8911 98
Pthresh	0.02402 0.8153 97	0.00333 0.9741 97	0.00872 0.9324 97	0.14605 0.1534 97	0.02730 0.7907 97	0.08378 0.4146 97
Mthresh	-0.13983 0.1697 98	0.01458 0.8867 98	-0.09988 0.3278 98	-0.19087 0.0598 98	0.15779 0.1207 98	-0.02075 0.8393 98
age	0.03733 0.7151 98	0.20692 0.0409 98	0.52593 <.0001 98	0.01130 0.9120 98	-0.05403 0.5972 98	-0.15587 0.1254 98
risk	0.02782 0.7857 98	-0.05316 0.6031 98	0.05701 0.5771 98	-0.01856 0.8560 98	-0.10474 0.3047 98	0.07568 0.4589 98
smoke	-0.03259 0.1588 98	0.14346 0.0060 98	0.27580 0.8518 98	0.01912 0.0938 98	-0.17019 0.2807 98	-0.11006 98
allernow	1.00000 0.0105 98	0.25731 0.2311 98	0.12208 0.0058 98	0.27686 0.2988 98	-0.10602 0.5996 98	0.05368 98
cold	0.25731 0.0105 98	1.00000 0.0066 98	0.27280 0.5146 98	0.06661 0.0160 98	-0.24275 0.6883 98	0.04104 98
meds	0.12208 0.2311 98	0.27280 0.0066 98	1.00000 0.2848 98	0.10913 0.0020 98	-0.30892 0.2856 98	-0.10895 98
surg	0.27686 0.0058 98	0.06661 0.5146 98	0.10913 0.2848 98	1.00000 0.5719 98	-0.05779 0.7108 98	0.03793 98

Table 3 Continued

Table 3 Continued

	wais	cesd	mmse	liv	wplace	ojob	smell
Mood	-0.08926 0.4110 87	0.01924 0.8532 95	0.04392 0.6776 92	-0.14944 0.1419 98	-0.04950 0.6284 98	-0.09048 0.3756 98	0.06607 0.5180 98
Memscore	-0.12692 0.2414 87	-0.03596 0.7294 95	0.21901 0.0360 92	0.20366 0.0443 98	0.20268 0.0453 98	-0.14794 0.1460 98	-0.02336 0.8194 98
Pthresh	0.11143 0.3070 86	-0.08162 0.4342 94	0.22864 0.0293 91	-0.09675 0.3458 97	-0.12178 0.2347 97	-0.04111 0.6893 97	0.04642 0.6516 97
Mthresh	-0.15394 0.1546 87	0.01025 0.9215 95	-0.11359 0.2810 92	-0.10527 0.3022 98	-0.16757 0.0991 98	0.02285 0.8233 98	-0.05413 0.5965 98
age	-0.08440 0.4370 87	-0.10786 0.2982 95	-0.42896 <.0001 92	0.01015 0.9210 98	-0.04954 0.6281 98	0.18338 0.0707 98	-0.20112 0.0471 98
risk	-0.01519 0.8889 87	0.17863 0.0833 95	-0.12436 0.2376 92	0.37210 0.0002 98	0.40000 <.0001 98	0.30992 0.0019 98	0.06102 0.5506 98
smoke	-0.08839 0.4156 87	-0.02136 0.8372 95	-0.04359 0.6799 92	0.02004 0.8447 98	0.05925 0.5622 98	-0.04927 0.6300 98	-0.30187 0.0025 98
allernow	0.13577 0.2099 87	0.10362 0.3176 95	0.21592 0.0387 92	0.21563 0.0330 98	0.23991 0.0173 98	-0.13835 0.1743 98	0.07263 0.4773 98
cold	-0.14981 0.1661 87	0.04513 0.6641 95	-0.03140 0.7664 92	0.16486 0.1048 98	0.05316 0.6031 98	0.05049 0.6215 98	-0.05667 0.5794 98
meds	-0.11966 0.2696 87	0.05418 0.6020 95	-0.18664 0.0748 92	0.07072 0.4890 98	-0.02930 0.7746 98	0.11376 0.2647 98	0.03249 0.7508 98
surg	0.18084 0.0937 87	0.09247 0.3728 95	0.11418 0.2785 92	0.13814 0.1750 98	0.11601 0.2553 98	-0.10577 0.2999 98	0.13341 0.1903 98

Table 3 Continued

Table 3 Continued

	growup	pest	plants	diseases	childal	stillal	ghelath
Mood	0.10478	0.01609	-0.08681	0.02735	-0.00832	-0.11418	.
	0.3045	0.8751	0.3953	0.7892	0.9352	0.2629	.
	98	98	98	98	98	98	98
Memscore	0.04131	0.18173	0.02891	-0.11022	-0.04336	-0.01577	.
	0.6863	0.0733	0.7775	0.2800	0.6716	0.8775	.
	98	98	98	98	98	98	98
Pthresh	-0.13596	0.02432	-0.13059	0.03836	-0.08678	-0.10226	.
	0.1842	0.8131	0.2023	0.7091	0.3980	0.3189	.
	97	97	97	97	97	97	97
Mthresh	-0.27346	0.08174	-0.04214	-0.06059	-0.21721	-0.19670	.
	0.0064	0.4236	0.6803	0.5534	0.0317	0.0522	.
	98	98	98	98	98	98	98
age	0.23090	-0.00205	0.07412	-0.03027	-0.05634	-0.12033	.
	0.0222	0.9840	0.4682	0.7673	0.5816	0.2379	.
	98	98	98	98	98	98	98
risk	-0.07895	0.12237	0.00000	0.16471	-0.03300	0.00305	.
	0.4397	0.2300	1.0000	0.1051	0.7470	0.9762	.
	98	98	98	98	98	98	98
smoke	0.13949	0.13614	0.09909	-0.07595	-0.10320	-0.01998	.
	0.1707	0.1813	0.3317	0.4573	0.3119	0.8452	.
	98	98	98	98	98	98	98
allernow	0.02471	0.10146	0.26483	0.04525	0.18866	0.39354	.
	0.8092	0.3202	0.0084	0.6581	0.0628	<.0001	.
	98	98	98	98	98	98	98
cold	0.03513	0.02853	-0.06177	0.31716	0.19582	0.18159	.
	0.7313	0.7804	0.5457	0.0015	0.0533	0.0735	.
	98	98	98	98	98	98	98
meds	0.28488	0.16727	0.18861	0.19697	0.06727	0.09855	.
	0.0045	0.0997	0.0629	0.0519	0.5104	0.3344	.
	98	98	98	98	98	98	98
surg	0.01996	-0.03407	0.05392	0.15771	0.08960	0.21927	.
	0.8454	0.7391	0.5980	0.1209	0.3803	0.0301	.
	98	98	98	98	98	98	98

Table 3 Continued

Table 3 Continued

	app	cook	flavors	dining	mil	mask	loss
Mood	.	0.24143	.	0.00398	-0.12369	-0.00594	0.11099
	.	0.0166	.	0.9689	0.2250	0.9537	0.2766
	98	98	98	98	98	98	98
Memscore	.	0.21484	.	0.19798	-0.11479	0.00352	-0.05222
	.	0.0336	.	0.0507	0.2604	0.9726	0.6096
	98	98	98	98	98	98	98
Pthresh	.	-0.07693	.	-0.06473	-0.02539	-0.11690	0.06000
	.	0.4539	.	0.5287	0.8050	0.2542	0.5593
	97	97	97	97	97	97	97
Mthresh	.	-0.03424	.	-0.10832	0.16489	0.01077	-0.10426
	.	0.7378	.	0.2884	0.1047	0.9162	0.3069
	98	98	98	98	98	98	98
age	.	-0.16776	.	-0.23483	0.43472	0.31178	0.04807
	.	0.0987	.	0.0199	<.0001	0.0018	0.6383
	98	98	98	98	98	98	98
risk	.	0.11239	.	-0.20542	0.02122	-0.02357	-0.07604
	.	0.2705	.	0.0424	0.8357	0.8178	0.4568
	98	98	98	98	98	98	98
smoke	.	-0.04691	.	-0.03192	0.07116	0.09426	0.00503
	.	0.6464	.	0.7551	0.4862	0.3559	0.9608
	98	98	98	98	98	98	98
allernow	.	0.03777	.	-0.04725	-0.01181	0.11063	0.08941
	.	0.7119	.	0.6441	0.9081	0.2781	0.3813
	98	98	98	98	98	98	98
cold	.	-0.06871	.	-0.03612	0.10155	0.11528	0.12239
	.	0.5014	.	0.7240	0.3197	0.2583	0.2299
	98	98	98	98	98	98	98
meds	.	-0.11258	.	-0.04692	0.09227	0.15230	0.05567
	.	0.2697	.	0.6464	0.3662	0.1344	0.5861
	98	98	98	98	98	98	98
surg	.	-0.08605	.	0.11879	-0.06796	0.06398	0.19632
	.	0.3995	.	0.2440	0.5061	0.5314	0.0527
	98	98	98	98	98	98	98

Table 3 Continued

Table 3 Continued

	Mood	Memscore	Pthresh	Mthresh	age	risk
ohealth	0.07707	0.16184	0.02730	0.15779	-0.05403	-0.10474
(Overall health	0.4507	0.1114	0.7907	0.1207	0.5972	0.3047
assessment)	98	98	97	98	98	98
Well	0.00127	0.01401	0.08378	-0.02075	-0.15587	0.07568
(Felt well that day)	0.9901	0.8911	0.4146	0.8393	0.1254	0.4589
	98	98	97	98	98	98
wais	-0.08926	-0.12692	0.11143	-0.15394	-0.08440	-0.01519
(Weschler Scale)	0.4110	0.2414	0.3070	0.1546	0.4370	0.8889
	87	87	86	87	87	87
cesd	0.01924	-0.03596	-0.08162	0.01025	-0.10786	0.17863
(CES-D rating)	0.8532	0.7294	0.4342	0.9215	0.2982	0.0833
	95	95	94	95	95	95
mmse	0.04392	0.21901	0.22864	-0.11359	-0.42896	-0.12436
(MMSE score)	0.6776	0.0360	0.0293	0.2810	<.0001	0.2376
	92	92	91	92	92	92
liv	-0.14944	0.20366	-0.09675	-0.10527	0.01015	0.37210
(Occupation –do for a	0.1419	0.0443	0.3458	0.3022	0.9210	0.0002
living)	98	98	97	98	98	98
Wplace	-0.04950	0.20268	-0.12178	-0.16757	-0.04954	0.40000
(Workplace setting)	0.6284	0.0453	0.2347	0.0991	0.6281	<.0001
	98	98	97	98	98	98
ojob	-0.09048	-0.14794	-0.04111	0.02285	0.18338	0.30992
(Other/pervious jobs	0.3756	0.1460	0.6893	0.8233	0.0707	0.0019
risk level)	98	98	97	98	98	98
Smell	0.06607	-0.02336	0.04642	-0.05413	-0.20112	0.06102
(Perceived sense of	0.5180	0.8194	0.6516	0.5965	0.0471	0.5506
smell)	98	98	97	98	98	98
growup	0.10478	0.04131	-0.13596	-0.27346	0.23090	-0.07895
(Environment grown up	0.3045	0.6863	0.1842	0.0064	0.0222	0.4397
in)	98	98	97	98	98	98
pest	0.01609	0.18173	0.02432	0.08174	-0.00205	0.12237
(Pesticide/chemical use	0.8751	0.0733	0.8131	0.4236	0.9840	0.2300
growing up)	98	98	97	98	98	98
Plants	-0.08681	0.02891	-0.13059	-0.04214	0.07412	0.00000
(Manufacturing plants	0.3953	0.7775	0.2023	0.6803	0.4682	1.0000
nearby)	98	98	97	98	98	98

Table 3 Continued

	smoke	allernow	cold	meds	surg	ohealth	well
ohealth	-0.17019 0.0938 98	-0.10602 0.2988 98	-0.24275 0.0160 98	-0.30892 0.0020 98	-0.05779 0.5719 98	1.00000 0.0179 98	0.23869 98
well	-0.11006 0.2807 98	0.05368 0.5996 98	0.04104 0.6883 98	-0.10895 0.2856 98	0.03793 0.7108 98	0.23869 0.0179 98	1.00000 98
wais	-0.08839 0.4156 87	0.13577 0.2099 87	-0.14981 0.1661 87	-0.11966 0.2696 87	0.18084 0.0937 87	0.01197 0.9124 87	. . 87
cesd	-0.02136 0.8372 95	0.10362 0.3176 95	0.04513 0.6641 95	0.05418 0.6020 95	0.09247 0.3728 95	-0.05671 0.5852 95	. . 95
mmse	-0.04359 0.6799 92	0.21592 0.0387 92	-0.03140 0.7664 92	-0.18664 0.0748 92	0.11418 0.2785 92	0.01409 0.8939 92	. . 92
liv	0.02004 0.8447 98	0.21563 0.0330 98	0.16486 0.1048 98	0.07072 0.4890 98	0.13814 0.1750 98	-0.11308 0.2676 98	0.02816 0.7831 98
wplace	0.05925 0.5622 98	0.23991 0.0173 98	0.05316 0.6031 98	-0.02930 0.7746 98	0.11601 0.2553 98	-0.19397 0.0556 98	0.03027 0.7673 98
ojob	-0.04927 0.6300 98	-0.13835 0.1743 98	0.05049 0.6215 98	0.11376 0.2647 98	-0.10577 0.2999 98	-0.04169 0.6835 98	-0.15662 0.1235 98
smell	-0.30187 0.0025 98	0.07263 0.4773 98	-0.05667 0.5794 98	0.03249 0.7508 98	0.13341 0.1903 98	0.09420 0.3562 98	0.18335 0.0707 98
growup	0.13949 0.1707 98	0.02471 0.8092 98	0.03513 0.7313 98	0.28488 0.0045 98	0.01996 0.8454 98	-0.17555 0.0838 98	-0.15566 0.1259 98
pest	0.13614 0.1813 98	0.10146 0.3202 98	0.02853 0.7804 98	0.16727 0.0997 98	-0.03407 0.7391 98	-0.23829 0.0181 98	0.07908 0.4389 98
plants	0.09909 0.3317 98	0.26483 0.0084 98	-0.06177 0.5457 98	0.18861 0.0629 98	0.05392 0.5980 98	-0.16027 0.1149 98	-0.11724 0.2503 98

Table 3 Continued

Table 3 Continued

	wais	cesd	mmse	liv	wplace	ojob	smell
ohealth	0.01197 0.9124 87	-0.05671 0.5852 95	0.01409 0.8939 92	-0.11308 0.2676 98	-0.19397 0.0556 98	-0.04169 0.6835 98	0.09420 0.3562 98
well	. . 87	. . 95	. . 92	0.02816 0.7831 98	0.03027 0.7673 98	-0.15662 0.1235 98	0.18335 0.0707 98
wais	1.00000 0.9382 87	0.00844 0.1410 87	0.16006 0.3978 86	-0.09179 0.4566 87	-0.08085 0.9240 87	-0.01038 0.5901 87	-0.05855 87
cesd	0.00844 0.9382 87	1.00000 0.1541 95	-0.14980 0.3179 92	0.10356 0.2598 95	0.11677 0.2518 95	-0.11874 0.6074 95	0.05338 95
mmse	0.16006 0.1410 86	-0.14980 0.1541 92	1.00000 0.3519 92	0.09816 0.2688 92	0.11650 0.2017 92	-0.13435 0.9229 92	0.01023 92
liv	-0.09179 0.3978 87	0.10356 0.3179 95	0.09816 0.3519 92	1.00000 <.0001 98	0.78555 0.0115 98	0.25421 0.1311 98	0.15359 98
wplace	-0.08085 0.4566 87	0.11677 0.2598 95	0.11650 0.2688 92	0.78555 <.0001 98	1.00000 0.1907 98	0.13330 0.4501 98	0.07717 98
ojob	-0.01038 0.9240 87	-0.11874 0.2518 95	-0.13435 0.2017 92	0.25421 0.0115 98	0.13330 0.1907 98	1.00000 0.9204 98	-0.01023 98
smell	-0.05855 0.5901 87	0.05338 0.6074 95	0.01023 0.9229 92	0.15359 0.1311 98	0.07717 0.4501 98	-0.01023 0.9204 98	1.00000 98
growup	0.02610 0.8103 87	-0.01321 0.8989 95	-0.10178 0.3343 92	-0.11597 0.2555 98	-0.10284 0.3136 98	-0.07478 0.4643 98	0.13758 0.1767 98
pest	0.03455 0.7507 87	0.11784 0.2554 95	0.05117 0.6281 92	0.02919 0.7754 98	-0.00157 0.9878 98	-0.18210 0.0727 98	0.03396 0.7399 98
plants	0.15078 0.1633 87	0.10406 0.3156 95	0.10520 0.3183 92	0.00000 1.0000 98	-0.10758 0.2917 98	-0.01936 0.8499 98	-0.00695 0.9458 98

