The Perception of Facial, Prosodic, and Lexical Emotion

Across the Adult Life Span

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Abstract

THE PERCEPTION OF FACIAL, PROSODIC, AND LEXICAL EMOTION ACROSS THE ADULT LIFE SPAN

By

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Age-related changes in emotional perception across facial, prosodic, and lexical communication channels were examined in 100 healthy normal adults (20-80 years) in the context of the fluid/crystallized theory of intellectual functioning (Horn, 1972). Emotional perception was expected to be highly related across modalities and was hypothesized as a crystallized ability. Emotional identification and discrimination measures were taken from the New York Emotion Battery (Borod, Welkowitz, & Obler, 1992). Eight discrete emotions, three positive and five negative, were assessed. Aspects of nonemotional cognitive ability, including crystallized and fluid intelligence, and auditory and visual perception, were also evaluated.

Results from structural equation models revealed that, though highly correlated, verbal (i.e., lexical) and nonverbal (i.e., facial and prosodic) emotional perception were best characterized as distinct in terms of their relations with other intellectual abilities. Both types of emotional perception were best represented as <u>separate</u> from crystallized and fluid intelligence. Though best represented as separate factors, a <u>functional</u>

relationship was seen, such that crystallized intelligence significantly influenced verbal emotional perception. According to correlational analyses, emotional perception as well as fluid intelligence evidenced strong inverse relations to age and strong positive relations to each other. When age was taken into account in the structural model, however, the relationship between emotional perception and fluid intelligence disappeared, suggesting that some common underlying age-based physiological changes contribute to age-related decline for both of these otherwise disparate abilities.

Correlational analyses revealed significant age-related decline in emotional identification abilities after controlling for nonemotional perceptual ability (see also Borod, Pick, Hall, et al., 2000). Independent group comparisons between younger and older individuals revealed an advantage for younger subjects on all emotional measures except one version of the prosodic discrimination task.

In an attempt to extend the common cause hypothesis (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994) to emotional perception, the relationship between age-related declines in sensory functioning and emotional perception was examined. Differences in hearing thresholds did not attenuate age-related variance in emotional perception by an appreciable amount.

Overall results are discussed in the context of neuropsychological theory, cognitive aging research, theories of adult emotional development, and emotional intelligence.

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I would like to dedicate this work to my family, with love and gratitude: to my husband, Ronnie D'Addario, for providing moral and financial support as well as often doing the job of two parents; to my children, Brian and Michael, for their patience and flexibility; to my mother and father, Donna and Jerry Hall, my sister and brother-in-law, Barbara and Steve Robinson, and my extended family in Ohio, for generously and frequently caring for my children; to my mother-in-law, Ida, for much-needed financial help; and, finally, to my sister, Lori...wish you were here.

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## Introduction

The present study is being undertaken to clarify the organization of systems responsible for emotional cognition and to elucidate the developmental pattern of emotional processing over the adult life span. Emotional perceptual abilities will be viewed across three communication channels of emotional processing, facial, prosodic, and lexical content. The tasks that will be utilized are part of the New York Emotion Battery (NYEB; Borod, Welkowitz, & Obler, 1992). Facial stimuli consist of the original slides of Ekman and Friesen (1976) plus additional slides developed by Borod, et al., while prosodic and lexical stimuli are composed entirely of material developed by Borod, et al. Within the facial and prosodic channels, one identification and one discrimination task will be administered, while lexical tasks will consist of word identification, sentence identification, and word discrimination. Within each task, eight discrete emotions (three positive and five negative) will be represented.

Two primary hypotheses will be explored. Initially, the existence of a common underlying emotional processor will be investigated. The relationship of scores on dependent measures of emotional perception across the three communication channels will indicate whether these channels more likely function as separate, or inter-related, systems. A high degree of relatedness is predicted among subjects' performance on emotional tasks across channels.

The second major inquiry in this study has to do with how age relates to emotional processing. Structural equation modeling techniques will be used to examine linkages among age and relevant variables, both emotional and nonemotional. Correlational techniques and independent group comparisons will be used to assess the relationship between age and performance on emotional tasks while controlling for subject variables and nonemotional aspects of cognition, such as visual and auditory perception and nonemotional lexical ability. Aging patterns of performance on emotional and nonemotional cognitive tasks will then be compared in the context of life span aging theory. The aging patterns of emotional perceptual abilities are expected to show significantly less linear decline across adulthood than the aging patterns of "fluid" (see below) cognitive abilities after the effects of relevant demographic and nonemotional cognitive variables are controlled. The aging pattern for emotional perceptual abilities is expected to look more similar to that of "crystallized" (see below) abilities, such as vocabulary, that show stabilization over the life span through experience and learning.

In addition to the two primary hypotheses, the effects of subject characteristics known to affect emotional processing and cognitive performance, such as gender and education, will be closely examined. Females are expected to perform significantly better than males on emotional tasks. Higher levels of education are expected to be associated with better performance on verbal nonemotional tasks and on lexical emotional tasks. Subsequent analyses will control for level of education on tasks where these associations are detected. In addition, the common cause hypothesis proposed by Baltes and Lindenberger (1997; Lindenberger & Baltes, 1994), which holds that common processes that cause decline in sensory functioning can explain much of the age-related variance in intellectual functioning, will be examined as it relates to emotional perception.

The effect of item valence (i.e., positive versus negative) on performance as a function of age and gender will also be explored. The superior decoding skills of females relative to males are expected to be more prominent on negatively versus positively valenced items. Also, it is expected that performance on items using negative emotional stimuli will show steeper declines with age than performance on positively valenced items.

Rationale for Hypothesis I

Early in the history of neuropsychology, rigid ideas regarding localization of function to discrete cortical areas were predominant. As the field has progressed, these notions have been replaced by the concept of functional systems involving numerous cortical and subcortical areas. In emotional functioning, as in other types of mental activity, complex, multimodal, and parallel processes are acknowledged to comprise even the most basic of emotional responses. While theorists emphasize the components of emotional processing that they find most compelling, a definitive and comprehensive theory of the functional emotional system has not been developed. Some workers approach the subject from a dimensional perspective (e.g., approach/avoidance, positive/negative, Davidson, 1993). Others maintain that emotions are primary organizers of human thought and action (Tomkins, 1962; 1963; Izard, 1971; Izard & Ackerman, 1997), and view discrete emotions (e.g., happiness, sadness, anger, fear) as fundamental to human motivation and comprising independent emotional subsystems (Zajonc, 1984). Others stress the primacy of cognition, assuming cognition to be a necessary antecedent of all emotional experiences. These theorists emphasize the evaluative aspects of emotion, consider cognition to be an integral part of even the most basic emotions, and take issue with the notion of emotional systems operating independent of cognition (e.g., cognitive appraisal models; Lazarus, 1984; 1991; Lazarus, Kanner, & Folkman, 1980).

The tasks utilized in this study assess abilities that have been referred to as the cognitive-communicative aspects (Heilman & Bowers, 1999), or cold cognitions, of emotion. These have been characterized by Bower, Bauer, and Heilman (1993) as "affect judgments and knowledge that can be detached from the more personal experience of an emotional state," including "knowledge of the emotional meaning of species-typical nonverbal communicative signals, for instance, facial expressions, tone of voice," (p. 433). These capacities have also been termed the "signal properties" of emotion (Malatesta, Culver, Tesman, & Shepard, 1989), and have been considered as a subset of the recognition processes. For example, a selective deficit in the comprehension of affective speech has been referred to as "auditory affective agnosia" (Heilman, Scholes, & Watson, 1975). The extent to which emotional recognition abilities are comparable across channels of communication in the intact emotional system can shed light on its organization. Though the information yielded by this comparison will not elucidate specific theories, it will contribute to a comprehensive notion of emotional functioning by supporting the existence of a single (unitary), or multiple (separate), processor(s) for emotional perception. Based on existing empirical data, where normal healthy subject populations have displayed similar performance on emotional tasks across communication channels, a strong positive relationship is expected on subjects' performance across channels in the present study. A significant aspect of the present investigation is that emotional perception will be tested in the same individuals across three communication channels (i.e., facial, prosodic, and lexical).