Table 3 Continued

Table 3 Continued

	growup	pest	plants	diseases	childal	stillal	ghelath
ohealth	-0.17555	-0.23829	-0.16027	-0.32096	-0.09334	-0.14903	.
	0.0838	0.0181	0.1149	0.0013	0.3606	0.1430	.
	98	98	98	98	98	98	98
well	-0.15566	0.07908	-0.11724	0.04652	0.06744	0.11019	.
	0.1259	0.4389	0.2503	0.6492	0.5094	0.2801	.
	98	98	98	98	98	98	98
wais	0.02610	0.03455	0.15078	0.10360	0.09874	-0.00479	.
	0.8103	0.7507	0.1633	0.3396	0.3629	0.9648	.
	87	87	87	87	87	87	87
cesd	-0.01321	0.11784	0.10406	-0.03133	0.02689	0.11805	.
	0.8989	0.2554	0.3156	0.7631	0.7959	0.2546	.
	95	95	95	95	95	95	95
mmse	-0.10178	0.05117	0.10520	0.04773	0.12264	0.04670	.
	0.3343	0.6281	0.3183	0.6514	0.2442	0.6584	.
	92	92	92	92	92	92	92
liv	-0.11597	0.02919	0.00000	0.18685	0.07369	0.01704	.
	0.2555	0.7754	1.0000	0.0654	0.4709	0.8678	.
	98	98	98	98	98	98	98
wplace	-0.10284	-0.00157	-0.10758	0.06026	-0.03631	-0.02442	.
	0.3136	0.9878	0.2917	0.5556	0.7227	0.8114	.
	98	98	98	98	98	98	98
ojob	-0.07478	-0.18210	-0.01936	-0.00181	-0.04257	-0.25497	.
	0.4643	0.0727	0.8499	0.9859	0.6773	0.0113	.
	98	98	98	98	98	98	98
smell	0.13758	0.03396	-0.00695	0.12652	-0.05011	0.11783	.
	0.1767	0.7399	0.9458	0.2144	0.6241	0.2479	.
	98	98	98	98	98	98	98
growup	1.00000	0.01526	0.20117	-0.03380	-0.07036	0.09760	.
	0.8815	0.0470	0.7411	0.4912	0.3390	.	
	98	98	98	98	98	98	98
pest	0.01526	1.00000	0.43142	0.08792	0.03076	0.08405	.
	0.8815	<.0001	0.3893	0.7637	0.4106	.	
	98	98	98	98	98	98	98
plants	0.20117	0.43142	1.00000	0.03890	0.14061	0.09458	.
	0.0470	<.0001	0.7038	0.1673	0.3543	.	
	98	98	98	98	98	98	98

Table 3 Continued

	app	cook	flavors	dining	mil	mask	loss
ohealth	.	0.17949	.	0.05670	-0.10827	-0.19659	-0.15085
	.	0.0770	.	0.5792	0.2886	0.0524	0.1381
	98	98	98	98	98	98	98
well	.	0.12758	.	-0.03229	-0.17829	-0.21405	0.02354
	.	0.2106	.	0.7523	0.0790	0.0343	0.8180
	98	98	98	98	98	98	98
wais	.	-0.04876	.	-0.12668	-0.11813	-0.13120	-0.09282
	.	0.6538	.	0.2423	0.2758	0.2258	0.3925
	87	87	87	87	87	87	87
cesd	.	0.10125	.	-0.07147	-0.04478	-0.02954	0.01249
	.	0.3289	.	0.4913	0.6666	0.7763	0.9044
	95	95	95	95	95	95	95
mmse	.	0.05093	.	0.19337	-0.45642	-0.36624	-0.07818
	.	0.6297	.	0.0648	<.0001	0.0003	0.4588
	92	92	92	92	92	92	92
liv	.	0.13940	.	0.08820	-0.06581	-0.02924	-0.06431
	.	0.1710	.	0.3878	0.5197	0.7751	0.5293
	98	98	98	98	98	98	98
wplace	.	0.16078	.	-0.03424	-0.08313	-0.04518	-0.06913
	.	0.1138	.	0.7379	0.4158	0.6587	0.4988
	98	98	98	98	98	98	98
ojob	.	0.01124	.	0.05134	0.04668	0.03888	-0.04872
	.	0.9126	.	0.6156	0.6481	0.7039	0.6338
	98	98	98	98	98	98	98
smell	.	0.20170	.	0.15738	-0.13255	0.01396	0.01898
	.	0.0464	.	0.1217	0.1932	0.8915	0.8528
	98	98	98	98	98	98	98
growup	.	0.00992	.	0.13986	0.06284	0.18731	0.16546
	.	0.9227	.	0.1696	0.5388	0.0648	0.1035
	98	98	98	98	98	98	98
pest	.	-0.11461	.	-0.04388	-0.05195	0.01109	0.01074
	.	0.2611	.	0.6679	0.6115	0.9137	0.9164
	98	98	98	98	98	98	98
plants	.	-0.19951	.	0.06120	-0.10960	-0.03804	-0.01339
	.	0.0489	.	0.5494	0.2827	0.7100	0.8959
	98	98	98	98	98	98	98

Table 3 Continued

Table 3 Continued

	Mood	Memscore	Pthresh	Mthresh	age	risk
Diseases	0.02735	-0.11022	0.03836	-0.06059	-0.03027	0.16471
(Had diseases that lost	0.7892	0.2800	0.7091	0.5534	0.7673	0.1051
sense of smell)	98	98	97	98	98	98
Childal	-0.00832	-0.04336	-0.08678	-0.21721	-0.05634	-0.03300
(Suffered childhood	0.9352	0.6716	0.3980	0.0317	0.5816	0.7470
allergies)	98	98	97	98	98	98
stillal	-0.11418	-0.01577	-0.10226	-0.19670	-0.12033	0.00305
(Still suffer allergies)	0.2629	0.8775	0.3189	0.0522	0.2379	0.9762
	98	98	97	98	98	98
ghelath	.	.	.	.	.	.
(General health rating)	.	.	.	.	.	.
	98	98	97	98	98	98
app	.	.	.	.	.	.
(Good appetite)	.	.	.	.	.	.
	98	98	97	98	98	98
cook	0.24143	0.21484	-0.07693	-0.03424	-0.16776	0.11239
(Likes to cook)	0.0166	0.0336	0.4539	0.7378	0.0987	0.2705
	98	98	97	98	98	98
flavors	.	.	.	.	.	.
(Enjoy flavors of foods)	.	.	.	.	.	.
	98	98	97	98	98	98
dining	0.00398	0.19798	-0.06473	-0.10832	-0.23483	-0.20542
(Enjoy dining out)	0.9689	0.0507	0.5287	0.2884	0.0199	0.0424
	98	98	97	98	98	98
mil	-0.12369	-0.11479	-0.02539	0.16489	0.43472	0.02122
(Military service)	0.2250	0.2604	0.8050	0.1047	<.0001	0.8357
	98	98	97	98	98	98
mask	-0.00594	0.00352	-0.11690	0.01077	0.31178	-0.02357
(Trained with gasmasks)	0.9537	0.9726	0.2542	0.9162	0.0018	0.8178
	98	98	97	98	98	98
loss	0.11099	-0.05222	0.06000	-0.10426	0.04807	-0.07604
(Experienced loss after	0.2766	0.6096	0.5593	0.3069	0.6383	0.4568
gasmask training)	98	98	97	98	98	98

Table 3 Continued

Table 3 Continued

	smoke	allernow	cold	meds	surg	ohealth	well
diseases	-0.07595 0.4573 98	0.04525 0.6581 98	0.31716 0.0015 98	0.19697 0.0519 98	0.15771 0.1209 98	-0.32096 0.0013 98	0.04652 0.6492 98
childal	-0.10320 0.3119 98	0.18866 0.0628 98	0.19582 0.0533 98	0.06727 0.5104 98	0.08960 0.3803 98	-0.09334 0.3606 98	0.06744 0.5094 98
stillal	-0.01998 0.8452 98	0.39354 <.0001 98	0.18159 0.0735 98	0.09855 0.3344 98	0.21927 0.0301 98	-0.14903 0.1430 98	0.11019 0.2801 98
ghelath	. . 98	. . 98	. . 98	. . 98	. . 98	. . 98	. . 98
app	. . 98	. . 98	. . 98	. . 98	. . 98	. . 98	. . 98
cook	-0.04691 0.6464 98	0.03777 0.7119 98	-0.06871 0.5014 98	-0.11258 0.2697 98	-0.08605 0.3995 98	0.17949 0.0770 98	0.12758 0.2106 98
flavors	. . 98	. . 98	. . 98	. . 98	. . 98	. . 98	. . 98
dining	-0.03192 0.7551 98	-0.04725 0.6441 98	-0.03612 0.7240 98	-0.04692 0.6464 98	0.11879 0.2440 98	0.05670 0.5792 98	-0.03229 0.7523 98
mil	0.07116 0.4862 98	-0.01181 0.9081 98	0.10155 0.3197 98	0.09227 0.3662 98	-0.06796 0.5061 98	-0.10827 0.2886 98	-0.17829 0.0790 98
mask	0.09426 0.3559 98	0.11063 0.2781 98	0.11528 0.2583 98	0.15230 0.1344 98	0.06398 0.5314 98	-0.19659 0.0524 98	-0.21405 0.0343 98
loss	0.00503 0.9608 98	0.08941 0.3813 98	0.12239 0.2299 98	0.05567 0.5861 98	0.19632 0.0527 98	-0.15085 0.1381 98	0.02354 0.8180 98

Table 3 Continued

Table 3 Continued

	wais	cesd	mmse	liv	wplace	ojob	smell
diseases	0.10360 0.3396 87	-0.03133 0.7631 95	0.04773 0.6514 92	0.18685 0.0654 98	0.06026 0.5556 98	-0.00181 0.9859 98	0.12652 0.2144 98
childal	0.09874 0.3629 87	0.02689 0.7959 95	0.12264 0.2442 92	0.07369 0.4709 98	-0.03631 0.7227 98	-0.04257 0.6773 98	-0.05011 0.6241 98
stillal	-0.00479 0.9648 87	0.11805 0.2546 95	0.04670 0.6584 92	0.01704 0.8678 98	-0.02442 0.8114 98	-0.25497 0.0113 98	0.11783 0.2479 98
ghelath	. . 87	. . 95	. . 92	. . 98	. . 98	. . 98	. . 98
app	. . 87	. . 95	. . 92	. . 98	. . 98	. . 98	. . 98
cook	-0.04876 0.6538 87	0.10125 0.3289 95	0.05093 0.6297 92	0.13940 0.1710 98	0.16078 0.1138 98	0.01124 0.9126 98	0.20170 0.0464 98
flavors	. . 87	. . 95	. . 92	. . 98	. . 98	. . 98	. . 98
dining	-0.12668 0.2423 87	-0.07147 0.4913 95	0.19337 0.0648 92	0.08820 0.3878 98	-0.03424 0.7379 98	0.05134 0.6156 98	0.15738 0.1217 98
mil	-0.11813 0.2758 87	-0.04478 0.6666 95	-0.45642 <.0001 92	-0.06581 0.5197 98	-0.08313 0.4158 98	0.04668 0.6481 98	-0.13255 0.1932 98
mask	-0.13120 0.2258 87	-0.02954 0.7763 95	-0.36624 0.0003 92	-0.02924 0.7751 98	-0.04518 0.6587 98	0.03888 0.7039 98	0.01396 0.8915 98
loss	-0.09282 0.3925 87	0.01249 0.9044 95	-0.07818 0.4588 92	-0.06431 0.5293 98	-0.06913 0.4988 98	-0.04872 0.6338 98	0.01898 0.8528 98

Table 3 Continued

Table 3 Continued

	growup	pest	plants	diseases	childal	stillal	ghelath
diseases	-0.03380	0.08792	0.03890	1.00000	0.33890	0.31398	.
	0.7411	0.3893	0.7038	0.0006	0.0016	.	
	98	98	98	98	98	98	98
childal	-0.07036	0.03076	0.14061	0.33890	1.00000	0.47875	.
	0.4912	0.7637	0.1673	0.0006	<.0001	.	
	98	98	98	98	98	98	98
stillal	0.09760	0.08405	0.09458	0.31398	0.47875	1.00000	.
	0.3390	0.4106	0.3543	0.0016	<.0001	.	
	98	98	98	98	98	98	98
ghelath	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	98	98	98	98	98	98	98
app	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	98	98	98	98	98	98	98
cook	0.00992	-0.11461	-0.19951	0.08804	-0.24390	-0.06089	.
	0.9227	0.2611	0.0489	0.3887	0.0155	0.5514	.
	98	98	98	98	98	98	98
flavors	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	98	98	98	98	98	98	98
dining	0.13986	-0.04388	0.06120	-0.13426	-0.09544	-0.08031	.
	0.1696	0.6679	0.5494	0.1875	0.3499	0.4318	.
	98	98	98	98	98	98	98
mil	0.06284	-0.05195	-0.10960	-0.13556	0.03362	0.00097	.
	0.5388	0.6115	0.2827	0.1832	0.7424	0.9924	.
	98	98	98	98	98	98	98
mask	0.18731	0.01109	-0.03804	-0.14771	-0.02917	0.06691	.
	0.0648	0.9137	0.7100	0.1466	0.7755	0.5127	.
	98	98	98	98	98	98	98
loss	0.16546	0.01074	-0.01339	-0.10622	-0.05339	0.12060	.
	0.1035	0.9164	0.8959	0.2979	0.6016	0.2369	.
	98	98	98	98	98	98	98

Table 3 Continued

Table 3 Continued

	app	cook	flavors	dining	mil	mask	loss
diseases	.	0.08804	.	-0.13426	-0.13556	-0.14771	-0.10622
	.	0.3887	.	0.1875	0.1832	0.1466	0.2979
	98	98	98	98	98	98	98
childal	.	-0.24390	.	-0.09544	0.03362	-0.02917	-0.05339
	.	0.0155	.	0.3499	0.7424	0.7755	0.6016
	98	98	98	98	98	98	98
stillal	.	-0.06089	.	-0.08031	0.00097	0.06691	0.12060
	.	0.5514	.	0.4318	0.9924	0.5127	0.2369
	98	98	98	98	98	98	98
ghelath	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	98	98	98	98	98	98	98
app	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	98	98	98	98	98	98	98
cook	.	1.00000	.	0.10952	-0.17990	-0.10927	-0.10100
	.	.	0.2831	0.0763	0.2841	0.3224	
	98	98	98	98	98	98	98
flavors	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	98	98	98	98	98	98	98
dining	.	0.10952	.	1.00000	-0.06540	0.05959	0.07373
	.	0.2831	.	0.5223	0.5600	0.4706	
	98	98	98	98	98	98	98
mil	.	-0.17990	.	-0.06540	1.00000	0.77164	0.29931
	.	0.0763	.	0.5223	<.0001	0.0028	
	98	98	98	98	98	98	98
mask	.	-0.10927	.	0.05959	0.77164	1.00000	0.48882
	.	0.2841	.	0.5600	<.0001	<.0001	
	98	98	98	98	98	98	98
loss	.	-0.10100	.	0.07373	0.29931	0.48882	1.00000
	.	0.3224	.	0.4706	0.0028	<.0001	
	98	98	98	98	98	98	98

Table 4. The output of the regression model for the discrimination task.

	Value	Std. Error	T-value	P-Value
μ	13.5	0.66	20.47	0.000
Mood	.807	.499	1.615	0.116
PEA threshold	-0.37	0.19	-1.979	0.057

Table 5. Summary report of linear regression models for discrimination task data formed using backward elimination.