Rationale for Hypothesis II

There is a comprehensive neuropsychological literature investigating the effects of age on cognitive abilities (for reviews, see Borod & Goodglass, 1980a; Ellis & Oscar-Berman, 1989; Koss, Haxby, De Carli, Schapiro, Friedland, & Rapoport, 1991; Schaie, 1996). Though work has been done with respect to emotional communication and aging, it has focused almost exclusively on the facial channel and the expressive mode. In addition, many comparisons have relied on conventional statistical methods to investigate changes across age groups, thus treating age as a categorical variable (Levenson, Carstensen, Friesen, & Ekman, 1991; Malatesta & Izard, 1984; Malatesta, Izard, Culver, & Nicholich, 1987; Moreno, Borod, Welkowitz, & Alpert, 1993).

One contribution of the present study will be the examination of the developmental pattern of emotional perceptual abilities within a theoretical framework that has proven helpful for understanding age trends in other areas of cognition. An attempt will be made to interpret the aging pattern of emotional perception by conceptualizing it in the context of the fluid/crystallized dichotomy. Importantly, this will include the use of statistical analyses that will permit detection of meaningful nonlinear trends in aging patterns. One primary hypothesis in this study is that emotional perception will remain essentially stable or improve across the life span at least until the early 70s. This prediction is based on four major lines of thought. First, past studies, reviewed below, have not consistently found differences among young, middle-aged, and older adults in their abilities to perceive emotional stimuli. In addition, in some investigations where age-related differences were observed, appropriate controls for abilities in nonemotional perception were not employed. Third, as elaborated upon below, it makes intuitive sense to attribute those qualities Cattell (1963) and Horn (1982) describe as characterizing the "crystallized" aspect of human intelligence (Gc) to emotional perception. Finally, there are some assumptions regarding potential aging patterns for emotional perception that can be gleaned from the parallels between the verbal lexicon (i.e., word knowledge) and the nonverbal lexicon (i.e., the comprehension of nonverbal signals of communication; Bowers et al., 1993).

Fluid/Crystallized Dichotomy

According to the two-factor model of intelligence described by Horn and Cattell (1963) and Horn and Donaldson (1980) and the research on which it is based (for review, see Horn, 1982a), there are two broad types of human intelligence showing divergent age patterns. One, based on sensory input and learning new information, reflects the ability to make novel associations. It is termed fluid intelligence, or Gf, and represents the relatively knowledge-free mechanics of cognition. Performance on tasks reflecting this broad, fluid domain reaches a peak in the early 20s and then decreases steadily throughout adulthood. This may be the ability that reflects neuropathological changes in the aging brain. The other, termed crystallized intelligence, or Gc, involves experience and wisdom. Gc represents the acquisition of specific information and improved social judgment based on decision-making skills practiced over the life span and does not show age-related decline until relatively late in life. Studies have shown that even after age 70 many higher-order capacities are preserved with maintenance of good health, while individuals in poor physical health tend to experience more rapid cognitive deterioration (Haaland, Linn, Hunt, & Goodwin, 1983; Howieson et al., 1993; Van Gorp, Satz, & Mitrushina, 1990; Tranel, Benton, & Olson, 1997).

Major theorists (Cattell, 1943; Hebb, 1949; Horn & Cattell, 1963) have noted that crystallized capacities are more likely to result in highly developed associative networks, representing plasticity in the nervous system (Horn, 1982a; 1982b; Salthouse, 1988; Whitbourne, 1985). Thus, cognitive decline is likely to be offset by the high levels of proficiency superimposed on functioning through experience and does not take place until and unless a more global physical decline brought on by a change in health status occurs.

Horn (1982b) maintains that it is not the capacity for concept attainment that distinguishes fluid intelligence, or Gf, from Gc, but the type of concept attained. If learning depends on cultural aids, it represents Gc, while dependence on idiosyncratic strategies for educing relationships and drawing inferences is reflective of Gf. In another description of the concepts of his theory, Horn includes "comprehension of communication" and "understanding conventional interpretations" as manifestations of Gc (1982b). In Horn's own words:

> Gc reflects acculturational learning. The society in which one is raised is organized to provide a huge series of lessons designed to convert the intellectual capacities of its members, particularly its youthful members, into a form of intelligence that is useful for maintaining and enhancing the society (p. 853).

Daniel Goleman, in his book Emotional Intelligence (1995), recognizes the importance of the acculturational component in the development of what he calls "emotional competence." Emotional competence is not a new concept. Saarni (1988; 1999), in her discussion of the integration of emotions and social relationships over childhood, ascribed the source of the term as she interprets it to Steve Gordon (1989). Gordon, a sociologist, defined it as the ways in which children become socialized to understand the cultural meaning of emotions. Both Gordon and Saarni see the development of emotional competence as the unintended consequence of social interaction, and see children as active creators of their emotional lives. For both Goleman and Saarni, the term denotes mastery of a broad range of abilities, including the expression and appreciation of facial and vocal cues, and the knowledge and appropriate use of emotional words.

Goleman believes that emotional competence can and should be developed with formal teaching methods. He reviews several instructional models that have managed to cultivate social judgment, empathy, and emotional control, and have contributed to the emotional development of young people as evidenced by outcome measures, such as reduction in crime and dropout rates and increases in academic and professional success. Though many such programs are in place, it is not yet common practice to formally and overtly train young people in the art of emotional behavior (as Goleman feels it should be). Still, society does provide ongoing lessons regarding acceptable emotional behavior in the form of feedback and reinforcement throughout life, beginning at the family level (e.g., parent/child), and extending to a broader community level (e.g., schools and government).

Intact emotional perception is reflected in the accurate recognition of social cues. As touched on above, it is an ability that in humans is dependent on acculturation, as its importance is stressed from infancy throughout development. Thus, it becomes an overlearned, socially desirable, and adaptive quality. Accurate identification and appropriate responding to the emotional cues of others in the society is a skill that is shaped and refined from an early age. The infant who responds to a mother's smile is rewarded with her obvious pleasure and excitement; the child who responds with appropriate concern to a peer's crying is reinforced with praise; the empathic adult is admired and sought out as a desirable companion. This description is illustrative not only of the crystallized quality of the apprehension of social cues, but the ecological validity of this capacity across the life span. As Pennington (1991) notes, the developmental course of social cognitive development continues well into adulthood, as roles change requiring new social cognitive abilities. "Because of their enormous adaptive significance, we would expect social skills to emerge early in development and to be relatively immune to perturbation" (p. 12).

It is likely that the development of nonverbal socio-emotional skills of communication is analogous to the development of language as proposed by interactionist theory (Bohannon, J.N., III & Warren-Leubecker, A., 1989). Humans have an innate predisposition to acquire these skills, however, the environment provides the stimulation and modification necessary for adequate and normal development. This theory is consistent with universality of facial expression, both intraspecific and interspecific (Brothers, 1989), as well as cultural and individual differences in emotional communication. Variability would be attributed to both inherent and environmental circumstances. As is seen in clinical populations, atypical brain states, whether they be inherited, acquired, or a combination of the two, often result in impairment in the ability to comprehend and communicate social cues.

This view is consistent with many current theories of emotional development, including discrete emotions theories, which have been among the most influential. These theories (Tomkins, 1962; Izard, 1971) stem from Darwin's (1965) original formulations concerning the source of human emotions, which emphasize the benefits of distinguishing types of emotions as well as the innate and adaptive nature of emotional functioning. They suggest that some stereotypic emotional behavior is already functional at birth and readily acknowledge the influence of socialization on subsequent emotional development (Malatesta et al., 1989). They further imply that the signal properties of emotion, such as facial and vocal expression and gesture, become well established in early childhood. Beginning in childhood and continuing throughout adulthood, due to increasing cognitive and social differentiation, modification occurs in facial expression (Dougherty, Abe, & Izard, 1996; Malatesta & Izard, 1984; see review of adult developmental theories of emotion below). The question of whether and to what extent efficacy in decoding the signal properties of emotion is maintained across adulthood has not been extensively studied, perhaps because the expectation is that this skill "reaches a certain level of mastery and thereafter remains stable" (Malatesta et al., 1987, p. 194).