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1[a]	0.525	0.275	0.055	2.48
2[b]	0.524	0.274	0.093	2.43
3[c]	0.518	0.268	0.122	2.39
4[d]	0.511	0.261	0.148	2.36
5[e]	0.501	0.251	0.168	2.33
6[f]	0.435	0.189	0.131	2.38
7[g]	0.343	0.117	0.087	2.44

[a]Predictors: (Constant), risk, mood, age group, PEA threshold, CESD, environmental influence, MMSE

[b]Predictors: (Constant), risk, mood, age group, PEA threshold, CESD, MMSE

[c]Predictors: (Constant), risk, mood, age group, PEA threshold, MMSE

[d]Predictors: (Constant), risk, mood, PEA threshold, MMSE

[e]Predictors: (Constant), risk, mood, PEA threshold

[f]Predictors: (Constant), risk, PEA threshold

[g]Predictors: (Constant), PEA threshold

Table 6. Discrimination linear model report including unstandardized and standardized coefficients.

Model		Unstd.Coefficients		Std. Coefficient		
		B	Std. Error	â	t	Sig.
1	(Constant)	-4.096	21.486		-0.191	0.85
	PTHRESH	-0.603	0.247	-0.527	-2.44	0.023
	AGROUP	0.467	0.743	0.149	0.629	0.535
	MOOD	0.584	0.645	0.191	0.905	0.375
	CESD	4.57E-02	0.111	0.086	0.411	0.685
	MMSE	0.602	0.697	0.235	0.863	0.397
	ENVINF	-5.21E-02	0.285	-0.042	-0.183	0.857
	RISK	-1.292	1.144	-0.246	-1.129	0.27
2	(Constant)	-3.904	21.024		-0.186	0.854
	PTHRESH	-0.59	0.231	-0.515	-2.554	0.017
	AGROUP	0.431	0.701	0.137	0.615	0.544
	MOOD	0.628	0.588	0.205	1.068	0.296
	CESD	4.81E-02	0.108	0.091	0.444	0.661
	MMSE	0.589	0.679	0.229	0.867	0.395
	RISK	-1.378	1.022	-0.262	-1.348	0.19
3	(Constant)	0.197	18.578		0.011	0.992
	PTHRESH	-0.577	0.225	-0.504	-2.56	0.017
	AGROUP	0.316	0.64	0.101	0.493	0.626

	MOOD	0.59	0.572	0.193	1.031	0.313
	MMSE	0.467	0.611	0.182	0.764	0.452
	RISK	-1.36	1.005	-0.259	-1.353	0.188
4	(Constant)	5.247	15.273		0.344	0.734
	PTHRESH	-0.542	0.211	-0.473	-2.571	0.016
	MOOD	0.633	0.557	0.207	1.136	0.266
	MMSE	0.313	0.518	0.122	0.605	0.55
	RISK	-1.349	0.99	-0.257	-1.363	0.184
5	(Constant)	14.471	0.846		17.097	0
	PTHRESH	-0.51	0.202	-0.446	-2.529	0.018
	MOOD	0.76	0.51	0.249	1.491	0.147
	RISK	-1.544	0.925	-0.294	-1.669	0.107
6	(Constant)	14.39	0.863		16.676	0
	PTHRESH	-0.497	0.206	-0.434	-2.414	0.023
	RISK	-1.486	0.944	-0.283	-1.574	0.127
7	(Constant)	13.572	0.706		19.213	0
	PTHRESH	-0.392	0.2	-0.343	-1.965	0.059

The model was created by backward elimination of the variables at a 0.1 significance level.

Table 7. Comparative performance of the discrimination models.

	Full Model	**PEA and Mood Model**
F Value	1.349	3.157
Deg. Of Freedom	6, 25	2, 25
P value	0.2732	0.057
R^2	0.2446	0.169

Table 8. The output of the identification regression model

	Value	Std. Error	T-value	P-Value
μ	16.05	0.532	30.22	0.000
Mood	0.356	0.382	0.93	0.359
PEA threshold	-0.200	0.139	-1.438	0.161
Risk	0.96	0.635	1.513	0.141

Table 9. Summary report of linear regression models for identification task data formed using backward elimination.

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1[a]	0.597611	0.357139	0.177137	1.647199
2[b]	0.589762	0.347820	0.197317	1.626876
3[c]	0.579264	0.335546	0.212499	1.611417
4[d]	0.550463	0.303010	0.203440	1.620659
5[e]	0.521572	0.272037	0.196731	1.627470
6[f]	0.458511	0.210232	0.157581	1.666658

[a]Predictors: (Constant), MMSE, environmental influence, mood, CESD, age group, risk, PEA threshold

[b]Predictors: (Constant), environmental influence, mood, CESD, age group, risk, PEA threshold

[c]Predictors: (Constant), mood, CESD, age group, risk, PEA threshold

[d]Predictors: (Constant), CESD, age group, risk, PEA threshold

[e]Predictors: (Constant), age group, risk, PEA threshold

[f]Predictors: (Constant), PEA threshold

Table 10. Identification linear model report including unstandardized and standardized coefficients.

Model		Unstd Coefficients		Std. Coefficient		
		B	Std. Error	ß	t	Sig
1	(Constant)	24.39257	10.91651		2.234466	0.03463
	AGROUP	-0.68443	0.396906	-0.30512	-1.72442	0.096977
	MOOD	0.45572	0.366436	0.212627	1.243656	0.225162
	PTHRESH	-0.16693	0.148573	-0.20548	-1.12357	0.271867
	RISK	1.57266	0.741088	0.423078	2.122095	0.043915
	CESD	-0.07194	0.061114	-0.21411	-1.1771	0.25024
	MMSE	-0.22062	0.366483	-0.10964	-0.60199	0.5526
	ENVINF	-0.09794	0.160406	-0.11715	-0.61058	0.546991
2	(Constant)	17.84831	0.983572		18.14641	2.22E-16
	AGROUP	-0.62316	0.378901	-0.27781	-1.64466	0.112079
	MOOD	0.435884	0.360448	0.203372	1.209283	0.237436
	PTHRESH	-0.18936	0.142052	-0.23309	-1.33302	0.194089
	RISK	1.484107	0.717381	0.399256	2.068784	0.048645
	CESD	-0.06009	0.057143	-0.17884	-1.05151	0.302698
	ENVINF	-0.10996	0.157195	-0.13153	-0.6995	0.490452
3	(Constant)	17.52687	0.861365		20.34778	0
	AGROUP	-0.62929	0.3752	-0.28054	-1.67721	0.105042
	MOOD	0.407998	0.354833	0.190361	1.149832	0.260296

	PTHRESH	-0.19738	0.140242	-0.24297	-1.40745	0.170702
	RISK	1.250051	0.628537	0.33629	1.988826	0.056942
	CESD	-0.06586	0.056007	-0.19601	-1.17584	0.249922
4	(Constant)	17.53703	0.86626		20.24453	1.11E-16
	AGROUP	-0.57527	0.374382	-0.25645	-1.53658	0.135621
	PTHRESH	-0.24417	0.13498	-0.30056	-1.80891	0.081215
	RISK	1.171463	0.628394	0.315148	1.864218	0.072807
	CESD	-0.06276	0.056263	-0.1868	-1.11546	0.274135
5	(Constant)	17.26563	0.834884		20.68028	1.11E-16
	AGROUP	-0.58957	0.375735	-0.26283	-1.56912	0.127468
	PTHRESH	-0.23843	0.135449	-0.2935	-1.76032	0.088898
	RISK	0.936746	0.594604	0.252004	1.57541	0.12601
6	(Constant)	16.19549	0.493164		32.83994	2.22E-16
	PTHRESH	-0.30387	0.131972	-0.37405	-2.30256	0.028418

The model was created by backward elimination of the variables at a 0.1 significance level.

Table 11. Comparative performance of the Identification models.

	Full Model	**Mood, PEA threshold, and Risk Model**
F Value	1.757	1.937
Deg. Of Freedom	6, 28	3, 30
P value	0.1545	0.145
R^2	0.2388	0.162

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Table 12. The output of the recognition regression model

	Value	Std. Error	T-value	P-Value
μ	-18.68	7.868	-2.344	0.026
Mood	0.26	0.316	0.824	0.418
Age Group	-0.868	0.37	-2.338	0.027
MMSE	0.899	0.257	3.5	0.002

Table 13. Summary report of linear regression models for Recognition data formed using backward elimination

Model	R	R^2	Adjusted R^2	Standard Error of the Estimate
1[a]	0.751266	0.564401	0.403917	1.345484
2[b]	0.751105	0.564159	0.433407	1.311779
3[c]	0.749844	0.562266	0.458043	1.282943
4[d]	0.745564	0.555865	0.475114	1.262576
5[e]	0.713049	0.508438	0.444321	1.299083
6[f]	0.673497	0.453598	0.408064	1.340795

[a]Predictors: (Constant), ENVINF, CESD, AGROUP, PTHRESH, MMSE, MOOD, RISK

[b]Predictors: (Constant), ENVINF, CESD, AGROUP, MMSE, MOOD, RISK

[c]Predictors: (Constant), ENVINF, CESD, AGROUP, MMSE, RISK

[d]Predictors: (Constant), ENVINF, CESD, AGROUP, MMSE

[e]Predictors: (Constant), CESD, AGROUP, MMSE

[f]Predictors: (Constant), AGROUP, MMSE

Table 14. Recognition linear model report including standardized and unstandardized coefficients.

		Unstd. Coefficients		Std. Coefficient		
Model		B	Std. Error	ß	t	Sig.
1	(Constant)	-18.6415	9.664513		-1.92886	0.068823
	AGROUP	-0.82062	0.39295	-0.36939	-2.08835	0.050464
	MOOD	0.101594	0.377445	0.049786	0.269163	0.790706
	PTHRESH	-0.01127	0.109758	-0.0183	-0.1027	0.919274
	RISK	-0.26808	0.670978	-0.0757	-0.39953	0.693957
	CESD	0.081143	0.063002	0.228645	1.287937	0.213234
	MMSE	0.849367	0.31508	0.483899	2.695721	0.014321
	ENVINF	0.205453	0.142526	0.268307	1.441516	0.165719
2	(Constant)	-18.6022	9.415027		-1.9758	0.062137
	AGROUP	-0.81624	0.380845	-0.36742	-2.14323	0.044574
	MOOD	0.107289	0.363999	0.052577	0.29475	0.771222
	RISK	-0.29183	0.614094	-0.08241	-0.47521	0.639783
	CESD	0.082237	0.06054	0.231726	1.358382	0.189469
	MMSE	0.845583	0.30508	0.481744	2.771678	0.011771
	ENVINF	0.210008	0.132057	0.274255	1.59029	0.127453
3	(Constant)	-17.8395	8.853453		-2.01498	0.056888
	AGROUP	-0.82068	0.372181	-0.36942	-2.20505	0.038735
	RISK	-0.3266	0.589404	-0.09223	-0.55413	0.585346

	CESD	0.090367	0.052707	0.254636	1.714532	0.101153
	MMSE	0.8194	0.285445	0.466827	2.870606	0.009153
	ENVINF	0.204187	0.127701	0.266653	1.598945	0.124771
4	(Constant)	-18.2669	8.679776		-2.10454	0.046981
	AGROUP	-0.76383	0.352084	-0.34383	-2.16946	0.041126
	CESD	0.0909	0.051861	0.256138	1.752756	0.09357
	MMSE	0.83066	0.280201	0.473241	2.964512	0.007159
	ENVINF	0.173279	0.113052	0.226289	1.532737	0.139596
5	(Constant)	-14.3522	8.53535		-1.6815	0.106196
	AGROUP	-0.7699	0.362241	-0.34656	-2.12538	0.044513
	CESD	0.085261	0.053226	0.240249	1.601865	0.122832
	MMSE	0.725733	0.279566	0.413463	2.595925	0.016157
6	(Constant)	-12.9623	8.763775		-1.47908	0.152125
	AGROUP	-0.8964	0.364879	-0.40351	-2.45672	0.021635

The model was created by backward elimination of the variables at a 0.1 significance level.

Table 15. Comparative performance of the Recognition models.

	Full Model	**Mood, Age group, and MMSE Model**
F Value	4.455	10.69
Deg. Of Freedom	5, 21	3, 24
P value	0.006	0.0
R^2	0.575	0.516

Figure 1. Relative efficiency of response to the odor discrimination task.

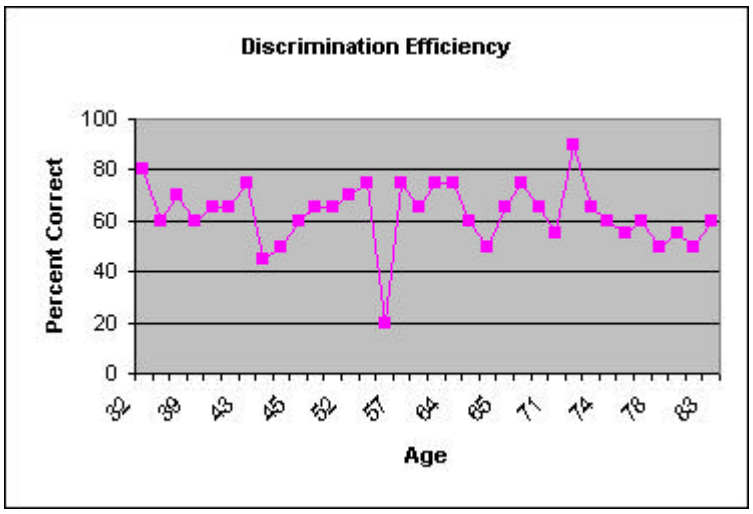
Discrimination Efficiency
Percent Correct
100
80
60
40
20
0
32
39
43
45
52
57
64
65
71
74
78
83
Age

Figure 2. Relative efficiency of response to the odor identification task.

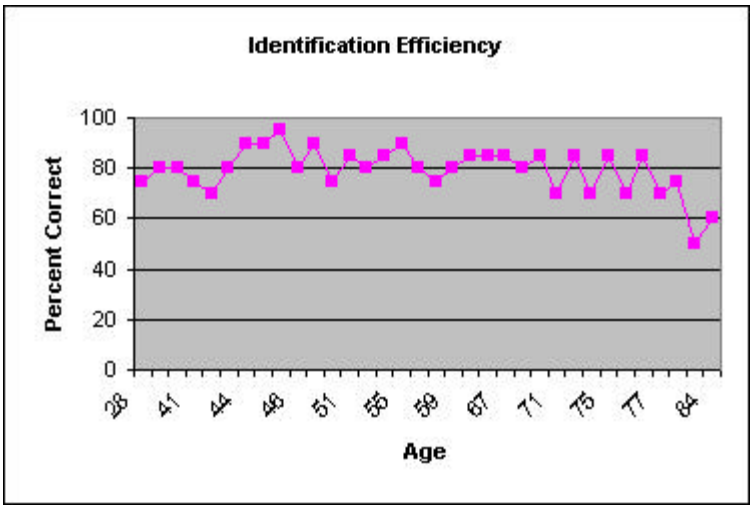
Identification Efficiency
Percent Correct
100
80
60
40
20
0
28
41
44
49
51
55
59
67
71
75
77
84
Age

Figure 3. Relative efficiency of response to the odor recognition task.


Recognition Efficiency
Percent Correct
100
80
60
40
20
0
33
40
44
50
53
62
69
72
74
83
Age

CHAPTER IV

CONCLUSIONS

Clearly, olfactory memory typically changes across the average human lifespan, although the changes are not directly tied to a chronological imperative. The chapters and appendices contained in this dissertation support previous research indicating that during the adult lifespan, numerous losses occur in abilities to sense and perceive odors as well as other sensory stimuli. Unlike much of the previous research on lifespan olfactory memory, however, the works contained herein acknowledge the heterogeneity of older adults, and explicitly notes the various impacts of environmental influence, pharmaceutical usage, mood, and cognitive status. This differentiation among older adults with regard to olfactory abilities has a number of health and safety implications, as well as theoretical import.

The review of literature presented in Chapter II noted the importance of olfaction in diagnoses of various pathologies and dementing illnesses. This increasing reliance on olfactory testing makes it essential that diagnosticians account for the environmental, pharmacological, and depressive indices as well as overt cognitive status when making such diagnoses as Alzheimer's, Parkinson's, and other diseases. Added to the findings of Chapter III that negative affect negatively influences olfactory memory, and the case for more background information is pertinent to such diagnoses.