The Nonverbal Affect Lexicon

Further evaluation of the potential "crystallized" attribute of emotional perception reveals a logical corollary to emotion theory. Bowers et al. (1993) have proposed the existence of a right-hemisphere (RH)-mediated system containing a "vocabulary of nonverbal affective signals (facial expressions, prosody, and gestures)" (p.433), which they have designated as the nonverbal affect lexicon (NAL). They speculate that this system is analogous to the left hemisphere (LH)-mediated verbal lexicon. The resistance of the verbal lexicon to the effects of aging is well-documented (for review, see Bayles & Kaszniak, 1987). Evidence for correspondence between other features of these parallel systems is summarized below. Because of the similarities that have already been detected in the functioning of the two systems, the expectation that they will show synonymous aging patterns seems consistent. If this is the case, the present study, in addition to providing evidence regarding the age course of emotional perception, may strengthen the notion of a nonverbal affect lexicon.

Rationale for Hypotheses Related to Valence

Predictions regarding valence are based on the following. first, the premise that discrete negative emotions are more difficult to discern than positive emotions. If this is the case, it would follow that women, who (based on past empirical findings) seem to have superior abilities overall in emotional perception, may have relatively greater ease at deciphering more complex emotional stimuli. With regard to age differences, identification of negative emotional stimuli may be more significantly impacted by age simply due to increased task complexity. This is based on the age-complexity phenomenon, a condition observed over a breadth of empirical studies, described by Salthouse (1996, p. 404) as "the positive relationship between task complexity and the magnitude of age differences in both speed and accuracy of task performance."

An alternative explanation for the predicted differences discussed above lies in the evolution-based theories of emotional expression that originated with Darwin (1965). According to Darwinian theory, it is the quick and accurate decoding of the negative expressions, such as anger and disgust, which is essential for the survival of the species. Because either of these expressions could signify potential danger to the organism (e.g., for anger, in the form of a threatening aggressor; for disgust, in the form of a toxic substance), it makes intuitive sense that these expressions would be more easily decoded than positive communications. From an ecological viewpoint, the same rationale that has been proffered as an explanation for women's overall superiority in emotional processing (i.e., their maternal roles, see Hall, 1978) would apply in the case of negative emotional signals. That is, the ability to detect such signals would be particularly important for women as carriers of offspring. If women are indeed more adept at decoding negative emotions, it is possible that this advantage may be hormonally based. It is common for women to become hypersensitive to food sources and to emotional signals in general during pregnancy. If the hormonal connection is valid, one would expect the female advantage in negative emotional processing to diminish with age as hormone levels decrease.

By contrast, the importance of survival of the individual as it relates to survival of the species lessens once the individual passes reproductive age. Therefore, one could argue, from a phylogenetic perspective, that the necessity of accurate and rapid response to danger signals is less important for the aged than for younger people. As discussed below, from an ontogenetic perspective, it may be more advantageous for the older individual to allocate less energy to the detection of negative stimuli, particularly if this permits maintenance of a greater focus on positive stimuli. Older people can and do make behavioral adjustments in the form of avoidance that result in less exposure to potentially harmful stimuli (e.g., not venturing out unaccompanied or at night, avoiding emotional confrontations) which may serve to compensate for less accurate identification of such sources or less efficient response mechanisms.

Another reason for the above prediction is the empirical evidence (reviewed below) from the aging and emotion literature indicating that older individuals (as compared to younger) process negative emotional stimuli less accurately than positive stimuli. Various workers in the field of emotion have espoused explanations involving the increase in positive experience (Dougherty, Abe, & Izard, 1996), rise in emotional well-being (Mroczek & Kolarz, 1998), and better self-regulation (Carstensen, 1995; Labouvie-Vief, 1997) that accompany old age. These changes have been characterized as socioemotional variants of the selective optimization with compensation model (Baltes, 1987, reviewed below), whereby older individuals compensate for the losses that occur in late adulthood by maximizing positive experience while minimizing negativity (Carstensen, 1992).

# Literature Review

## Aging and Cognitive Changes: Theories and Empirical Findings

### The Fluid/Crystallized Dichotomy

In his more recent work, Horn has identified purer cognitive measures of intelligence, focusing on eight or so abilities in addition to the original two (Kaufman, 1994, p. 50). Some of the additional abilities included in Horn's model are: Short-term Acquisition and Retrieval (SAR), Broad Speediness (Gs), Broad Visualization (Gv), Quantitative Thinking (Gq), and Auditory Intelligence (Ga). In order to clarify Horn's factors and their relationship to the WISC-III (Wechsler Intelligence Scale for Children-3rd Edition, 1991), Kaufman reviews the subtests of the WISC-III that correspond to each factor. His classifications are based on his collaborations with Horn. (Note that some subtests are categorized as both Gf and Gc, while others are included only in Horn's more refined model.) Subtests classified as Gc include Vocabulary, Information, Comprehension, Similarities, and Picture Arrangement. Subtests classified as Gf include Picture Arrangement, Block Design, Object Assembly, Similarities, and Arithmetic. Arithmetic, along with Digit Span, is also classified as SAR, while Coding, Symbol Search, and Object Assembly are examples of Gs. Block Design, Picture Completion, and Object Assembly exemplify Gv. The WISC-III does not measure Gq, or Ga. Because most of the tests that are collectively administered to obtain a general intelligence quotient (as well as other types of neuropsychological instruments) represent more than one of these abilities, it is very difficult to get pure measures of unique factors. Furthermore, as Horn himself warns (1982b, p. 855), in any heterogeneous sample it is likely that the same test is measuring somewhat different processes in different people. Thus, empirical findings tend to reflect dominant trends (as opposed to conclusive evidence) in the operation of distinct processes.

Using similar imperfect methodology, other authors have obtained results comparable to those found by Horn and his colleagues, and have interpreted them in terms of the Gf/Gc dichotomy (Hochandel & Kaplan, 1984; Kaufman, Reynolds, & McLean, 1989, Schaie, 1994). Horn's theory has been influential in shaping many of the instruments currently used to measure intelligence (Kaufman, 1994), which typically contain subtests grouped on the basis of two broad factors analogous to Gf, Gc, and three or four more specific factors.

The Seattle Longitudinal Study

The work of Schaie and his colleagues (for review, see Schaie 1990; 1994; 1996) is based on the assessment of mental abilities in over 5,000 adults over as long as 35 years. Seven groups of subjects were assessed over this time span on Thurstone's (1938) primary mental abilities (verbal meaning, space, reasoning, number, and word fluency), and dimensions of rigidity-flexibility. Similar to Horn, the theoretical basis of Schaie's work is Thurstone's conceptualization of psychometric intelligence as specific and separate primary abilities. Thurstone argued that individuals have widely ranging proficiency in various abilities, and did not stress the utility of an underlying general ability, or "g" factor (Spearman, 1927). Whereas Horn and his collaborators (Horn, 1982b) have emphasized a second order system that included the primary abilities as components of broader abilities, Schaie has advocated assessment at the primary level for the study of adult development. He argues that the concept of one-dimensional intelligence is not useful beyond adolescence because there is no single validity criterion, such as school performance, and because empirical findings reveal differential age patterns for different dimensions of intelligence (Botwinick, 1977; Schaie, 1983). Schaie feels that as individuals increase their expertise in specific skills over the age span, general ability becomes less important (Schaie, 1990).

Schaie investigated differences in life-course ability patterns using the cohort sequential design, and also compared cross-sectional with longitudinal data. Using multiple markers to measure inferred constructs, he found differences in the aging patterns of his six factor scores, depending on whether the data were derived from cross-sectional or longitudinal studies. Cross-sectional patterns showed virtually linear declines for inductive reasoning, spatial orientation, perceptual speed, and verbal memory. Verbal ability remained stable from 40 to the late 60s. The longitudinal data, which are not influenced by cohort effects but may be confounded by time-of-testing effects or selection survival, showed modest increases until age 60 in all latent construct abilities except numeric ability and processing speed. Numeric ability showed a slight decline and processing speed a substantial decline before 60. Even into the late 80s, verbal ability showed virtually no decline, while remaining abilities evidenced declines ranging from .5 SD to 1.5 SD (Schaie, 1994).

When interpreting findings in the context of the Gf/Gc formulation, Schaie noted that though decrements are seen in Gf at an earlier point in the life span, Gc shows a steeper decline once the late 70s are reached (Schaie, 1994).

<u>The Processing-Speed Theory</u>

Salthouse (1988; 1996) proposed the processing-speed theory to explain age differences reported in measures of fluid cognition. He argues that the reduction in processing speed limits cognitive performance for two reasons: (a) there is not enough time to perform operations germane to the task at hand ("limited time mechanism," [1996; p. 404]); and, (b) the products of early processing on which optimal performance is dependent, are not available when later processing is complete ("simultaneity mechanism," [p. 405]). The simultaneity mechanism would predict that processing speed deficiencies would negatively affect task performance, even when time constraints were removed, as pertinent information becomes displaced or degraded, and thus, unusable. This theory would also predict that age differences would increase with task complexity. Because it rests on explaining an underlying general factor of the age-related change in performance, the processing-speed theory can be applied to a variety of cognitive tasks. The degree to which sluggish processing will affect a particular task will vary according to task demands.

Salthouse has accumulated a substantial breadth of research supporting his theory by showing considerable reduction in age-related variance after controlling for measures of speed (for review, see Salthouse, 1996). He suggests some possible neurophysiological mechanisms that could account for this phenomenon, including slower speed of transmission along pathways (possibly due to demyelination) and delayed synaptic transmission (a possible result of neurotransmitter dysfunction). He has also suggested that the consequences of slower processing may include alterations in strategy such as a reliance on previously acquired solutions instead of novel problem solving strategies.

Neuroanatomical and Neurophysiological Changes With Age

Some conditions that have been identified as characteristic age-related changes in the brain include neuronal loss and shrinkage, loss of myelin, cortical atrophy, the presence of neurofibrillary plaques, and changes in neurotransmitter levels (see Nicholas, Connor, Obler, &

Albert, 1998). Recent investigations have shown that neuron loss is minimal in the cortex and primarily occurs in subcortical structures, including specific nuclei in the basal forebrain (Albert, 1993). Neurofibrillary tangles are widely distributed throughout the cortex and particularly concentrated in medial temporal areas (Nicholas et al., 1998), which are important for memory and language. Loss of dendritic structures has also been observed in the posterior superior temporal gyrus, especially in the left hemisphere (Anderson & Rutledge, 1996). These conditions subsequently result in synaptic reorganization, decreased conductivity, and decreased connectivity (Albert, 1993; Grady et al, 1994).

Recent studies reviewed in Morrison and Hof (1997), including both animal and human data, suggest that neither neuronal loss, cytoskeletal changes related to neurofilament proteins, nor the minor formation of neurofibrillary tangles that occur in normal aging are likely to account for age-related impairment of hippocampal and neocortical functions. Morrison and Hof discuss recent evidence from the animal literature (i.e., monkeys; Peters et al., 1996) suggesting that prefrontal involvement in cognitive impairment may be related to disruption of the myelin sheath in the subcortical white matter as opposed to destruction of neurons or projections in prefrontal cortex.

Morrison and Hof (1997) also explore neurochemical changes that impact on the function of hippocampal pathways and, in turn, may be causally related to age-based decline in cognition and memory. Specifically, they point to studies showing circuit-specific decreases in dendritic levels of NMDA receptors, which are known to mediate memory processes and long-term potentiation (the process by which new learning takes place) in aged rodents and nonhuman primates. Finally, they review studies from the neuroendocrinology literature suggesting that estrogen has a protective effect with respect to the regulation and maintenance of intact hippocampal circuits.

Based on a review of PET studies, Tulving, Kapur, Craik, et al. (1994) made a persuasive case for their hemispheric encoding/retrieval asymmetry (HERA) model of prefrontal involvement during the encoding and retrieval of episodic memory. They suggest that left prefrontal cortical regions are differentially more involved in the mediation of semantic retrieval and the simultaneous encoding of novel aspects of retrieved information into episodic memory. By contrast, right prefrontal regions are preferentially utilized for the retrieval, or effortful search, of episodic memory. For example, during experimental procedures in which subjects are given a word stimulus and required to generate a verbal association to that stimulus, the initial generation of the associative word requires semantic retrieval. Thus, left prefrontal cortices are differentially more activated than other brain areas and participate more fully, not only in accessing the verbal association from semantic memory, but in encoding the testing experience to episodic memory. The act of recalling the resulting word association entails accessing the testing experience, and thus, requires episodic retrieval during which right prefrontal areas are differentially activated.

Neuroimaging studies have revealed decreased activation of prefrontal circuits in the left hemisphere for older relative to younger adults during encoding (Cabeza, Grady, Nyberg, et al., 1997; Grady et al., 1995). Less anterior frontal activation (Schacter, Savage, Alpert, Rauch, & Albert, 1996) and decreased activation of right prefrontal areas (Cabeza et al., 1997) have been noted in older adults during retrieval of episodic information. These differences suggest that the HERA model, which accurately summarizes encoding and retrieval in younger adults, does not hold in old age.

Age differences in metabolic activation have also been observed in other cortical areas. Less activation of prestriate cortex and increased activation in occipitotemporal cortex were found in older adults' processing of facial stimuli (Grady et al., 1994). Age-related reductions in temporo-occipital processing were seen during encoding of verbal material (Cabeza et al., 1997). In the same study, age-related increases were observed for insular activity during verbal encoding and for left prefrontal activation during episodic retrieval (whereas the HERA model would predict right prefrontal activation during episodic retrieval). Cabeza et al. concluded that the pattern of age-related decreases in local activity and increases in recruitment of alternate cortical areas may reflect the use of less efficient disruptive strategies in some cases and denote beneficial compensatory activity in others.

Schacter et al. (1996) compared older and younger adults on high recall (easier to remember) and low recall (more difficult to remember) conditions of a verbal memory task. During the high recall condition, stimulus words were exposed for longer periods, and deeper encoding took place as a result of the more complex semantic task subjects were required to perform on the stimuli. During the low recall condition, the verbal stimuli were exposed for a briefer period, and more shallow encoding took place due to the simpler perceptual task subjects were asked to perform. Schacter et al. found similar patterns of hippocampal activation associated with the successful recollection of the high recall verbal stimuli for older and younger groups. Bilateral hippocampal regions were differentially activated for the high recall condition as compared to the baseline condition (simple semantic association task), while differential right hippocampal activation was noted when the high recall and low recall conditions were compared. Schacter et al. surmised, based on previous work (see Moscovitch & Winocur, 1992), that the hippocampus may take part in an automatic pattern completion retrieval operation, expressed subjectively as confidence in a recalled item. They concluded that the lower number of high recall items retrieved by the older group reflected inefficient encoding, while similar hippocampal activation observed in both age groups reflected the fact that once the information was encoded, it was remembered just as successfully by older as by younger adults.

By contrast, Schacter et al. (1997) found that older and younger adults, when asked to retrieve low recall words, showed markedly different patterns of prefrontal activations. When low recall measurements were compared to baseline measurements, the younger group showed bilateral increases in blood flow in anterior prefrontal regions, whereas the older group's frontal activations were more caudal and showed less right frontal activation and the additional recruitment of Broca's area. When the low recall condition was compared to the high recall condition, significant left frontal increases in activation were observed in both groups, however, the older group again engaged Broca's area. The authors concluded that the age-related decrease in anterior frontal activation, particularly on the right, was reflecting a problem in engaging or initiating the episodic retrieval mode, which, as mentioned above, is mediated by the right frontal region. They speculated that the additional activation of Broca's area seen in the older individuals reflected inefficient phonetic search strategies initiated subsequent to failure to activate retrieval modes. As further support for this conjecture, Schacter et al. compared their work with that of Grady et al. (1995), where older individuals, during the recall and recognition of facial stimuli, displayed anterior frontal activations relative to a non-memory control task without the additional activation of Broca's area.

Grady et al. also found an interesting contrast between younger and older age groups in hippocampal activations during encoding of facial stimuli. While young people engaged the left prefrontal, anterior cingulate, and right hippocampal areas, in older people, reliable activation was not noted in these regions. The older group's decreased accuracy during the recognition condition was attributed to less efficient encoding as reflected by their differential activation patterns.

In another metabolic study, Hazlett et al. (1998) compared the performance of younger (20-49) and older (60-87) adults matched in proficiency at executing a list-learning task. The authors found that, although the older adults adopted a similar strategy (semantic categorization) to the younger adults, older adults used different brain regions to perform the task. In the younger adults, frontal brain areas were active, while in the older adults, more brain activity was observed in posterior areas. This may reflect a flexible response to processing deficits in frontal areas that have occurred as a result of aging. Elderly subjects who perform successfully have the ability to adapt to physiological changes by utilizing mnemonic strategies (such as visual imagery) requiring the activation of more intact cortical areas, such as occipital association cortices. Hazlett et al. proposed that age-related decline is a function of a "lack of agility in mobilizing alternate cortical resources" (p. 441).