Appendix B furthers this stance through the recognition of confounds added by environmental and pharmacological influences on olfactorial memory. Mercaptan levels added to the US natural gas supply have already approached saturation points, yet many older adults are still at risk due to loss of sensitivity. By understanding that loss of odor sensitivity is not an inherent effect of normative aging, the possibility exists to assess those most at risk and take action to increase safety.

As mentioned at the beginning of this dissertation, humans are not static, isolated beings but, rather, dynamic individuals who grow and change constantly in an environment that also changes. Although some older adults will be the normative agers most commonly used in this research, and some will be superlative agers like the centenarians in Appendix A, others will suffer pathological aging. To address changes in humans, one must take care to maintain the specificity of the population being addressed, as humans are an extremely heterogeneous group, and the heterogeneity represented is greater among older adults than among younger people. By considering the factors addressed herein, researchers are better able to better understand comparability of sensory systems through their relative stimuli.

By maintaining comparability of stimuli across the sensory modalities when stimuli were adjusted relative to their absolute thresholds, changes in performance across all modalities would be more indicative of the common cause stance. Specific deficits in sensory systems which the individual's experiences have developed lower automaticity effects, such as olfaction and possibly haptic sensation, would be supportive of the aging-induced cognitive load hypothesis due to the relative changes in demand characteristics for these sensory systems.

Thus, Baltes and Lindenberger's (1997) common cause hypothesis may be addressed in a complete and meaningful sense. It would be possible to negate the issues of differing sensory loads or lexicality effects of the various stimuli that limit true comparisons at this point. This type of testing would allow for a settling of the debate over the common cause theory versus the aging-induced cognitive load hypothesis which considers relatively simple sensory tasks to increase in cognitive complexity and demands as participants age. If Baltes and Lindenberger are correct and there is a common cause of overall change in intellectual and sensory function, although it should be considered that the individual abilities in a sensory system may mediate cognitive efficacy through protracted sensory underload, then several sensory modalities must be tested in an environmentally appropriate context, which would include olfaction. Therefore, the basic work presented here allows for such testing by demonstrating the relative impact of various influences that would otherwise confound the proposition and preclude answers to this important theoretical question.

References

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APPENDIX A

ODOR THRESHOLD, RECOGNITION, DISCRIMINATION, AND IDENTIFICATION IN CENTENARIANS [3]

[3] Elsner, R.J.F. 2001. Accepted by Archives of Gerontology and Geriatrics. Reprinted here with permission of publisher

Abstract

The main purpose of this study was to learn the use of select measures that are relevant to olfactory discrimination, identification, and recognition and to ascertain the appropriateness of extant methods and procedures for adaptation for use with the oldest-old. A second purpose of this study was to attempt initial examination of the relationship of different memorial systems in the oldest old through an atypical sensory modality. Twenty-one centenarians (M = 105.1 years) were tested on odor thresholds for Phenethyl Alcohol (PEA) and Menthol, recognition and discrimination of lexically challenging odors, and identification of common odors. Chronological age was not found to be a significant predictor of abilities for any of the tasks. Thresholds for PEA and Menthol were found to be better than anticipated levels, and were associated with odor recognition and certainty of response. MMSE scores were not found to be associated with olfactory measures, contrary to expectations. Findings suggest much of the previous research into olfactorial abilities of older adults may have failed to account for the influence of illness, trauma, dementia, and pathologies typically associated with age. In light of their performance on the tasks, the relative good health and cognitive status of the participants strengthens the idea that olfaction is an appropriate addition to diagnostic tests of Alzheimer's and other diseases.

Keywords: Centenarians, olfaction, memory, identification, thresholds, recognition

Introduction

The older segment of the population is the fastest growing portion of the world population. The United Nations (1999) estimates the number of people over age 60

globally exceeding one billion by the year 2020, and will comprise more than 30% of the populations of most of the developed world. The fastest growing segment within the over-60 bracket is that of centenarians.

Centenarians hold a special place in the investigations of age-associated changes of sensory, perceptual, and memory systems. Not only surviving, but in some instances thriving, they are superlative examples of the limits of human abilities. As other researchers (e.g., Baltes & Lindenberger, 1997) have pointed out, declines in hearing and vision can drastically influence scores on tests of memory and intelligence. Although no truly analogous tests are available for other sensory modalities, it is still possible to test memory through these other systems (e.g., Fuld , 1981; Fuld, Masur, Blau, Crystal, & Aronson, 1990). This paper addresses the topic of the olfactorial abilities of centenarians in order to explore memorial abilities. No work in the olfaction literature, and little in the memory literature, addresses this group. This paper is a first step in examining the sensorial and perceptive abilities of these remarkable individuals. This examination is done in relation to extant indicators of cognition and memory in order to better understand the difference between age-associated changes in ability and those that arise from other causes.

It is understood that some extant research on centenarians have focused on healthy, cognitively intact individuals, not necessarily representative samples (Ritchie, 1998). This does not, however negate the effects found within the population tested. For example, Suzman, Willis, and Manton (1992) describe the centenarian population as having 30% of individuals with no memory problems, 20% with some problems, and 50% having serious memory problems. Given this information, it is important to

remember that these particular expert survivors may indicate superlative, as opposed to normative, aging. With the demographic shifts under way, this upper echelon of the population is large and important enough to justify independent observation with the hope of aiding others in achieving this chronological status.

Research summarized by Cain and Stevens (1989) showed that chronological age is strongly associated with impairment of the sense of smell. An odor identification procedure used by Eskenazi, Cain, and Friend (1986) showed that normal adults from 20 to 50 years of age could identify 85 to 100% of the odors presented. Deterioration of odor identification began about age 50, and 60-year-old adults could identify 65 to 70% of these odors.

Doty, Applebaum, Giberson, Sikorsky, and Rosenberg (1984) reported one of the seminal research projects on lifespan olfactorial abilities. Testing a total of 1,955 people attending a state fair, scores on the test used reached an optimal level of ability between twenty- and fifty-years of age. By age eighty, scores for three-quarters of the individuals tested plummeted to nearly chance performance.

The findings of Doty and colleagues should not be taken as a statement of absolute aging research, but as a naturalistic experiment without control for dementia or pathologies. The precipitous, age-associated drop in abilities that they reported is an important consideration for the daily activities of older individuals. Perhaps insight into the nature of the declines can be partially explained by the current understanding of the prevalence in older adults of pathological states that affect olfaction. These states include disease, dementia, nutritional deficiencies, and insults and injuries. Among these, dementia is most often considered relative to aging.

Epidemiological studies have indicated that dementia effects 6-10% of the North American population over age 65, with two-thirds of these Alzheimer's sufferers (Hendrie, 1997). Over the past few decades it has become clear that Alzheimer's Disease (AD) and Parkinson's Disease (PD) compromise olfactory functions (Doty, 1991). Doty (1997) reviewed the olfactorial indicators and contributions to detection of a variety of pathological and physiological states, including neurodegenerative diseases like AD, PD, amyotrophic lateral sclerosis, Down's syndrome, Huntington's disease, and others. As humans age, there is a higher probability of being affected by these diseases. Thus as the population ages, there is a greater need to diagnose these diseases as early and accurately as possible. Recently the importance of olfaction in this area has become clear. The impact of lexical functioning and detection sensitivity on the deficit of odor identification in AD was studied in persons diagnosed with probable and questionable AD by Morgan, Nordin, and Murphy (1995). They concluded that odor identification tests have a correct AD classification rate of 83-100%, much higher that previously possible.

The main purpose of this study was to learn the use of select measures that are relevant to olfactory discrimination, identification, and recognition and to ascertain the appropriateness of extant methods and procedures for adaptation for use with the oldest-old. Another purpose of this study was to attempt initial examination of the relationship of different memorial systems in the oldest old through an atypical sensory modality.

Methods

Participants: Participants were recruited from the participant pool of the Georgia Centenarian Study which is a multidisciplinary longitudinal study of survival and adaptation (Poon, Clayton, Martin, Johnson, Courtenay, Sweaney, Merriam, Pless, &

Thielman, 1992). Participants were tested in their homes. These participants live in all parts of the State of Georgia, thus a considerable amount of travel was involved in data collection, negating the possibility of controlled laboratory testing. Twenty-one participants, aged 101-115 (mean age 105.1) were recruited and were representative of the population of older individuals in Georgia (27% Black, 70% female).

We obtained information on all pharmaceuticals and over-the-counter medications that they take to identify those which would inhibit their olfaction (Schiffman, 1983). Participants were also asked about smoking and tobacco use, allergies, and recent colds or flu.

Stimuli. For each task, all components were placed into separate sealed, opaque 20ml polyethylene vials, thus assuring a consistent amount of headspace relative to the desired level of aromatic concentration. Vials were labeled with three-digit numbers in order to enforce a double-blind nature of this procedure. Where appropriate, a placebo of de-ionized, distilled water or light odorless mineral oil was also used in an identical vial to ensure against guessing, misreporting of sensation, or perceptual abnormalities.

Five ml of each stimuli were presented inside of gauze-wrapped cotton balls within opaque polyethylene jars with odor-tight lids. The gauze and cotton balls allowed for obstruction of visual cues from the stimuli without obstructing airflow. All samples were presented at nose level after instructions to take a "natural" sniffs (i.e.: not “strong” or “weak” sniffs; Mozell et al., 1986) of the stimuli.

Procedure. Participants were tested individually in their homes. Participants were evaluated for their cognitive status a battery of tasks including the MMSE (Folstein, Folstein, & McHugh, 1975), the Global Deterioration Scale (Reisberg, Ferris, de Leon, &

Crook, 1982), and the WAIS Vocabulary test (Wechsler, 1944). The number of years of formal education was also recorded for each participant.

The olfactory battery was administered after the participant completed the MMSE and other measures. We have employed a four component methodology suggested by Schiffman (personal correspondence). This procedure includes detection thresholds for olfactorial and trigeminally stimulating substances, an odor recognition task, an odor discrimination task, and an odor identification task. It was imperative that adequate time was allowed between each task, so several minutes of rest and cordial discussion was inserted between each. There were several topics of conversation that were avoided, such as foods and personal issues which were known to be strongly emotional in these particular adults from their long-term participation in the Centenarian Study.

Detection Threshold. The odor detection threshold examined the least amount of a substance that could be detected by the participants. The task was a two alternative (test stimulus & control) forced-choice ascending concentration single series procedure. The stimuli presented during this task were menthol dissolved in light odorless mineral oil and phenethyl alcohol dissolved in deionized water. Five concentrations of each odorant were offered in a dilution series with a dilution factor of 3 for both odorants in their respective solutions. Control stimuli of deionized water and light odorless mineral oil were presented in the same quantities in identical apparatus. The task had been explained to the participants as determining which of the two samples presented in each pair had a stronger odor and describing the odor if possible.

Odor Recognition. The odor recognition task required participants to smell and remember a target odor and recognize that target from four forced-choice alternatives.

The task used four odorants: geraniol, methyl salicylate, benzaldehyde, and caproic acid. Participants were asked to sniff one of these odorants in a single bottle, randomized across participants, count aloud from one to ten, then sniff all four of the odorants in their respective separate bottles and designate which was the odor they had been asked to remember. The backward counting was included based on data from Engen, Kuisma, and Eimas (1973), who had employed spoken backward counting as a disrupter of odor memory. Their results were verified in a series of experiments reported by Murphy (1995). This was the impetus for inclusion here, but the time required for counting also aided in preventing speeded age-associated olfactory adaptation and slowed recovery of the olfactory epithelium (Stevens, Cain, & Oatley, 1989).

Odor Discrimination. The odor discrimination task presented pairs of odors that were sometimes identical and sometimes different, and asked participants to tell whether or not they were the same. Participants were instructed to ignore the intensity of the odors and concentrate of the qualities of the odors. Stimuli were presented in a random order and were composed of the following pairs: benzaldehyde and caproic acid, n-butanol and citral, benzaldehyde and geraniol, geraniol and citral, methyl salicylate and caproic acid, and each of these individual odorants, benzaldehyde, caproic acid, n-butanol, citral, and methyl salicylate paired with themselves.

Odor Identification. The odor identification task consisted of the participants being told the name of an odor, then presented with two samples and asked to judge which one was the odor that had been named. As familiar odorants have been shown to be more easily identified than uncommon odorants (Schab, de Wijk, & Cain, 1991), the stimuli used in the identification component of this study were common odorants selected

from a list compiled by Cain and Gent (1986). The procedure was similar to that used by Schemper, Voss, and Cain (1981). The pairs were presented in a randomized order and consisted of: ground coffee and peanut butter, peppermint extract and anise extract, vanilla extract and cinnamon oil, baby oil and honey, bubble gum and almond extract, anise extract and ground coffee, peanut butter and cinnamon oil, honey and peppermint extract, vanilla extract and bubble gum, and almond extract and baby oil.

Results

Summaries of mean and standard deviations of specific descriptors and tests are reported in Table 1. The results of the GDS indicated that all of the participants were fully functional. As the GDS scores did not agree with the MMSE, scores were adjusted according to Reischies and Geiselmann (1997) to verify the cognitive status of the participants as intact. Eight of the participants had unadjusted MMSE scores between 12 and 15, indicating dementia, seven had scores between 17 and 22, indicating some impairment, and five had scores between 23 and 27, indicating intact status. After adjustment, only four of the participants were considered to have some impairment. Unadjusted scores were used in analyses to allow for better comparison with other studies.

When we examined the olfactorial abilities of the participants in regard to their drug utilization, we found that of the twenty-one, only three were using any pharmacological agents on a regular basis. Two used blood pressure medicines, the third took an analgesic. These individuals were those who had some of the worst thresholds, but no significant deviation on MMSE scores from other participants although they were among the lowest scoring.

Detection Threshold. The distribution of the MMSE scores by age and relative to the thresholds for the two odorants is shown in Figure 1.

The odor detection threshold task for the phenethyl alcohol showed the lowest threshold possible for 16 of the 21 centenarians, indicating far better performance than expected. Associations of age with the thresholds for PEA (F (9, 20), p>.4775) and Menthol (F (9, 20), p>.4979) were not significant. Two of the participants had stated that they had been completely anosmic for thirty to forty years due to illness. The threshold tasks gave some support for that claim for one participant, but the second demonstrated an adequate detection of the menthol and average performance on all later tasks. Thirteen of the participants detected menthol at the lowest levels used, and six detected it at the second lowest level. It should be remembered that the ascending staircase used was a single trial due to the frailty of many of the participants, and thus does not account for cautiousness of the individuals as mentioned by Doty (1991).

Odor Recognition. For the odor recognition task, 66.7% of the respondents identified the correct item from the four possible choices, though the overall level of certainty was not very high, with a mean response of 2.55 out of possible 4. Contrary to expectations, regression (PROC GLM) found age to not be a significant predictor (F (1, 20), p>.2197) of veracity of response. As expected, certainty of response of the recognition task was also significant to the recognition itself (F (1, 20), p>.0217). These responses are similar to those found for a much younger sample by Jones, Moskowitz, and Butters (1975) at the 0-second retention interval. This level of almost 70% still warrants the examination of odor memory including a second retention interval. A component of the MMSE examination includes a memory test with a counting and

spelling distracter, and the participants who had difficulty with these distractors were also unable to correctly identify the target odor. The ability to recognize these suprathreshold odors was significantly associated with the PEA threshold, ($\underline{F}$ = (2, 20), p>.0029), as those with better thresholds were more certain of their responses.

Odor Discrimination. The odor discrimination task showed mixed results, with many pairs of stimuli approaching chance levels, and one pair (caproic and caproic) being significantly worse than chance, which may be an indicator of the lack of understanding of the task more than memorial difficulties with particular odorants. As expected, odor discrimination was significantly associated ($\underline{F}$ (5, 20), p>.0035, R^2 = .66) with identification, but not with any other factor. This task encountered many problems with this population. Reported olfactorial exhaustion was one of the greatest problems, but certainly boredom and lack of motivation with this task played major roles. Four participants refused to complete the task. Percent correct responses based on trials attempted are shown in Figure 2.