Cabeza, McIntosh, Tulving, Nyberg, and Grady (1997) applied structural equation modeling to PET data from a previous experiment (Cabeza, Grady, et al., 1997) in an attempt to discern whether age-related regional differences in activation were reflective of local neural deterioration or a more global change in the networks subserving the cognitive tasks employed. Results of the path analysis were supportive of a more global reorganization of function that the authors compared to that observed after brain damage. They concluded that their results were supportive of the theory that age-related changes in effective connectivity contribute to observed changes in activation.

Linking Physiological Changes with Functional Decline

As Nicholas et al. (1998) observe, because the networks responsible for the basis of language are widely distributed, decreased connectivity would likely be responsible for difficulties with lexical retrieval and comprehension, the most frequently reported language changes concomitant with normal aging. Because language activity is dependent on an intact auditory system, changes that occur in peripheral and central auditory systems also impact on the comprehension of spoken language.

For memory functions, both neuroanatomical (Morrison & Hof, 1997) and metabolic (Grady et al., 1995) evidence support the notion that hippocampal circuits responsible for encoding of novel stimuli are affected by age-related decline, whereas those involved in the successful recollection of well-learned stimuli remain intact (Schacter et al., 1997). While the left frontal area is important for semantic retrieval, the right frontal area is involved with retrieval of episodic information in the intact brain. The studies reviewed above have shown that in older individuals, right frontal areas are much less differentially active during tasks requiring episodic retrieval. In older individuals, more brain regions are recruited for retrieval, and a shift toward more posterior activation is seen.

These types of studies lend support to the notion that tasks requiring fluid cognition for their efficient execution and which demand active participation of the frontal lobes (e.g., novel problem-solving and new learning) are vulnerable to the physiological changes that accompany age (Hazlett et al., 1998). Reduced processing efficiency in these areas leads to recruitment of other cortical regions. This additional activation increases the time necessary to accomplish the task and likely impacts on other aspects of task efficiency as well. As Hazlett et al. (1998) suggest, successful aging often involves the ability to apply effective strategies through the use of alternate cortical resources (such enhancing semantic categorization with visual imagery, which taps more posterior brain regions).

The Common Cause Hypothesis

Other workers have proposed that age differences in measures of fluid cognition are highly related to the same underlying cause responsible for sensory losses seen in old age. Baltes and Lindenberger (1997) postulate the "common cause hypothesis" to explain the increase with advancing age in correlations between sensory decline and the decline in performance on a variety of cognitive tasks. In an extensive, interdisciplinary study (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994) a battery of 14 cognitive tests was administered to 687 adult subjects (age 25 to 103). Subsequently, through structural modeling techniques, three fluid (i.e., reasoning, speed, and memory) and two crystallized (i.e., knowledge and fluency) first order intellectual ability factors were specified from the cognitive tests administered. Age gradients of sensory functions (visual and hearing acuity) were more negative than those for tasks representing the fluid domain (perceptual speed, reasoning, and memory). In turn, as Horn's theory would predict, the "fluid" tasks had more negative gradients than tasks representing knowledge and fluency, the authors' two crystallized, pragmatic abilities. Further analysis of the data showed that a large portion of the age-related variance in the cognitive tasks could be accounted for by sensory loss.

The authors conclude that a large part of the mechanisms that cause age-related decline in sensory performance (see "Neuroanatomical and Neurophysiological Changes With Age" and "Linking Physiological Changes with Functional Decline" sections above) also bring about declines over the age span in more complex cognitive functions. Thus, developmental changes in higher-order processes can be explained by the aging of peripheral sensory processes. This implies that these mechanisms are operating in a relatively global, rather than domain-specific, way.

Theory of Selective Optimization With Compensation

Baltes (1987) proposes a theory for life-span intellectual development as a dynamic between growth, or gain, and decline, or loss. His theory incorporates the notions of multidimensionality and multidirectionality of life-span intelligence and the interplay between multiple-ability systems. Historically, aging has been viewed as decline; one way to look at development that is capable of explaining the different aging courses seen in separate components of intelligence (e.g., fluid and crystallized) in a parsimonious way is to see development as a gain-loss relationship. According to this view, each point of development can be conceptualized as a joint expression of aspects of growth and decline. As the individual ages, the proportions of gains to losses in adaptive capacity shifts as gains lessen and losses increase.

According to Baltes (1987), successful aging is due to "selective optimization with compensation," a process which has three features, each reflecting a gain/loss relationship. As one ages, an increased specialization in adaptation occurs; this is a general feature of life-span development (see Schaie, 1994). A second feature is the occurrence of adaptation to the limits imposed by decreased plasticity. Tucker & Desmond (1998) have alluded to decreased plasticity and increased stability as a necessity for the development and maintenance of identity over the life span. They note that, based on research done in the field of neural networks, a fundamental problem limiting the capacity of a network to adapt is that new learning causes a potentially catastrophic loss of old learning. Thus, over the course of human development, a stability/plasticity dilemma arises and becomes an issue of whether to retain or adapt. Tucker and Desmond characterize the gain/loss relationship across the life span as a necessary trade-off between identity and adaptation--between accommodating new data and stabilizing representation of prior experience. This notion is not only consistent with Baltes' theory, but with socioemotional theories that refer to the more salient goals of older individuals as involving deeper understanding of the self, maintenance of self-image, and increased self-regulation (Carstensen, 1992; Labouvie-Vief, 1998).

The third feature of selective optimization with compensation involves the onset of individual selective and compensatory strategies that deal with growing deficits over the life span. The objective of these efforts is life mastery and effective aging. For example, when thresholds of capacity are exceeded, individuals may become more selective by reducing the number of high-efficiency domains in which they are actively participating. Compensation may come in the form of substitute mechanisms, such as the use of different combinations of component skills to produce comparable levels of overall performance. Specific manifestations of selective optimization with compensation will vary according to an individual's life experience. The application of this theory to emotional functioning is discussed below.

The Right Hemisphere Aging Hypothesis (RHA)

The RHA postulates that the right hemisphere is more vulnerable to the effects of aging than the left (Albert & Kaplan, 1979; Borod & Goodglass, 1980a; 1980b; Brown & Grober, 1983; Brown & Jaffe, 1975; Ellis & Oscar-Berman, 1989; Goldstein & Shelly, 1981; Kaplan, 1980; Klisz, 1978). This hypothesis was based on empirical findings of differential patterns of age trends on tasks thought to be mediated by the right versus the left hemisphere (e.g., performance versus verbal subtests of the WAIS-R [Albert & Kaplan, 1979; Klisz, 1978]; and right versus left parietal lobe tests [Farver, 1975]). However, some workers (Meudell & Greenhalgh, 1987; Salthouse, 1995) suggest grounds for the contention that past comparisons of age differences in verbal and spatial information processing are weak. Namely, tests thought to reflect the two separate processes are not equivalent in a number of other features (e.g., the degree to which the task is influenced by previous knowledge, presence of time limits, mode of response). Though Salthouse and others (Schear & Nebes, 1980; Shelton, Parsons, & Leber, 1982) found no differential age-related effects when using equivalent tasks, Tubi & Calev (1989) and Meudell and Greenhalgh reported larger age differences with a parallel visual-spatial task when compared to a verbal task. When Hale and Myerson (1996) compared older (mean age 69.7) subjects with undergraduates on lexical and nonlexical tasks, the degree of age-related slowing was much larger for the nonlexical tasks. The authors then matched individuals from each group for speed of lexical processing. They found that while older adults displayed a large discrepancy between lexical and nonlexical processing speed, for the younger group, the time taken to process lexical and nonlexical information was equivalent.

Other methods of testing the RHA hypothesis in normal subjects are those that compare stimulus presentations to each hemisphere (i.e., dichotic listening, tachistoscopic, and lateral eye movement paradigms). This literature has also been equivocal in terms of supporting the RHA hypothesis. Using dichotic listening tasks, Clark and Knowles (1984) and Johnson et al. (1979) reported a right-ear advantage with advancing age, suggesting decreased efficiency in RH processing. However, when ear differences in hearing threshold were controlled for, Borod and Goodglass (1980b) and Nebes, Madden, and Berg (1980) failed to replicate this effect. In fact, Borod, Obler, Albert and Stiefel (1983) later showed that asymmetrical hearing loss (indicated by increasing right ear/LH superiority for pure tone perception) did occur with age. Rastatter and Lawson-Brill (1987) employed a dichotic listening/reaction time paradigm and found that right ear presentations produced significantly faster reaction times to verbal stimuli (relative to left ear presentations) for geriatric subjects. They compared these data to previous findings in child and young adult samples and found significant differences, such that the older individuals appeared to have linguistic capabilities more lateralized to the left hemisphere. The finding that RH linguistic ability is inhibited in older individuals relative to younger is supportive of the RHA hypothesis.

More recently, Alden, Harrison, Snyder, and Everhart (1997) proposed that the discrepancies found in previous findings on dichotic listening tasks testing the RHA hypothesis might be attributable to the use of simple versus complex dichotic listening tasks. To test this possibility, they employed both a simple (presentation of concurrent phonemes) and a complex (addition of an intention task requiring subject to switch focus to one ear) task in a sample of younger (mean age, 20) and older (mean age, 72) females. The RHA hypothesis was supported using the intentional task, while for the simple nonfocused presentation of phonemes, no age differences were found.

Data from tachistoscopic studies (Byrd & Moscovitch, 1984; Nebes et al., 1983; Obler, Woodward, & Albert, 1984) suggest that there are no systematic changes in the lateralization of language processing with age. Moreno, Borod, Welkowitz, & Alpert (1990), in a study examining lateralization of emotional expression and perception functions with age, found no evidence for accelerated deterioration of RH-mediated task performance.

Though findings have been discrepant, it seems that overall, in studies where possible sources of confounding have been minimal (e.g., equating visual/verbal tasks and controlling for differential hearing loss) less support has been seen for differential aging of the two hemispheres. Alden et al. (1997) suggest that equivocal findings can be explained in terms of the levels of complexity of the tasks employed. They propose that the RHA phenomenon may operate only in the context of complex tasks requiring intentional processes and thus, frontal mediation. This would imply that the hemi-aging hypothesis would be limited to frontal regions of the right hemisphere.

## Neuropsychological Changes with Age

Linguistic Processes. Life-span stability of certain types of verbal skills has been established. These include vocabulary (for review, see Bayles & Kaszniak, 1987), verbal subtests of the WAIS (Arenberg, 1978), and verbal subtests of the WMS (Benton, Eslinger, &

Damasio, 1981; Botwinick, 1977; Obler & Albert, 1984; 1985; Wechsler, 1958). Investigations of other verbal abilities, however, reveal some decline (e.g., comprehension [Obler, Fein, Nicholas, & Albert, 1985; Obler, Nicholas, Albert & Woodward, 1985] and verbal retrieval [Howieson, Holm, Kaye, Oken, B.S., & Howieson, J., 1993]).

Though verbal fluency tasks such as the Controlled Oral Word Association Test (COWAT; Spreen & Benton, 1969) and animal naming have been found to be stable by some researchers (Cronin-Golomb, 1990), others have found small, but significant decrements with age (Lezak, 1976; Obler & Albert, 1981; Schaie & Parham, 1977). Differential age patterns have been found for the two types of fluency tasks. No age effects were detected on tasks requiring the production of phonemically similar words (e.g., F-A-S; Obler & Albert, 1985). By contrast, a decline was found on tasks requiring the production of words from the same category (e.g., semantic fluency tasks such as animal naming; Kozora & Cullum, 1995; Obler & Albert, 1985; Tomer & Levin, 1993; Troyer, Moscovitch, & Winocur, 1997). As noted by Huff (1990), verbal fluency tests involve a combination of skills (e.g., sustained attention, speed, suppression of dominant responses), therefore, it is hard to say to what degree they reflect lexical retrieval ability.

Differences seen between results from cross-sectional studies, which tend to suggest sharp declines between middle and old age in some verbal skills (Kaufman, Reynolds, & McLean, 1989; Kramer & Jarvik, 1979), and longitudinal studies, which show modest increases with declines in the 70s and 80s (Horn & Donaldson, 1976; Schaie, 1994). Discordant results from the two types of studies may be attributed to methodology. With cross-sectional designs, which examine differences among subjects from each of a number of age groups, groups are created based on the chronological ages of subjects at the time of the study. Results from a cross-sectional design are vulnerable to cohort or generation effects. (These refer to the influence of generational differences in experience and may involve areas such as nutrition, education, environment, or socioeconomic status.) Longitudinal studies look at within-subject differences over time. Data from longitudinal studies are vulnerable to loss of subjects from the research (i.e., subject mortality), testing effects, and history effects. Subject mortality can arise due to factors such as poor health or finding the research stressful, which may result in a biased sample. Testing effects may result in improved performance due to increased practice, while history effects refer to influences on behavior related to changes in prevailing attitudes at the time of testing. The age-related decline seen in cross-sectional designs, therefore, may be related to generational differences, while the lack of these differences in the longitudinal data could be a reflection of a biased sample (Bordens & Abbott, 1991).

Visuospatial Processes. Decline with advancing age has been found in visuospatial perception (e.g., short-term visual memory and facial recognition [Benton, Eslinger, & Damasio, 1981]; perceptual closure [Wasserstein, Thomson, Sorman, & Barr, 1982]; and construction (Borod, Goodglass & Kaplan, 1980; Farver, 1975; Klodin, 1975; for review, see Salthouse, 1992). Notably, as discussed by Salthouse (p.183), persons in occupations requiring superior spatial abilities (i.e., air traffic controllers and airline pilots) have shown patterns of age-related declines on assorted spatial tests, suggesting that preservation of these abilities is not sustained with practice. Though it is the speed factor in constructional tasks that is most closely associated with age (Van Gorp, Satz, & Mitrushina, 1990), controlling for speed does not eliminate age differences (Doppelt & Wallace, 1955; Klodin, 1976; Storandt, 1976; for review, see Botwinick, 1984).

Reasoning Abilities. Denney (1974; 1980) and Denney and Denney (1982) did a series of studies assessing concept formation as a function of age. They found that younger people tended to use superior concepts for categorization, and were more efficient and quicker at forming concepts. Concept formation improves in the aged when problems are framed in a more familiar, concrete way (Denney, 1980; Arenberg, 1968). Along the same lines, Cronin-Golomb (1990) suggests that the differences in aging patterns between verbal and nonverbal reasoning tasks, the former of which appear to be more resistant to aging, may be related to task features. She maintains that verbal materials are perceived as more familiar and less complex than nonverbal stimuli.

Studies of set-shifting are equivocal, with some workers finding that cognitive flexibility does not change with age (Boyarsky & Eisdorfer, 1972; Mejia, Pineda, Alvarez, & Ardila, 1998; Nehrke & Coppinger, 1971) and others maintaining that rigidity in conceptual set-shifting increases with age (Hartley, 1981; Offenbach, 1974; Rabbitt, 1977).

Learning and Memory. A breadth of research exists documenting memory changes as a function of age (for reviews see Huppert, 1990; MacKay & Abrams, 1996; Smith, 1996). In addition to impaired encoding (Huppert, 1990), faulty retrieval (Mitrushina, Satz, Chervinsky, & D'Elia, 1991), processing speed (Nettelbeck, Rabbitt, Wilson, & Batt, 1996), and individual variables (Mejia, et al., 1998) have been implicated. Short-term simple span is among the most resistant to age effects, however, when manipulation of the material is required (e.g., when testing working memory as in recalling stimuli in a reversed or different order), recall becomes vulnerable to aging. Some authors have concluded that the elderly have less processing resources at their disposal, and subsequently, are disproportionately inefficient under recall conditions (Craik & McDowd, 1987), and under encoding conditions requiring divided attention (e.g., working memory paradigms; Huppert, 1990). Salthouse (1982) has postulated that it is increased task complexity that is responsible for this taxing of resources. However, the results of a study by Craik and McDowd (1987) suggests that it is the increasing requirements for self-initiated process, and lesser involvement of external supports (as in recognition, cued recall, and priming paradigms), that disrupts memory performance. The study by Mejia et al., comparing younger (55-70) and older (71-85) adults on memory and executive functioning tasks, supports Craik and McDowd's hypothesis. In this study, differences among the two groups were seen in memory, but not in executive functioning tasks. Differences were particularly significant in the free recall condition of the associative memory task.