Odor Identification. The odor identification task, unlike the discrimination task, was easily understood and enjoyed by the participants. One of the difficulties found was the lack of familiarity of the participants with several of the stimuli. This was especially true for anise/licorice, which needed to be described as “black jelly beans” or the “sticky white candy you got during the summer” during childhood (a Southern colloquialism described to us by one of the first centenarians we tested). Only twelve of the participants attempted to identify anise/licorice. Similarly, almond, cinnamon, baby oil, and bubble gum posed problems for many centenarians, respectively with only thirteen, fourteen, fifteen, and fifteen respondents each. Familiarity with bubble gum was also significantly

negatively correlated (p>0.0445) with advancing age. An interesting note was that the one item repeated, peanut butter, was identified correctly 85.7% of the time at the first presentation, and 95% of the time the second.

There were several instances of significant interaction that were expected, and a few that were expected but not found. For example, identification was associated with menthol (F (2, 20), p>.0294), but not with PEA threshold (F (2, 20), p>.2428). This could be partially due to lack of understanding of the task or uncertainty of response during this first task. Identification was not associated (F (12, 20), p>.6493) with the unadjusted MMSE score which we knew to not be fair and representative. The responses for the recognition task were strongly associated (F = 8, 20), p>.0268) with the responses to the identification task. Certainty of response of the recognition task was significant to identification (F (8, 20), p>.0132, R^2=.74), which indicated that those who were able to identify items were more certain of their responses, which was not surprising. Certainty was also aligned with PEA threshold (F (2,20), p>.0029), which is indicative of better function through the olfaction-memory complex.

The question of the olfaction-memory complex was also addressed by the finding of significance when PEA threshold was regressed by vocabulary score (F (16, 20), p>.0008, R^2 = .995). Those with better vocabulary skills also had better PEA thresholds. While not essential to the discussion of olfactorial abilities, in this particular population this is most likely due to overall status, but needs to be examined across the entire lifespan as part of a question of lifestyle and clarity of thought more than on physiological abilities.

It should be noted that although many studies indicate higher education to be associated with better performance, in this population this was not the case. For example, vocabulary regressed by education was not significant (F (8, 20), $p>.2866$), nor was unadjusted MMSE by education (F (8, 20), $p>.6039$).

Discussion

When considering the results of this study, a few issues must be mentioned. It is extraordinary that so few of the participants were taking any medications. The limitations of this study stand out, especially in the ceiling effects in the threshold, discrimination, and identification tasks. The levels of odorants that were used erred on the side of caution for olfactorial exhaustion in this traditionally frail population, but are supported by earlier studies which had demonstrated log-linear declines in abilities with age.

Those individuals with the best vocabulary scores showed no overall superiority of ability over those with lower scores, raising the question of how the olfactorial stimuli is processed and retained by the Central Executive in working memory. According to Engen (1991), odors tend to be named with reference to certain contexts in which they occur or are used and with associates at the same level of abstraction. Experiments with the use of different odor labels (e.g., Engen, 1987) suggest that due to this effect, we need to consider the relative merits of various models of memory as they apply to olfaction. From other disciplines come alternatives that are often overlooked in mainstream psychology, for example what is described as lexical collocation (Halliday and Hasan, 1976) in linguistics. This may be a better semantic model for how odors are encoded, as it refers to the association of items which regularly co-occur. The cohesion of lexical tags occurring with odor stimuli under specific context can lead to pairings of categories

within semantic relationships. This cohesive effect in the lexical environment leads to collocation of memory activation in both the limbic olfaction memory systems and the higher-order lexical systems. Such a perspective would allow for the notion that semantic memory and odor identification tap the same cognitive domain, while accounting for differential abilities in recognition memory for odors where stimulus intensity has been accounted for.

It is also of import that the initial MMSE scores supported the expected levels of dementia in this population, but these low expectations were not met by the relatively high adjusted scores and subsequent extraordinary performance. These considerations are taken as support for the basic hypothesis set out by Baltes and Lindenberger (1997) that there is a common cause of overall change in intellectual and sensory function, but it should be considered that the individual abilities in a sensory system may mediate cognitive efficacy through protracted sensory underload. This combination of the theories of Baltes and Lindenberger may aid in explaining the differences in underuse and underutilization of sensory systems that may be accounting for such large portions of age-associated change.

From the results presented in the current study, several basic conclusions can be made. First, it can be concluded that the abilities of centenarians are far superior to those envisioned for them. The ceiling effects in the odor threshold and identification tasks support the findings by Wysocki and Gilbert (1989) that age-response curves for different odors vary across the life span, while at the same time bringing forth the question of the impact of lexicality effects on these curves.

Second, it can be discerned that a more sensitive testing of the thresholds of the oldest old may be very helpful in identifying the distinction between declines in olfaction caused by age and those caused by various traumas, insults, and pathologies which may accompany age. The abilities of the participants in this project lend support to a hypothesis that the occurrences of these traumas, insults, and pathologies have overshadowed and confounded any actual age-associated decline in abilities. This hypothesis would also aid in explaining why there is an asymptote at the oldest decade in the decline curve in the seminal study by Doty and colleagues (1984), as the pathologies are less evident in expert survivors. This is an important point in that the chemical senses are not able to be tested as quickly as other sensory modalities, especially in the oldest-old, thus we need to maintain the highest reliability of the measures used to avoid unnecessary re-testing. In our review of the literature, we found minimal reporting of reliability indices in olfaction measures. In one clinical study conducted at the Lexington, Kentucky VA Hospital, the test-retest correlations for the identification of 14 odors was greater than .93 (Lawless, 1986). They were able to report indices of internal consistency and test-retest reliability from 60 to 90-year-olds.

The exceptionally poor performance of many participants on the discrimination task may have been attributable not only to fatigue and lack of motivation, but to inhibition failures. Several of the participants were visibly agitated after smelling the first few samples presented. When asked about this, two stated that they were still trying to figure out what the first odors were, indicating that the lack of lexical tags for these odors was distracting to the point of failure to inhibit concentration on labeling them.

Clarification is needed on whether the lack of familiarity with the odors or the lack of lexicality accounts more for this phenomenon.

One classic index used in the study of olfactory functioning is the ease with which participants can name familiar odors, given a sniff, out of context (Doty, Shaman, Krefetz, & Dann, 1981; Douek, 1974). This is different from the identification task in the present study in which names were given before presentation of the odors. As we wish to examine the natural status of the individual and their changes due to aging, we allow for the contextual basis of familiarity with the odors that might be found in the home. In the next phase of this research, there are two potential paths that are in desperate need of attention. At some point, we intend to prime the participants through reading a list of the possible odorants. This should aid in the performance, as is evident using other modalities, such as in tachistoscopic word recognition (Jacoby & Dallas, 1981) and picture naming (Snodgrass & Feenan, 1990) while avoiding the pitfalls experienced in this project due to a lack of familiarity with the odorants used. A second avenue of inquiry would be to explore the adult lifespan perspective by expanding this research to include individuals from other age groups. This might allow for not only the establishment of a truly normative data set, but if longitudinally maintained, it would hold potential to discover the lifespan changes in olfaction and the various memory systems. Such information could be used not only for better predictive and diagnostic measures, but also for understanding some facets of causality based on the life trajectories of the participants.

As Engen, Gilmore, and Miar (1991) pointed out, it is difficult to assess impairments of cognition, perception, or primary sensory capacity at a functional level as

reflected by olfactory deficits. Research is needed which can differentiate between these aspects of olfaction to determine which is most indicative of the causation of the changes and declines reported.

Both peripheral and central functions are involved in olfaction, especially with older individuals, and the relationship between these two is generally unknown (Booth, 1995). In the study of normative aging processes, one of the central questions which has not been adequately addressed is how do peripheral and central functioning influence each other. Lindenberger & Baltes (1995) posed the question: "is there a central processor that controls both peripheral and central processes in normal aging?" And as the peripheral and/or central function begin to decline, as often observed in aging, how do these functions interact or summate to influence the observe performance? Koss, Weiffenbach, Haxby, & Friedland (1988) suggested that early chemosensory impairment in Alzheimer's disease is due to central rather than peripheral dysfunction. Though this may seem obvious, even in a worst-case scenario it implies that central processing may need to be more closely examined. It would be important to examine variations in both peripheral and central processing and evaluate the inter-relationship and inter-dependencies to ascertain the effects of aging on declines in sensory abilities. The absence of Alzheimer’s and dementia within the current study aids in understanding the impact of inclusion of olfactory assessment in diagnostic procedures for the disease state as reported by Morgan, Nordin, and Murphy (1995) as well as the idea that age itself is not the causal factor for age-associated loss in sensory perception.

From a practical perspective, deterioration in both peripheral and central functions has direct and inter-related impact on the activity of daily living and quality of life of an

aging individual. An important research and practical question for the older adults is how we could utilize the remaining intact functions to compensate and maintain an acceptable quality of life as long as possible.

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Table 1. Descriptive statistics of participants.

	Mean	SD	Min	Max
Age	105.1	3.78	101	115
MMSE	18.6	4.80	12	27
Vocabulary	21.3	12.9	7	45
Education	6.85	4.8	0	16

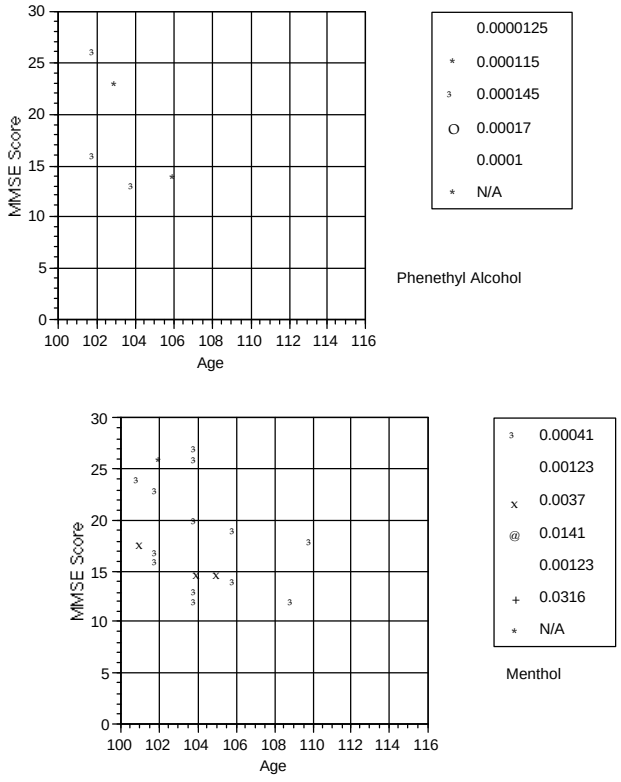

Figure 1. Mini-Mental State Exam Scores by age and in relation to threshold for Phenethyl Alcohol and Menthol.

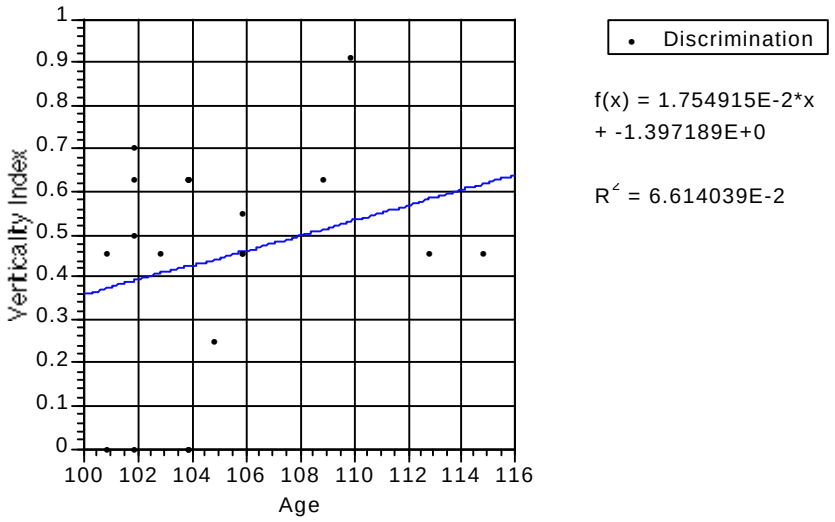

Figure 2. Percent correct responses for odor discrimination task.

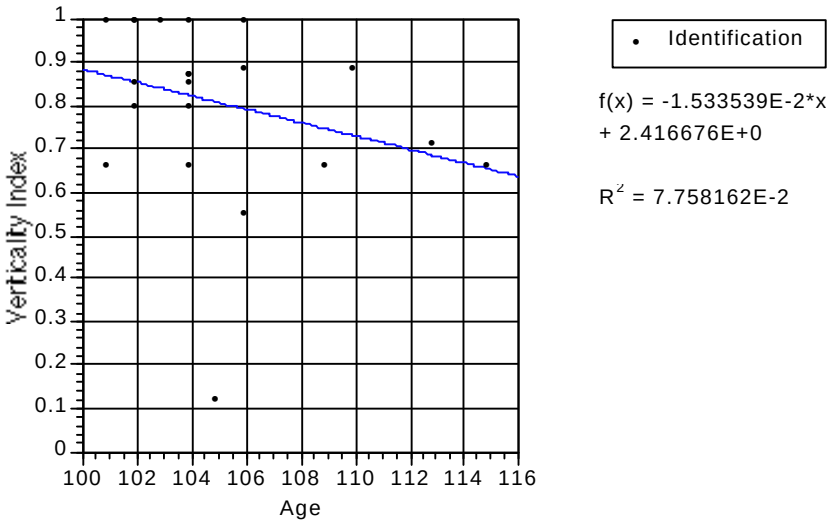

Figure 3. Percent correct responses for odor identification task.

APPENDIX B

ENVIRONMENT AND MEDICATION USE INFLUENCE OLFACTORIAL ABILITIES OF OLDER ADULTS.[4]

[4] Elsner, R.J.F. 2001. Environment and medication use influence olfactorial abilities of older adults. Journal of Nutrition, Health, and Aging, 5, 5-10.

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Abstract

Fifty participants aged 50-96 (M = 70.4) in two groups (environmentally at-risk and low-risk) were administered a set of four olfactory tasks, WAIS Vocabulary, MMSE, and demographic questionnaires. Environmental risk was defined as having worked in places where exposure to caustic fumes (e.g., formaldehyde, toluene, etc.) was common and long-term. Olfactory tasks included detection thresholds for phenethyl alcohol (PEA; assesses olfactory function) and menthol (assesses olfactory and trigeminal function); odor recognition in a forced-choice paradigm; odor difference discrimination; and odor identification with supplied names. The high-risk group had significantly higher thresholds for PEA, and significant within-group variability for menthol. Medication usage and cognitive status were significantly associated with odor recognition. Only medication was strongly associated with the odor discrimination task. Medication usage, environmental risk, and age in order were found to be the greatest risk factors for odor identification. The conclusions highlight the need to carefully consider environmental and pharmacological effects in age-associated sensory tasks.

Introduction

Research summarized by Cain and Stevens (1989) showed that chronological age is strongly associated with impairment of the sense of smell. Doty, Applebaum, Giberson, Sikorsky, and Rosenberg (1984) reported one of the seminal research projects on lifespan olfactorial abilities. Testing a total of 1,955 people using the University of Pennsylvania Smell Identification Test (UPSIT), scores on the test used reached an optimal level of

ability between twenty- and fifty-years of age. By age eighty, scores for three-quarters of the individuals tested plummeted to nearly chance performance.

The findings of Doty and colleagues should not be taken as a statement of absolute aging research, but as a naturalistic experiment without control for dementia, pathologies, or any other confounds. The precipitous, age-associated drop in abilities that they reported is an important consideration for the daily activities of older individuals. Perhaps insight into the nature of the declines can be partially explained by the current understanding of the prevalence in older adults of various states that affect olfaction. These states include disease, dementia, nutritional deficiencies, and insults and injuries. Among the most powerful of these may be the effects of environmental conditions that would provide heightened risk of insult and injury to the olfactory system.

The only comprehensive study detailing the amalgamated effects of environmental influences on older adults came from the National Geographic Smell Survey (Corwin, Loury, & Gilbert, 1995). This study reported data from 712,000 respondents who took the scratch-and-sniff test of six odorants. The findings show differential abilities for specific odors, thus bringing up the question of why sensitivity to some odorants are more adversely affected than others. Although there were numerous methodological issues of concern with this study, overall the results indicated that the workplace might determine the olfactorial abilities of individuals as they age more than other factors. Workplaces, especially factory work, determine not only exposure to toxic or caustic substances, but also potential for increased head injury. The selective declines also lend credence to the central processing deficit hypothesis previously discussed.