Though Petersen, Smith, Kokmen, Ivnik, and Tangalos (1992) found decrements in rates of acquisition of a word list in adults 62 to 100 years of age, they did not see evidence of delayed recall deficits. In fact, delayed recall, or forgetting, remained relatively stable across age groups when scores were adjusted for the amount of material initially learned. As mentioned above, in a recent study (Mejia et al.), associative paired learning was particularly worse in older adults. However, Benton et al. (1981) saw no significant changes in associative learning or immediate story recall in adults ages 65 through 84. Over the entire life span, aging patterns tend to show steady declines from middle age for immediate recall of stories (Abikoff,

1989) and declines from the 20s (Wechsler, 1987) or 30s (Albert, Duffy, & Naeser, 1987) for delayed recall of prose passages.

Visual memory shows decline at an earlier stage of the life cycle (Van Gorp & Mahler, 1990) and may show more rapid deterioration with advancing age (Arenberg, 1978).

Conclusions

In summary, various cognitive aging theories attribute the decline of intellectual abilities that occurs over the life span to different underlying causes (e.g., decreased rate of processing, more rapid RH deterioration, differential strategies and organization due to experiential factors, age-associated loss in the integrity of brain physiology).

Research has supported the stability of vocabulary skills and verbal relative to spatial reasoning, while most visuospatial skills and rate of processing show clear decline. The relative preservation of problem-solving ability appears to be dependent on task characteristics, with older people having less difficulty when the stimuli are more concrete and familiar. The literature comparing the performance of older and younger individuals on tasks reflecting other abilities, such as word fluency and set-shifting, has been equivocal. Most aspects of performance in learning and memory decline with age (visual sooner and more severely than verbal), though preservation of short term simple span and delayed memory have been documented.

Most concur in the belief that it is useful to examine aging patterns of specific abilities as opposed to more general constructs, citing evidence that diverse skills exhibit differential degrees of decline or stability in old age. Some developmental theorists have proposed parsimonious explanations for patterns of decline, such as gain/loss models. The present study will examine the perception of emotion as a function of age along with aging patterns of nonemotional cognitive skills, including sensory functioning. Results will then be discussed in the context of aging theories.

## Emotion: Theories and Empirical Findings

As mentioned above, a single, comprehensive, widely accepted theory of emotional functioning does not exist. Theorists have approached the subject from many different viewpoints, including subjective feeling (as in dimensional models), specific motoric patterns (as in discrete emotion models), and the link between cognitive evaluation and behavior patterns (as in cognitive appraisal models). In addition, theories linking emotional behavior with neurochemical and neuroanatomical circuits or systems, such as LeDoux's dual path model (1989) and Gray's septo-hippocampal theory (1982) have been influential and informative. Developmentally-oriented theories (e.g., differential emotions theory, Izard, 1971; attachment theory, Bowlby, 1969, 1973, 1980; Labouvie-Vief's [1998] cognitive-emotional integration theory; and socioemotional selectivity theory, Carstensen, 1992) have also inspired a breadth of research over the last thirty years. Only those theories deemed pertinent to the present study will be reviewed. They include: developmental theories mentioned above, due to their obvious relevance to this investigation of aging effects on emotional perception; Bowers et al.'s (1993) theory of the nonverbal affect lexicon, due to the analogies that can be drawn to verbal skills and their aging patterns; and, right hemisphere superiority theory because it is germane to aging in the context of the RH deterioration hypothesis. Other sections included below are reviews of studies examining the relationship among emotional communication channels; studies of emotional communication, particularly emotional perception, over the adult life span; and, the valence hypothesis, as it is relevant to predictions made regarding positive and negative affect.

Emotion and Adult Development

Differential Emotions Theory. Differential emotions theory (Izard, 1971; see also Dougherty, et al., 1996; Izard & Ackerman, 1997; Izard & Malatesta, 1987) emphasizes the significance of the emotional system as the primary motivational force for human thought and action. The theory assumes the existence of a limited number of fundamental, discrete emotions with particular characteristics, phenomenological, motivational and signal properties (Malatesta et al., 1989). These discrete emotions are seen as "motivational subsystems of personality" (Dougherty, et al., p. 29), and are thought to retain their particular characteristics across situations and over the life span. For example, throughout life and across situations, anger motivates people to overcome the frustrating barrier to a goal. Though a particular situation may elicit several emotions (e.g., anger, disgust and contempt), which together form a cluster referred to as hostility, the three emotions retain their separate and unique motivational tendencies.

Differential emotions theory holds that there are basic emotions, constituting the independent emotion systems, that emerge in infancy and childhood and remain as part of the human repertoire of emotions throughout life. These emotions, which include interest, joy, anger, sadness, fear, surprise, and disgust, do not depend upon cognitive development for their emergence, or on cognitive appraisal processes for their activation. In addition, there are emotion systems characterized as dependent, and which include guilt, shame, shyness, and contempt. These systems do not emerge until cognitive development enables their activation (e.g., one cannot experience shyness and shame until one achieves the cognitive ability to differentiate self and other). These dependent systems also do not (with the possible exception of contempt) have corresponding universal facial expressions.

There are two central principles of DET that are applied to lifespan development. They are the constancy of emotional feeling and emotion-based aspects of personality. Though the conditions associated with discrete emotions change, the assumption that core emotional states remain constant over the life span is what Izard and colleagues see as the basis for stability in personality and sense of self. For example, perceived danger will always elicit fear and the fear feeling will reliably activate protective behavior. However, what is considered dangerous changes as a function of many factors associated with age (e.g., accumulation of past experience, decline in physical strength). According to Izard and colleagues, emotional constancy over the life span is highly adaptive for several reasons. First, according to DET, affective-cognitive structures are associations between feeling states and stored memories (e.g., in infancy, joy and being embraced by a caregiver; in adolescence, joy and a first romantic encounter. These are said to be related to personality development (e.g., interest and joy are positively correlated with the personality dimension of extroversion). If feeling states changed over the course of a lifetime, and joy came to feel some other way, then the affective-cognitive structures that are depended upon to give a particular personality type pleasure would no longer do so. This would result in a change in the behavior pattern that constitutes that personality type. For example, if an extrovert could no longer depend upon social interaction to elicit the specific feeling of joy, the pursuit of social interaction would no longer be motivated (Dougherty et al., 1996; Izard & Ackerman, 1998).

Another evolutionary advantage to emotional constancy throughout life is the ability to learn from consistent experience, thus enabling anticipation and preparation for emotional situations. Finally, the maintenance and strengthening of relationships over life is largely based on reliable communication of emotional feelings. Without stability of emotional feeling despite aging and individual experience, shared feelings and subsequent development of mutual trust and understanding would not be possible.

DET assumes that core feeling states of fundamental emotions and the basic form of the emotional expressions that correspond to them are stable across the life span. What changes in the course of adult development are the connections among personality subsystems, particularly the emotion, cognition, and action systems. These connections show different developmental trends. For example, the affective-cognitive processes of recognition and verbal labeling of emotional expression (largely what is being examined in this study) are achieved by late childhood and remain stable throughout adulthood. Other links between emotion and cognition continue to develop through the life span. For example, the ability to consider another person's perspective with regard to their beliefs and desires when anticipating their emotional response in particular situations is a skill that can continue to be refined throughout life. Affective-cognitive structures are believed to increase in number and complexity until they become so elaborate as to be defined as value systems or personal ideologies. Emotion elicitors are also hypothesized to change with age in response to the increase and differentiation of cognitive abilities.

The work of Izard, Malatesta, and colleagues has shown that though the basic form of emotional facial expressions does not change as a function of age, subtle differences in the configuration of expressive signals do develop as a consequence of maturity. Beginning in childhood and continuing throughout life, pure, singular, emotional expressions decline and are replaced by more complex, mixed displays. Gradually the use of masking, miniaturization, fragmentation, and blending become characteristic of adult emotional expression. With respect to frequency and intensity of emotional experience, DET proponents have found no differences between younger and older adults (Malatesta & Kalnok, 1984).