Although there have been many excellent studies dealing with the topic of aging and olfaction, there are methodological issues that prevent most studies from answering important questions concerning the reasons for the diminishment of abilities that most extant research has found. For example, few studies have screened participants for their pharmaceutical use. Although Ship and Weiffenbach (1993) reported that general medication use did not statistically influence olfactory abilities, but they did not examine differences in specific medications. Not all pharmaceutical products influence olfaction, but many broad categories do (PDR, 1997). For instance, one classification that typically influences olfactory abilities is anticholinergics. This classification of medications affects olfaction directly by drying and decreasing mucosa (cf. Astor, Hanft, & Ciocon, 1999) as well as by causing or exacerbating cognitive impairment (Gray, Lai, & Larson, 1999). As certain anticholinergics are typically prescribed to treat conditions such as Parkinson's disease, research into this area must consider these effects carefully to avoid misinterpretations (Doty, 1992; Doty, Deems, & Stellar, 1988; Wenning, Shephard, Hawkes, Petuchevitch, Lees, & Quinn, 1995). These particular medications are a good example, as they are taken in a wide variety of circumstances.

Blazer, Federspeil, Ray, and Schaffner (1983) reported multiple anticholinergic medications being taken by many older people with alarming prevalence. This rate of usage is not only dangerous because of toxicity, but also because drug-drug and drug-food interactions can have negative effects on cognition and mood. Schiffman, Graham, Shaid, and Sattely-Miller (1997) have reported that multiple pharmaceuticals can also cause deficits and distortions in taste. Pharmacological use and side effects may aid in explaining the uniformity of chemosensory losses (Cain & Stevens, 1989). A vital facet is

missing if these pharmacological interactions are among the primary influences on age-associated changes in odor memory but are not included in the study design. To assess the impact of pharmacology on aging and olfaction, it must be considered at least in screening participants.

The main purpose of this study was to examine the relative effects of medication and environmental history to the overall efficacy of olfactorial memory. To this end, both cognitive and olfactorial tests were required to examine the nexus of the environmental and pharmacological factors.

Methods

Participants: Only healthy, community-dwelling non-smokers who were not currently suffering any allergic reactions or recent colds or flu were invited to participate. Participants were recruited from two sources to vary the experiential factors of environment that might influence olfactorial abilities. First, participants were recruited from seniors groups at two churches in Athens, GA. None had life- or work-conditions that placed them at environmental risk for olfactory loss. The second group of participants was recruited from retirees of a wood-processing mill in northeast Georgia. This group was seen as being at-risk for olfactory loss due to heightened potential for exposure to industrial and chemical products (e.g., caustic fumes, paint thinner, formaldehyde, toluene, etc.) which might traumatize or cause long-term injury to the olfactory epithelium and bulb. Both groups grew by word-of-mouth volunteers who were friends of the participants and wanted to join the study, but limits were placed to maintain some balance between the sizes of those with histories of living and working in environments considered low-risk (N = 26) and at-risk (N = 24).

The employment histories of low-risk participants included domestic, office, and professional occupations. The at-risk group had typically been employed as construction, farm, or industrial workers and management. In instances where there was overlap of professions, the participants were placed in the at-risk group (e.g., physician working in a wood processing plant). Information was gathered on all pharmaceuticals and over-the-counter medications that participants take to identify those that would inhibit their olfaction (Schiffman, 1983).

Stimuli: For each task, all components were placed into separate sealed, opaque 20ml polyethylene vials, thus assuring a consistent amount of headspace relative to the desired level of aromatic concentration. Vials were labeled with three-digit numbers in order to enforce a double-blind nature of this procedure.

Five ml of each stimuli were presented inside of gauze-wrapped cotton balls within opaque polyethylene jars with odor-tight lids. The gauze and cotton balls allowed for obstruction of visual cues from the stimuli without obstructing airflow. All samples were presented at nose level after instructions to take a single "natural" sniff (i.e.: not “strong” or “weak” sniff; Mozell, Hornung, Sheehe, & Kurtz, 1986) of the stimuli.

Procedure: Participants were tested individually in their homes. Participants were evaluated for their cognitive status using the MMSE (Folstein, Folstein, & McHugh, 1975). To assist in understanding the role of lexical abilities in specific memory tasks, the WAIS Vocabulary test (Wechsler, 1944) was administered. The number of years of formal education was also recorded for each participant.

A four component methodology developed previously (Elsner & Poon, 1997) was employed. This procedure includes detection thresholds for olfactorial and trigeminally

stimulating substances, an odor recognition task, an odor discrimination task, and an odor identification task. Stimuli selected in the previous study were employed here. As it is imperative that adequate time was allowed between each task, the MMSE, WAIS, and demographic questionnaire were completed between administration of the odor tasks.

Detection Threshold. The odor detection threshold was employed here to ensure that none of the participants were anosmic or had thresholds so high as to unduly confound results. The task examined the least amount of a substance that could be detected by the participants. The task was a two alternative (test stimulus & control) forced-choice ascending concentration single series procedure. The stimuli presented during this task were menthol dissolved in light odorless mineral oil and phenethyl alcohol dissolved in deionized water. Phenethyl alcohol is a pure odorant, meaning that it only stimulates the olfactory nerve. Menthol, on the other hand, stimulates the olfactory nerve as well as the trigeminal nerve. As the olfactory bulb is more susceptible to damage from insult and injury, this distinction is important.

Five concentrations of each odorant were offered in a dilution series with a dilution factor of 3 for both odorants in their respective solutions. Control stimuli of deionized water and light odorless mineral oil were presented in the same quantities in identical apparatus. The task had been explained to the participants as determining which of the two samples presented in each pair had a stronger odor.

Odor Recognition. The odor recognition task required participants to smell and remember a target odor and recognize that target from four forced-choice alternatives. The task used six odorants: geraniol, citral, n-butanol, methyl salicylate, benzaldehyde, and caproic acid. Participants were asked to sniff one of these odorants in a single bottle,

randomized across participants, count aloud backward from ten to one, then sniff all four alternative odorants in their respective separate bottles and designate which was the odor they had been asked to remember. The procedure was repeated for ten trials.

Backward counting between the target and alternatives was included based on data from Engen, Kuisma, and Eimas (1973), who had employed spoken backward counting as a disrupter of odor memory. Their results were verified in a series of experiments reported by Murphy (1995). The time required for counting also aided in preventing speeded age-associated olfactory adaptation and slowed recovery of the olfactory epithelium (Stevens, Cain, & Oatley, 1989) that might confound actual olfactorial abilities.

Odor Discrimination. The odor discrimination task presented pairs of odors that were sometimes identical and sometimes different, and asked participants to tell whether or not they were the same. Participants were instructed to ignore the intensity of the odors and concentrate of the qualities of the odors. Stimuli were presented in a random order and were composed of the following pairs: benzaldehyde and caproic acid, n-butanol and citral, benzaldehyde and geraniol, geraniol and citral, methyl salicylate and caproic acid, and each of these individual odorants, benzaldehyde, caproic acid, n-butanol, citral, and methyl salicylate paired with themselves.

Odor Identification. The odor identification task consisted of the participants being told the name of an odor, then presented with two samples and asked to judge which one was the odor that had been named. As familiar odorants have been shown to be more easily identified than uncommon odorants (de Wijk, Schab, & Cain, 1995), the stimuli used in the identification component of this study were common odorants selected

from a list compiled by Cain and Gent (1986). The procedure was similar to that used by Schemper, Voss, and Cain (1981). The pairs were presented in a randomized order and consisted of: ground coffee and peanut butter, peppermint extract and anise extract, vanilla extract and cinnamon oil, baby oil and honey, bubble gum and almond extract, anise extract and ground coffee, peanut butter and cinnamon oil, honey and peppermint extract, vanilla extract and bubble gum, and almond extract and baby oil. The name provided to participants during each trial was the first listed in each pair above.

Results

Data were analyzed using the SAS computer program (SAS Institute, 1998) using correlation matrices (PROC CORR) and hierarchical regression models (PROC GLM). Summaries of mean and standard deviations of specific descriptors and tests are reported in Table 1. All participants were cognitively intact. Although there was relatively little medication use, a large number of the medications being used were in categories listed (PDR, 1997) as having a potential negative influence olfactorial abilities as discussed earlier.

A correlation matrix for the data found no relationship between age and medication use, but there was a significant inverse correlation between age and MMSE scores (r = -0.573; p>|R| = 0.0001). Inverse correlations were also found between age and vocabulary score (r = -0.622; p>|R| = 0.0001) and education (r = 0.0001; p>|R| = 0.0001). Higher educational attainment was also correlated with higher MMSE scores (r = 0.406; p>|R| = 0.0035).

Detection Threshold. For the detection threshold of PEA, age was found to have no effect when regressed for all participants. However, when separated by environmental

risk groups, the high risk group was found to have a significant age association (P>F = 0.0039; 20, 23; R^2 = .997). PEA detection was significantly associated with MMSE scores (P>F = 0.0165; 5, 49; R^2 = .263).

Menthol detection was found to be significantly associated with age (P>F = 0.0001; 33, 49; R^2 = .937). Further examination by environmental risk group found variation to be non-significant for the low-risk group, whereas the high-risk group was significant (P>F = 0.0053; 20, 23; R^2 = .996). MMSE scores showed no relationship with menthol detection.

Odor Recognition. The mean percentage correct on the odor recognition task was 0.788 (SD = 0.164). For the recognition task, age and environmental group were not found to be significant predictors of performance. Medication usage, however, was found to be significantly associated with this ability (P>F = 0.0001; 5, 49; R^2 = .444), as was MMSE (P>F = 0.0220; 5, 49; R^2 = .251). As would be expected, there was a relationship to certainty of response (M = 3.04, SD = 0.755) and performance on this task (P>F = 0.0054; 3, 49; R^2 = .238).

Odor Discrimination. The mean response percentage correct for the odor discrimination task was 0.670 (SD = 0.179). When examined for ability to discriminate between odors, no significant association was found for age, MMSE, or environmental risk. Medication usage was the only factor found to predict performance of this task (P>F = 0.0185; 5, 49; R^2 = .258).

Odor Identification. For all participants, the mean percentage correct for the odor identification task was 0.734 (SD = 0.159). Contrary to our predictions, there was no significant association of vocabulary or education on odor identification. Medication

usage (P>F = 0.0001; 5, 49; R^2 = .493) was found to be the strongest association, followed by environmental risk (P>F = 0.0298; 1, 49; R^2 = .095) and age (P>F = 0.0441; 33, 49; R^2 = .822). A model testing identification as dependent on age, MMSE, medications, and environmental risk was found to be non-significant (P>F = 0.0934; 43, 49), but did account for most of the variance (R^2 = .954).

Discussion

The data presented here demonstrate the importance of considering the exogenous as well as endogenous influences in olfactory variability. Although this was a self-selected participant group, and therefore the generalizability to the population at large may not be strong, the strength of the argument for the influence of life-course environmental risk and pharmacological interference associated with sensory function is persuasive. Although using different tasks, these findings are basically in accordance with the findings of Corwin, Loury, and Gilbert (1995), and support their assertion that there is an influence of environmental stimuli in maintaining or degrading the olfactorial abilities across the adult lifespan. One potential criticism of the present study may view the participant selection as overly simplistic in examination of environment, as the at-risk participants typically experienced insult to their olfactory bulbs far beyond normal levels.

As this study did not have statistical power for advanced multifactorial models of age-associated change in olfactory function, it is important to acknowledge the limitations of the study. When considering the results of this study, no single task should be seen as an absolute verification of one theory or another. Rather, the collected body of data should be used to question the impact placed on the aging process itself in the changes often accompanying age.

Several considerations are relevant in the discussion of these results. First and foremost is the prevalence of ceiling effects in the detection threshold tasks. Due to the majority of the low-risk environment group displaying ceiling performance on this task, a lot of the variability that might be found in this group could not be explored for age-associated deficit. At the same time, the relative performance of the two groups indicates that the effects of environmental factors and pharmacological usage far outweigh the relative change associated with the natural aging process.

Recognition abilities for the two groups in the present study showed that for this particular set of abilities, pharmacological interference with the perceptive and or cognitive processing abilities o the participants was much stronger that the lifespan experiences. The lack of significant difference between the risk groups might be taken as evidence of the importance of cognitive, rather than physiological status in memory for odors.

A specific consideration is that odor recognition is an explicit, episodic task in which odors are presented in a variety of sequences, and the participant must judge whether or not the particular odor has been presented before. This test of previous exposure of a stimulus in the short-term memory stores does not inherently require verbal labeling, but covert labeling may occur, potentially either increasing or decreasing performance. Odor memory, like memory for other sensory modalities, tends to undergo labeling during encoding, whether overt or covert. This phenomenon was reported by Engen, Kuisma, and Eimas (1973), whose results were verified in a series of experiments reported by Murphy (1995).

The importance of the influence of pharmaceuticals also weighs heavily in the discrimination task. Taken together, this leads to questions of other sensory and perceptive changes in aging. If both the recognition and discrimination functions of sensory systems are impaired by pharmaceutical use, then it stands to question the impact on other functions typically attributed solely to aging. This is not to say that the normal aging process does not instigate a natural decline in abilities to some degree, but rather that the precise levels of the declines may not be as drastic as some previous studies have inferred. The recognition task relies on episodic memory, whereas the identification task relies on semantic memory. Larsson (1997) reviewed the age differences found in episodic odor recognition memory and reported that the differences result in a large part from cognitive abilities, specifically semantic memory. Larsson and Bäckman (1993, 1997) demonstrated that age-associated differences in odor recognition memory were eliminated when the semantic memory task of odor identification was statistically controlled for.

An odor identification procedure used by Eskenazi, Cain, and Friend (1986) showed that normal adults from 20 to 50 years of age could identify 85 to 100% of the odors presented. Deterioration of odor identification began about age 50, and 60-year-old adults could identify 65 to 70% of these odors. The present study employed a different methodology that would account for the higher rate of 73% reported, as participants did not need to spontaneously generate names, and lexicality had been activated for each odor. Although the procedures differ, these two studies are supportive of the idea that in the general population there is a diminution of abilities associated with aging. The present

study however asserts that the preponderance of change is not caused by aging per se, but rather by the physical and cognitive accumulation of experiences over the lifespan.

An interesting note was that when a very similar methodology was used for centenarians (Elsner & Poon, 1997), ceiling effects were found for the identification task. Why these same effects were not present in a cognitively-intact younger group is curious, but may be due to significantly more time allowed for the centenarians to recover from odor presentations.

One of the hypotheses for this study had been that those individuals with the highest WAIS Vocabulary scores would have an advantage in the semantic odor identification task. As this was not the case, it may imply that other, less obvious lexical abilities are at work. An individual's lexicon for sensory stimuli is often seen as reliant on the overt and covert labeling that would be facilitated by verbal labeling (cf. Engen, Kuisma, & Eimas, 1973). It is, perhaps that a separate covert system exists which is not subject to subvocalization and other phonoarticulatory processes in short-term memory. Further research is needed as to what specific cognitive domains are being tapped by these processes.

One potential avenue for this exploration would be examining the differences between the present study and that of Larsson (1997), who found verbal ability and odor identification to tap the same cognitive domain. The most likely explanation would be the lexical search and generation functions of semantic memory were in much higher demand in Larsson's methodology, whereas the present method was not cognitively demanding for odor labels, as no choices had to be made for semantic categorization before encoding. Brosseau and Cohen (1996) conclude that the representations of semantic

categories are different in young and old people, possibly caused by developmental differences affecting the quality of experience and knowledge. Considering this perspective, perhaps odors outside the realm of normal experience may need to be synthesized to explore the depth of non-lexical memory.

Richardson and Zucco (1989) describe odor identification as the intersection of the bottom-up process of sensory functioning and the top-down process of cognitive abilities. In fact, all of the tasks presented here conform to this statement, although the specific cognitive processes differ to some degree by task. The intersection of functioning and abilities may be influenced by endogenous or exogenous influences.

From the significant role of environmental risk and medication usage on so many of the tasks performed in this study, several assumptions may be made. First, it may be safe to assume that the combination of debilitating exogenous factors, such as insult, injury, and illness, and endogenous factors, such as cognitive decline, pharmacological status, nutrition, dehydration, etc., contribute to the declines typically seen in aged individuals more than does the natural aging process itself. As there is no definitive standard of normative decline against which the performance of older adults can be compared, this is partly speculative inference. A second assumption is that may be made is that our understanding of environmental influences of olfactory function is limited and needs to be expanded. The distinctions between what constitutes an environmental risk to olfactory function may need to be explored further. Areas of influence not previously explored fully, such as genetic and cultural contributions to olfactory abilities, also need to be explored more fully to understand the origins of individual differences and lack of predictability based on previous studies of human olfaction.

The present study serves as a stepping-stone for the advancement of the understanding of age-associated change in olfactorial abilities and memory. While it is clear that age itself is not the sole cause of sensory loss, it is still an important part of the equation. As other contributors to decline are explored, a better understanding of what a truly normative aging process might be may emerge and allow for adjusting the focus of research accordingly.

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Table 1. Descriptive statistics of participants.

	Low-Risk Group		High-Risk Group	
	Mean	**SD**	**Mean**	**SD**
Age	70.2	12.94	69.9	12.11
MMSE score	29.2	1.73	28.9	1.62
Number of medications*	1.4	1.44	1.3	1.61
WAIS Vocabulary Score	31.3	9.26	29.8	10.31
Years of Formal Education	12.3	4.54	12.5	3.87

* Medications taken affecting olfaction as defined by Schiffman (1983).

APPENDIX C

STRUCTURED INTERVIEW

Structured Interview

Note to interviewer: Please ensure that the participants know the time required for participation in this study (about one and half hours). Make them feel comfortable with these very personal experiences that you are about to ask them, and be willing to listen to a few anecdotes if necessary.

Question	Response (Write NEATLY, please)
Please tell me when you were born	
What do you do for a living?	
What kind of setting is your workplace?	
Have you ever had another job? If so, what was it?	
Do you have a relatively good sense of smell?	
What kind of place or places did you grow up in? Rural, Urban, etc.	
Did people use a lot of chemicals, like pesticides, in your areas?	
Were there any manufacturing or processing plants near where you lived?	
Have you ever had any diseases that make you lose your sense of smell?	
Did you suffer allergies as a child?	
Do you still suffer allergies?	
Have you ever had surgery on your nose?	
Are you in generally good health?	
What, if any, prescription drugs do you take, and what are they for? (please write down **all** drugs, even if you need to use the back of this page to do so)	
What, if any, over-the-counter drugs are you taking or have taken recently?	

How is your appetite? Do you like to cook?	
Do you enjoy the flavors of foods?	
Do you enjoy dining out? If so, in what kinds of places?	
Have you ever been in the military?	
If so, did you have to be trained with gas masks, perhaps even been exposed to chemical agents to teach you what to expect?	
If so, did you suffer any noticeable loss of smell from this?	

Thank the participant for being so patient. Next, administer the MMSE, WAIS, and CES-D.

APPENDIX D

INSTRUMENTS

WAIS-R 2
VOCABULARY

Reminder to tester:

Please provide the following information at the point, even though it is contained elsewhere in the book. It is needed for scoring and interpretation of the cognitive performance measures.

Gender of Participant _____ Last Occupation _____

Age of Participant _____ Highest Grade in School _____

Race of Participant _____

COMPLETE THE FOLLOWING ITEMS CONCERNING THE PARTICIPANT'S RESPONSES AS TO WHETHER THE PARTICIPANT COULD/COULDN'T ANSWER OR WAS/WASN'T IMPAIRED IN ANSWERING BECAUSE OF THE REASON LISTED BELOW:

WAIS....2 PROBLEMS _____

0 = No problem; 1 = Visual Impairment; 2 = Hearing Impairment; 3 = Vision & Hearing Impairment; 4 = Reading Impairment Other than Vision; 5 = Unable Other (State Reason in Margin); 6 = Tried & Gave Up; 7 = Subject Refused; 8 = Missing Data (State Reason in Margin) 9 = Participant Died During Testing; A = Dementia

REMINDER TO TESTER:..... ***This is not a timed test.***

1 The Vocabulary subscale does not require that the subject have vision not be able to read. Do not skip vocabulary for any of these reasons. Emphasize the spoken recitation of the words, and pay less emphasis to the printed word list. Display the word list despite visual impairment or reading difficulty.

2. Discontinue Vocabulary after **5 consecutive** failures. If in doubt whether a failure has occurred, keep going. You can always rescore if the data has been obtained. If you stop too soon, we may lose the data we do have. Try to score as you go along, but if this is not possible, ask extra items so you are certain that you have obtained at least 5 consecutive failures.

3. Remember to actually write in the definitions provided by the subjects. This allows us to rescore as needed. Do not just enter points.

4. Be certain to include the scores for items 1 - 3 in your total, even if there was no need to actually administer them to the subjects.

Score 2,1,0

1. Bed	
2 Ship	
3. Penny	
4. Winter	
5. Breakfast	
6. Repair	
7. Fabric	
8. Assemble	
9. Enormous	
10. Conceal	
11. Sentence	
12. Consume	
13 Regulate	
14. Terminate	
15. Commence	
16. Domestic	
17. Tranquil	
18. Ponder	
19. Designate	
20. Reluctant	
21. Obstruct	
22. Sanctuary	
23. Compassion	
24. Evasive	
25. Remorse	
26. Perimeter	
27. Generate	
28. Matchless	
29. Fortitude	
30. Tangible	
31. Plagiarize	
32. Ominous	
33. Encumber	
34 Audacious	
35. Tirade	
Total	

Folstein Mini-Mental State Exam

Reminder to testers:

1. We now want participant to perform **both** the serial 7's (subtracting 7's from 100) and spelling **WORLD** backwards. You should administer both, even if the subject gets first entirely correct. If the participant makes a mistake in subtraction, allow the subject to continue without correction. Scoring will not penalize cumulatively. For example, if subject says 92 rather than 93 but then says 85 which is 92 take away 7, subject gets credit for 85.
2. If the participant is illiterate, i.e. cannot spell **WORLD** FRONT WARDS, therefore cannot be expected to spell **WORLD** backwards, ask the subject to provide any world (such as his/her name) of equal or slightly longer length that participant knows how to spell. Write that word on the score sheet, and ask the participant to spell that world backwards. Write down the response given, verbatim, and we will score it.
3. **FILL IN BLANKS WITH RESPONSES FROM PARTICIPANT & <u>INDICATE IF THE RESPONSES ARE CORRECT...I.E. WITH A CHECK MARK!</u>** Remember, we have no way to determine retroactively whether some of the answers were correct.

Person Administrating _____
Date of Administration of FOLSTEIN_____
Day of Week _____

I. ORIENTATION

A. You ask: "What is today's date and season?". You should prompt for omitted items.

What is the year?	_____
Season?	_____
Day of month	_____
Day of week	_____
Month	_____

B. You ask: "Can you tell me...

What town are we in?	_____
What county are we in?	_____
(or, "What county is....in?)	_____
What state are we in?	_____
What is your phone number?	_____
(or alternate number?)	_____

II. REGISTRATION

You ask: "Now I would like to test your memory. I will say three words. Just listen, and then repeat them for me."

Toothbrush	_____
Cigarette	_____
Pen	_____

Then, repeat the list up to **6** times in an effort to get the participant to repeat all three

correctly as you stated them. This is done to prepare the participant for the delayed recall later in the instrument. **LIST THE NUMBER OF TRIALS NEEDED HERE ___**

III. ATTENTION AND CALCULATION
YOU ADMINISTER BOTH PARTS A and B

A. You ask: *"Listen, I want you to start at 100 and then subtract -- take away-- 7 then take away 7 from that, and keep taking away 7 until I say stop. Okay? Ready. Go."*

You may demonstrate one time, if needed, but that time does not count and participant must take one additional subtraction (down to 58). **IF YOU HAD TO DEMONSTRATE, CIRCLE THE 93 SO WE WILL NOT COUNT THAT.**

100	**93**	**86**	**79**	**72**	**65**	**58**
___	___	___	___	___	___	___

B. YOU ASK: *"Listen, I want you to spell the word **WORLD** BACKWARDS. Go ahead."*

CORRECT:	**D**	**L**	**R**	**O**	**W**
PARTICIPANT RESPONSE:	___	___	___	___	___

IV. RECALL

YOU ASK: *"Can you tell me the three words I asked you to repeat a few minutes ago?"*

If no response, you may cue the participant with the first word, **toothbrush**, but then that response does not count. Indicate the necessity of the cue below, by circling toothbrush. We need to know if it was cued recall or not.

TOOTHBRUSH:_____ CIGARETTE:_____ PEN:_____

V. LANGUAGE & PRAXIS

A. You ask: *"Look here, what is this?* (pointing at watch)

WATCH:_____

B. You ask: *"Look here, what is this?* (pointing at pencil)

PENCIL:_____

C. You ask: *"Now, I am going to say a phrase, listen to it, and repeat it to me when I am completely finished:* **No ifs ands or buts!"**

1 point if 8-15 letters: _____ 0 point if less than 8 letters ___

D. You ask: "*Take this paper in your right hand, fold it in half; put in on the floor."* (present at midline'; lap instead of floor is okay if infirmity is present).

paper in right hand: _____
fold in half: _____
put on floor:_____

E. You ask" "*Read this* ("Close you eyes" which is printed on the last page of the Folstein Exam) *and do what it says."*

participant closed eyes: yes_____ no_____

F. You ask: "*Here's a pencil and a piece of paper. I want you to write a complete sentence for me. Just make one up, but be sure it is a complete sentence."*

Have the participant perform this item on the following sheet of paper where the pentagons are to be drawn.

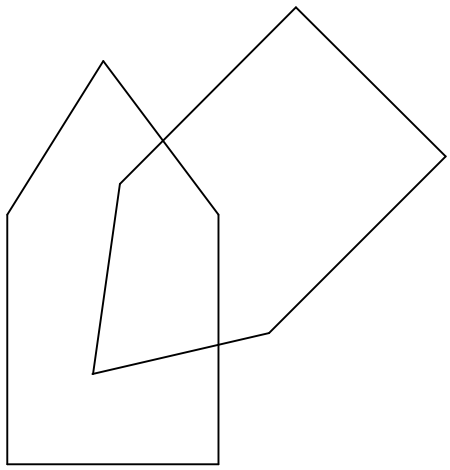
G. You ask: "*Look at this drawing. Make one just like it. Go ahead."*
Have the participant perform this item on the following sheet of paper in available space.

Are all 10 angles and intersections present? Yes___ No___

H. Finally, estimate participant's level of consciousness, by circling the appropriate level as follows:

ALERT	DROWSY	STUPOR	COMA
1	2	3	4

CLOSE YOUR EYES



CES-D

	During the past week…	Rarely or none of the time	Some-times	Often	Most or all of the time
1	I was bothered by things that don't usually bother me	0	1	2	3
2	I did not feel like eating	0	1	2	3
3	I felt like I could not shake the blues	0	1	2	3
4	I felt just as good as other people	0	1	2	3
5	I had trouble keeping my mind on what I was doing	0	1	2	3
6	I felt depressed	0	1	2	3
7	Everything I did was an effort	0	1	2	3
8	I felt hopeful about the future	0	1	2	3
9	I thought my life had been a failure	0	1	2	3
10	I felt fearful	0	1	2	3
11	My sleep was restless	0	1	2	3
12	I was happy	0	1	2	3
13	I talked less than usual	0	1	2	3
14	I felt lonely	0	1	2	3
15	People were unfriendly	0	1	2	3
16	I enjoyed life	0	1	2	3
17	I had crying spells	0	1	2	3
18	I felt sad	0	1	2	3
19	I felt that people disliked me	0	1	2	3
20	I could not "get going"	0	1	2	3

TOTAL: ____

Velten 1
Positive

1. If your attitude is good, then things are good, and my attitude is good
2. This is Great—I really do feel good—I *am* elated about things
3. Happiness is the key to success and I am successful
4. I have so many things to be thankful for
5. I feel Great!
6. I am a likable person
7. I have many good traits
8. Most people enjoy my company
9. I have many happy memories
10. I know that I am a wonderful person!
11. Goodness, I am so very happy!
12. There are many things about me that people like
13. Today I feel wonderful!
14. I am a very fortunate person to be so happy
15. My views really are the best ones, whether on politics or any other subject
16. I have made many great decisions in my life
17. Other people show me that I am really wonderful
18. I have many enjoyable things to do each day
19. When I need people, they are there for me
20. I feel that I am a wonderful person
21. I have great friends
22. Today I feel very healthy
23. I know that I can overcome any obstacle because I am a good person
24. I feel very attractive today
25. It is a great day to be alive
26. Days like this are wonderful, and I feel good about myself
27. Nothing can go wrong when I feel this happy
28. My body is telling me that I am really happy
29. I am an honest person and people know that
30. People like that I have such good intentions
31. I have no conflicts in my life that cannot be overcome
32. I am a very nice person
33. Most people are basically good and decent
34. I feel fabulous!
35. I really trust my instincts today, and my thinking is really sharp
36. I am so happy I could just start singing any minute
37. My heart is full of love today
38. I know that I can do anything I set my mind to
39. I am worthwhile person to know
40. I know that I am attractive
41. I am very content
42. I feel so happy!
43. I have a lot to be thankful for, and I really am thankful for it all

44. I am a great person and people like me
45. Today is **my** day!
46. Nothing could keep me down today!
47. I really feel wonderful
48. I really am elated about things today
49. I feel like dancing!
50. Days like today should be savored because they are so good
51. I deserve to be really happy, and I am!
52. Good things come to good people, and I have received a lot of good things
53. I love to smile!
54. I make other people happy much of the time
55. I feel like the sun is shining even when it rains
56. I am a warm and loving person
57. People love me!
58. I have music in my soul
59. I have a warm smile that makes other people happy to see
60. Today I feel completely invincible!
61. I am a good person and I like myself!
62. I am a very fortunate person
63. I feel really great today
64. I wish everyone could be as happy as I am today
65. The beauty in the world brings me a great deal of joy
66. I am a hard worker and people respect me
67. I am *so* happy!
68. Nothing can get me down on a wonderful day like today
69. I have a great life and people who love me
70. I am a fantastic person
71. I am capable of great joy
72. I make other people happy
73. I am a good person
74. It is a wonderful time to be alive in this beautiful world
75. I have a great attitude, which is why I do well at so many things
76. Wow! I feel great today!
77. Today is a wonderful day and I am a wonderful person
78. I know that people like me a lot
79. I am a very happy person
80. I possess many attributes that people admire greatly
81. People are attracted to me for many reasons
82. I am among the best people I know
83. I am very likeable
84. I am a valuable member of my community and others do recognize this
85. I am very pleased that so many people respect me, my opinions, and my abilities
86. I love life and life loves me
87. I am a happy, lovable person
88. I recognize the beauty and joy of life’s little blessings

Velten 2
Neutral

1. Utah is the Beehive State
2. The sky is blue due to refraction of light
3. Stainless Steel does not stain, but it does rust
4. The word **"phobia"** refers to a group of symptoms brought on by feared objects or situations.
5. As of 1940, a total of 90 patents had been taken out on shaving mugs.
6. “Demain” is the French word for tomorrow
7. Camel's-hair brushes are not made of camel's hair
8. Tuesday follows Monday
9. Mechanical refrigeration was invented in 1851
10. Blue is the most common favorite color
11. White is a popular wall color
12. Chad is a country in Africa
13. PM in time readings stands for post meridian
14. Mauve was the first “created” color
15. The number ten is “dix” in French
16. The atomic symbol for hydrogen is H
17. Air is mostly nitrogen
18. Desks are good places to write letters
19. The first computer bug was an actual moth
20. Most people find humor attractive
21. Alaska is more than twice as large as Texas
22. More than half of Americans are obese
23. Ants live in colonies
24. The Pacific is the largest Ocean
25. The metric system was invented by Benjamin Franklin
26. Rain is good for plants
27. The dog chewed on a bone in the shade
28. The capital of Ireland is Dublin
29. Circus is Latin for a circle
30. A group of geese is called a gaggle
31. A group of lions is called a pride
32. Only 3% of Americans ever use a passport
33. A Hexagon has six sides
34. A circle has 360 degrees
35. Calcium intake helps prevent osteoporosis
36. Cheese is a good source of calcium
37. Spinach is a good source of iron, but inhibits calcium uptake
38. Most chopsticks in Asia are made from wood grown in the US
39. *Tenor* is derived from the Latin word *tenare*
40. Squares have four sides
41. There is nothing magic about a marker
42. White is the presence of all colors

43. Black is the absence of all color
44. Wheels are for rolling
45. “Tires” can also be spelled “tyres”
46. Jokes are meant to be funny
47. I before E except after C
48. Some plants eat animals, such as the venus fly-trap
49. Walking is good exercise
50. Sky color is always a product of light refraction
51. The computing power of processors doubles every 18 months
52. RAM means Random Access Memory
53. The deBeers family controls 95% of diamond production
54. Music calms the savage beast
55. Visible light is a small portion of the sun’s radiation
56. The chemical notation for water is H_2O
57. Water constitutes more than 90% of the human body
58. Calcium accounts for about 2% of body weight
59. Most cities have a 35 mph speed limit
60. The Amazon is the longest river in the world
61. Aspirin can be derived from willow bark
62. An octagon has eight sides
63. DNA is composed of only six major chemicals
64. Oxygen is a very corrosive chemical
65. Most guitar strings are made of nylon
66. A meritocracy is a society based on merit
67. Graphite is a form of carbon
68. Jets are faster, but propeller-driven planes are more fuel efficient
69. It takes about two weeks to cross the Atlantic Ocean on a modern seaship
70. Paper is made from wood pulp
71. Packaging is the single most expensive part of a breakfast cereal
72. Black and green teas are made from the same leaves
73. Capcasin is the hot chemical in spicy peppers
74. China and India each have more than 1 billion citizens
75. Pink used to be the most common color for houses
76. Hydrogen is the most abundant element in the universe
77. There are 60 seconds in a minute
78. Woofers and tweeters are types of audio speakers
79. Canaries were used in coal mines to detect gas leaks
80. Houses are most people’s single greatest investments
81. The first personal computer sold was the “Osborn”
82. A “Baker’s Dozen” means 13 objects
83. Most “rare-earth” metals are not found on earth.
84. Vulcanized rubber has had sulfur added to it
85. Alexander the Great suffered from epilepsy
86. The deserts of Somalia have the lowest ambient volume in the world
87. Most computer hard drives spin between 5400 and 7200 rpm.
88. Salt and sugar are the two most common food preservatives

Velten 3
Negative

1. Most people can't be trusted
2. Today I feel like the world is against me
3. Happiness is a fleeting thing that few can capture
4. I have very few things to be thankful for
5. I feel really sad
6. I am not a likable person
7. I don't have many good traits
8. Few people enjoy my company
9. I have many sad memories
10. I know that I am a hard person to get along with
11. I wish I could be happy
12. There are many things about me that people dislike
13. Today I feel like being alone and doing nothing
14. I am a very unfortunate person to be so sad
15. Few people listen to my views on any subject
16. I have made many poor decisions in my life
17. Other people show me that I am not appreciated
18. I have few enjoyable things to do each day
19. When I need people, they are rarely there for me
20. I feel that I am not a worthwhile person
21. I have no real friends
22. Today I feel very unhealthy
23. Today I can be stopped by any obstacle
24. I feel very unattractive today
25. It is a great day to be alone and sleep
26. It should be rainy and storming when I feel like this
27. Everything goes wrong when I feel this down and blue
28. My body is telling me that I am really unhappy
29. People don't always trust me, and I don't trust them
30. Sometimes I wonder why I feel such anger so often
31. I have conflicts in my life that cannot be overcome
32. I am not a very nice person
33. Few people alive today are good and decent
34. I feel terrible!
35. I don't always trust myself to make decisions
36. I am so sad I could just start crying any minute
37. My heart is empty and aching today
38. I am unable to do most things today
39. Few people value spending time with me
40. I know that I am not attractive
41. I am not very content
42. I feel so unhappy!

43. I feel I have been cheated out of getting what I deserve
44. The way I feel tells me I am very sad
45. Other people are more successful than me
46. Sometimes I think people *are* out to get me
47. I really feel horrible
48. I really am blue and disheartened about things today
49. I feel like crying!
50. Days like today should be forgotten because they are so bad
51. People sometimes enjoy being rude to me for no reason
52. People around me are luckier than I am
53. I wish I could smile, but I just can't
54. My feelings for other people are rarely returned
55. I feel like it is raining even when the sun is shining
56. People around me tell me that I am cold and uncaring
57. Few, if any, people really love me
58. People call me a grinch behind my back
59. I easily get embarrassed about my looks
60. Today I feel completely vulnerable!
61. Sometimes I don't really like myself
62. I am not a very fortunate person
63. I feel really gross today
64. I wish everyone could be as miserable as I am today
65. The beauty in the world brings me a great deal of pain
66. I am unappreciated in the work I do
67. I am *so* unhappy!
68. Everything gets me down on a miserable day like today
69. I have a hard life and no people who love me
70. I am a selfish person
71. I am not capable of much joy
72. I make other people unhappy
73. Few think I am a good person
74. It is sad to live in this bad day and age
75. My pain defines me
76. Evil has won out in the battle for mankind
77. There is more hatred in the world today
78. People don't like me, but I don't like them
79. I am hateful because others are mean to me
80. I possess many attributes that people disapprove of
81. I feel like my body is falling apart
82. I feel sick most of the time
83. I am not very likeable
84. No-one would miss me if I left town today
85. I would change my life if I could, but I am helpless
86. I hate life and life hates me
87. My body tells me that I am miserable
88. Optimists deserve the bad things that happen to them

APPENDIX E

TESTING PACKET FOR OLFACTION STUDY

Testing packet for Olfaction study

(Pages 1-7 to be used for testing.)

Participant ID #_____

Test Condition	Cohort Group

Please remember that contents of this packet are confidential information.

Participant Information

Please fill in the appropriate information.

Age		**Education**	
Career		**Employment setting-** Ask if exposed to harsh chemicals	At Risk / Don't know / Not-at risk

Ask the following:

1. Are you or have you been a smoker or tobacco user? — Yes / In Past / No
2. Do you have any allergies acting up right now? — Yes / recently / No
3. Have you recently had a cold, flu, or any respiratory distress? — Yes / recently / No
4. Are you taking any medications right now? — Yes / No
   If yes, please get full list, including aspirin or any over-the-counter drugs and home remedies.
5. Have you ever had surgery of the nose? — Yes, recently / Over a year ago / No
6. How would you rate your overall physical health? — Excellent / Good / Fair / poor
7. Do you feel well today? — Yes / No

Neurological Assessment information:

TEST	Score
WAIS-Vocabulary	
CES-D	

Test	Score
MMSE	

Please list all pharmaceuticals taken (including over-the-counter) over the past week.

Detection Threshold- PEA

Circle the number of the vial responded to as being stronger.

Trial	Vial 1	Vial 2	Description
1	468	342	
2	785	393	
3	119	639	
4	632	413	
5	554	732	
6	657	804	
7	982	442	
8	431	881	
9	246	325	
10	382	216	
11	581	905	
12	891	569	
13	762	832	
14	680	401	
15	613	827	
16	783	189	
17	101	338	
18	512	287	
19	322	317	
20	754	238	

Detection Threshold- Menthol

Circle the number of the vial responded to as being stronger.

Trial	Vial 1	Vial 2	Description
1	661	238	
2	978	289	
3	312	535	
4	825	309	
5	747	628	
6	850	700	
7	760	338	
8	624	777	
9	439	221	
10	575	112	
11	774	801	
12	669	465	
13	955	728	
14	873	297	
15	196	723	
16	976	85	
17	294	234	
18	705	183	
19	515	213	
20	947	134	

Odor Recognition.

Have participant take a natural whiff of the target odor, then count backwards from ten. Present the four forced-choice alternatives in any order. Circle the odor bottle chosen by the participant as matching the target.

Trial	Target	Choice 1	Choice 2	Choice 3	Choice 4
1	565	678	142	705	991
2	882	573	193	369	655
3	216	859	439	632	918
4	729	777	213	201	487
5	651	100	532	627	913
6	754	880	604	011	275
7	664	198	242	138	424
8	528	609	681	087	373
9	343	419	125	117	403
10	479	851	016	038	324

Odor Discrimination

Mark each set of bottles as Same or Different

Trial	Vial 1	Vial 2	Description	
1	195	241	Same	Different
2	315	600	Same	Different
3	428	834	Same	Different
4	667	625	Same	Different
5	174	609	Same	Different
6	413	131	Same	Different
7	713	433	Same	Different
8	891	706	Same	Different
9	140	591	Same	Different
10	686	322	Same	Different
11	645	122	Same	Different
12	071	611	Same	Different
13	700	370	Same	Different
14	751	913	Same	Different
15	854	855	Same	Different
16	897	841	Same	Different
17	037	267	Same	Different
18	785	224	Same	Different
19	839	766	Same	Different
20	277	012	Same	Different
21	935	112	Same	Different
22	324	633	Same	Different
23	833	670	Same	Different
24	258	240	Same	Different
25	961	592	Same	Different
26	926	124	Same	Different
27	185	646	Same	Different
28	788	400	Same	Different
28	221	787	Same	Different
30	563	452	Same	Different

Odor Identification

Circle the number of the vial responded to as being the same as the word presented.

Trial	Name	Vial 1	Vial 2	Description
1	Coffee	257	592	
2	Mint	939	238	
3	Vanilla	806	80	
4	Honey	520	891	
5	Almond	154	699	
6	Ginger	438	326	
7	Anise	886	354	
8	Vinegar	810	327	
9	Apple	974	907	
10	Garlic	491	691	
11	Rose	100	736	
12	Peanut Butter	824	285	
13	Cinnamon	289	74	
14	Orange	848	187	
15	Fennel	70	969	
16	Cloves	687	125	
17	Coffee	372	877	
18	Molasses	455	336	
19	Alcohol	883	618	
20	Lemon	873	41	
21	Coconut	31	565	
22	Rose	514	411	
23	Grapes	408	129	
24	Tobacco	430	502	
25	Fennel	779	530	
26	Ginger	694	660	
27	Orange	333	741	
28	Alcohol	308	957	
29	Garlic	541	402	
30	Rose	163	254	

Keys to The setup of odorants and scoring

Detection Threshold- PEA-KEY

Trial	Vial 1		Vial 2	
1	468	Blank	342	C10
2	785	C10	393	Blank
3	119	C9	639	Blank
4	632	Blank	413	C9
5	554	Blank	732	C8
6	657	Blank	804	C8
7	982	C7	442	Blank
8	431	Blank	881	C7
9	246	C6	325	Blank
10	382	C6	216	Blank
11	581	Blank	905	C5
12	882	C5	009	Blank
13	762	Blank	832	C4
14	111	Blank	444	C4
15	613	C3	827	Blank
16	714	C3	876	Blank
17	101	C2	338	Blank
18	521	C2	321	Blank
19	322	Blank	317	C1
20	275	C1	577	Blank

Detection Threshold- Menthol-KEY

Trial	Vial 1		Vial 2	
1	661	Blank	238	C10
2	978	C10	289	Blank
3	312	C9	535	Blank
4	825	Blank	309	C9
5	747	Blank	628	C8
6	850	Blank	700	C8
7	760	C7	338	Blank
8	624	Blank	777	C7
9	439	C6	221	Blank
10	575	C6	112	Blank
11	774	Blank	801	C5
12	641	C5	917	Blank
13	955	Blank	728	C4
14	306	Blank	427	C4
15	196	C3	723	Blank
16	226	C3	555	Blank
17	294	C2	234	Blank
18	983	C2	214	Blank
19	515	Blank	213	C1
20	438	C1	302	Blank

Odor Recognition.-KEY

Odorants used: geraniol, citral, n-butanol, methyl salicylate, benzaldehyde, and caproic acid

Trial	Target	Choice 1	Choice 2	Choice 3	Choice 4
1	565 geraniol	678 caproic acid	142 geraniol	705 benzaldehyde	991 n-butanol
2	882 citral	573 geraniol	193 citral	369 n-butanol	655 caproic acid
3	216 benzaldehyde	859 benzaldehyde	439 caproic acid	632 citronellal	918 geraniol
4	729 n-butanol	777 caproic acid	213 n-butanol	201 citral	487 methyl salicylate
5	651 guiacol	100 n-butanol	532 benzaldehyde	627 caproic acid	913 guiacol
6	754 methyl salicylate	880 methyl salicylate	604 n-butanol	011 geraniol	275 benzaldehyde
7	664 caproic acid	198 caproic acid	242 geraniol	138 benzaldehyde	424 citral
8	528 citronellal	609 citronellal	681 geraniol	087 n-butanol	373 caproic acid
9	343 geraniol	419 citral	125 methyl salicylate	117 geraniol	403 n-butanol
10	479 n-butanol	851 n-butanol	016 caproic acid	038 guiacol	324 geraniol

Odor Discrimination- KEY

Bottles are filled with: benzaldehyde and caproic acid, n-butanol and citral, benzaldehyde and geraniol, geraniol and citral, methyl salicylate and caproic acid, and each of these individual odorants, benzaldehyde, caproic acid, n-butanol, citral, and methyl salicylate paired with themselves.

Trial	Vial 1	Vial 2	Description
1	445 benzaldehyde	552 caproic acid	Different
2	119 methyl salicylate	032 caproic acid	Different
3	176 n-butanol	220 citral	Different
4	500 benzaldehyde	386 geraniol	Different
5	280 n-butanol	902 n-butanol	Same
6	335 geraniol	672 citral	Different
7	879 benzaldehyde	126 benzaldehyde	Same
8	407 methyl salicylate	743 methyl salicylate	Same
9	976 benzaldehyde	081 geraniol	Different
10	661 citral	724 citral	Same
11	337 n-butanol	832 n-butanol	Same
12	071 benzaldehyde	611 benzaldehyde	Same
13	700 phenethyl alcohol	370 guiacol	Different
14	751 citral	913 citral	Same
15	854 caproic acid	855 caproic acid	Same
16	897 benzaldehyde	841 geraniol	Different
17	037 phenethyl alcohol	267 phenethyl alcohol	Same
18	785 geraniol	224 citral	Different
19	839 benzaldehyde	766 caproic acid	Different
20	277 methyl salicylate	012 caproic acid	Different
21	935 caproic acid	112 caproic acid	Same
22	324 n-butanol	633 citral	Different
23	833 guiacol	670 guiacol	Same
24	258 n-butanol	240 n-butanol	Same
25	961 benzaldehyde	592 benzaldehyde	Same
26	926 methyl salicylate	124 caproic acid	Different
27	185 phenethyl alcohol	646 phenethyl alcohol	Same
28	788 benzaldehyde	400 caproic acid	Different
28	221 methyl salicylate	787 methyl salicylate	Same
30	563 geraniol	452 citral	Different

Odor Identification-KEY

Circle the number of the vial responded to as being the same as the word presented.

Trial	Name	Vial 1	Vial 2	Name	Consistant?
1	Coffee	257	592	Peanut Butter	Yes
2	Anise	939	238	Mint	Yes
3	Vanilla	806	80	Cinnamon	No
4	Honey	520	891	Orange	Yes
5	Fennel	154	699	Almond	Yes
6	Ginger	438	326	Cloves	No
7	Anise	886	354	Peanut Butter	No
8	Alcohol	810	327	Vinegar	Yes
9	Apple	974	907	grapes	Yes
10	Garlic	491	691	Lemon	No
11	Coconut	100	736	Rose	No
12	Peanut Butter	824	285	Tobacco	Yes
13	Cloves	289	74	Cinnamon	No
14	Lemon	848	187	Orange	Yes
15	Fennel	70	969	Molasses	No
16	Vinegar	687	125	Cloves	No
17	Vanilla	372	877	Coffee	No
18	Honey	455	336	Molasses	Yes
19	Alcohol	883	618	Vinegar	Yes
20	Almond	873	41	Lemon	No
21	Coconut	31	565	Cloves	No
22	Rose	514	411	Ginger	No
23	Grapes	408	129	Vinegar	Yes
24	Garlic	430	502	Tobacco	No
25	Fennel	779	530	Mint	No
26	Alcohol	694	660	Ginger	Yes
27	Orange	333	741	Almond	No
28	Apple	308	957	Alcohol	Yes
29	Fennel	541	402	Garlic	Yes
30	Rose	163	254	Honey	No