The Influence of Attachment Style on Emotional Development. According to Bowlby (1969, 1973, 1980), the attachment system is a biologically based system that assures the maintenance of physical and emotional well being in young and helpless offspring. Both infants' and caregivers are predisposed to the system, with infants capable of signaling distress from birth and primary caretakers inclined to respond to those signals. Though the development of attachments is a universal event, the quality of the bond and pattern of emotional communication between infant and caretaker (usually the mother) differ. The work of Ainsworth and her colleagues in the "Strange Situation" (see Ainsworth, Blehar, Waters, & Wall, 1978) showed that attachment relationships take three basic forms, depending upon how a child's needs are characteristically negotiated within a dyadic interaction. These are: secure attachment, which allows a child to develop autonomy and a stable sense of self and results from consistent and sensitive caregiving; insecure avoidant attachment, which arises from insensitive caregiving that is overstimulating and/or rejecting, and results in a child who avoids seeking comfort from the mother, feigning independence; and, insecure ambivalent attachment, which is a response to inconsistent, unpredictable caregiving and results in a child who is alternately clinging and rejecting.

Research has shown that attachment styles are retained over childhood and into adulthood (for review, see Magai & Passman, 1997). This stability is said to be due to "internal working models" which generalize the primary attachment relationship to other relationships over the life span. When infants and toddlers are securely attached, they show less hostility and anger and more exploratory behavior than insecurely attached peers (Ainsworth, Bell, & Stayton, 1971; Ainsworth et al., 1978) and are better problem-solvers, more enthusiastic, and exhibit more positive affect (Matas, Arend, & Sroufe, 1978). In a study by Elicker, Englund, and Sroufe (1992) most children exhibited the same attachment styles they had displayed in infancy up to age eleven.

Insecurely attached children also display different attentional strategies to emotionally laden information and vary in their emotional expressiveness from securely attached children. Ambivalent children have been observed to show hypervigilance to stressful stimuli and to show enhanced expressivity, while avoidant children repress negative affect and inhibit expressive behavior (Cassidy, 1994). Adults have been shown to display similar attachment styles and the attentional and expressive characteristics associated with these. Ambivalent adults are hypervigilant to stressful situations, experience others as unpredictable, and tend to feel helpless and anxious. Avoidant types repress negative affect, find it difficult to trust others and avoid demonstrations of attachment behavior. Secure adults, on the other hand, tend to trust others, have realistic views of their own capabilities, typically exhibit positive affect, but are capable of acknowledging, expressing, and processing negative feelings as well (Cassidy, 1994; Magai & McFadden, 1995; Sperling & Berman, 1994).

Magai (1999) reported data associating attachment types with specific facial expression and decoding biases. In this study, which included subjects ranging from the mid-20s to the mid-80s, attachment style was assessed using the Bartholomew (Bartholomew & Horowitz, 1991) four-category model, which breaks down avoidant attachment into two types and refers to ambivalent attachment as preoccupied. The fearful avoidant style characterizes people who desire emotional closeness but are fearful of rejection, whereas the dismissing avoidant style typifies those that devalue or are not interested in intimacy. Magai's results showed that a predominance of joy expressions and a facial decoding bias for shame predicted expressions secure attachment. Fearful avoidant subjects showed a predilection for shame expressions, and to attribute sadness to ambiguous faces, which, Magai notes, is not surprising considering the low self-esteem and shyness that characterizes these individuals (Magai & Passman, 1997). Mixed or ambivalent expressions and a tendency to see anger in faces predicted dismissive attachment. As Magai & Passman (p.120) point out, this is consistent with the repression of negative emotions. Ambivalently attached, or preoccupied, subjects tended more frequently to exhibit facial expressions of disgust. When attachment needs are repeatedly sought and not met, disillusionment may result, giving rise to disgust.

The same study reviewed above revealed a significant contribution of age in predicting dismissive and secure attachment. Secure attachments were more prevalent among younger individuals, while dismissive attachments were observed more often in the older individuals. This may be a function of reduced security in old age, or a result of cohort effects. As Magai & Passman (1997) report, many of the older individuals in this study had been raised in an atmosphere where child-rearing concepts espoused by Watson, which discouraged open expressions of parental affection and warmth, were followed. This, as opposed to chronological age, may have contributed to the predominance of dismissive attachment styles seen in the older cohort. A study using autobiographies written by college students over the course of several decades to code attachment style (Pinkham, 1996) found that cohorts born earlier in the century were more dismissive and less secure than later cohorts. Because age was controlled in this case (cohorts were of similar ages when they wrote the autobiographies) these results support the notion that cohort effects contribute to age differences in attachment style.

Labouvie-Vief's Model of Cognitive-Emotional Integration. Labouvie-Vief's (1997; 1999) formulation represents the construction of a theory of adult development that is based on both psychodynamic and Piagetian perspectives. Important influences for her theoretical formulations include Jung (1933) and Erikson's (1984) attempts to extend identification processes from the parental relationship, through peers and community, to the human condition at large. In addition, Kohlberg (1969) and Loevinger's (1976) emphases on widening circles of social relations (resulting in more mature relational perspectives in the case of Kohlberg, and increasingly complex regulatory structures, in the case of Loevinger), were influential in the development of Labouvie-Vief's theory.

Labouvie-Vief's theory conceptualizes a hierarchical (not necessarily age-related) system consisting of five levels of emotional development reflecting cognitive-emotional reorganization. The levels are differentiated according to five dimensional criteria: affective complexity, interpersonal perspective, self-other differentiation, reflectivity, and ideals (see Labouvie-Vief, 1997).

Labouvie-Vief entered the realm of emotion and cognition through her initial investigation of more general information processing changes across adulthood. She found through studies involving the interpretation and recall of textual information (Labouvie-Vief, 1994; Adams, Labouvie-Vief, Hobart, & Dorosz, 1990) that until middle adulthood (40-55 years) thinking becomes increasingly more symbolic and emotionally relevant. She, along with others (Carstensen, 1992; Carstensen & Turk-Charles, 1994), found that though a preference for emotion-based responses is retained in older individuals, their responses are more global and undifferentiated. She concluded that although older adults frequently use emotion-based language, this may not necessarily imply the ability to reason about emotions in complex ways. Increases in emotion-based language may be a result of mechanisms like awareness of time and mortality (Carstensen, Gross, & Fung, 1997). Or, as Labouvie-Vief (1997) suggests, the nebulous quality of affective responses seen in older individuals may reflect less complex emotion regulation strategies resulting from limitations in fluid intelligence.

In their work on emotional understanding, Labouvie-Vief, DeVoe, & Bulka (1989) report more differentiated emotional experience as a function of maturity (not necessarily age), as measured by understanding of emotion terms, description of inner and outer emotional experience, monitoring of emotional processes, and reliance on self-generated standards for emotion regulation. Less mature individuals used strategies like forgetting, ignoring and redirecting thoughts to repress emotional tension and remain free from conflict, and depended on others for confirmation of their feelings. More mature individuals more fully acknowledged and examined emotional feelings, defining their emotional lives on the basis of internal, as opposed to external, criteria.

More recently, Labouvie-Vief has expanded investigations into the realm of self and parental relationships and ways in which increasingly complex levels of emotional development predict coping strategies. She found that, just as the self becomes viewed from a perspective of history and multiple contexts as a function of maturity, so do parents. When predicting coping strategies from emotion representation, ego level, verbal ability, and gender, Labouvie-Vief and colleagues (Labouvie-Vief et al., 1989; Diehl, Coyle, & Labouvie-Vief, 1996) found two significant variates, gender, and a developmental dimension represented by age and the other variables. Use of mature coping and defense strategies increased across age groups, while use of immature strategies declined. However, increases in use of immature mechanisms were seen in the oldest group (from 60-69 to 70+), which may be indicative of a reversal or abatement among the oldest subjects.

Labouvie-Vief suggests that, parallel to the cognitive changes documented by aging research in psychometric intelligence, developmental transformations occur in how people view themselves, reality, and emotions. These reorganizations are linked to self-other relationships and maturity of coping processes. With advanced cognition, more complex and powerful linkages between the systems of emotion and cognition evolve. Through this process affects can be tolerated and even cherished. As Labouvie-Vief (1997) points out, the ability to maintain composure in the face of extreme affect is associated with advanced forms of wisdom and spirituality.

Cognitive complexity, defined as a combination of crystallized intelligence, ego level, and reflective intelligence, is, according to Labouvie-Vief, a more significant factor than age in adaptive cognitive reorganization. This is supported by her findings, where younger people with these qualities evidenced higher scores on measures of emotional constructs, and overall, peak performance on measures of emotional constructs were achieved in middle age. She gives two possible explanations for findings showing decline in measures of reflective cognition, self- and emotional representation, and maturity of defense and coping mechanisms in older (60+) age groups. Because lower reflective cognition scores were related to lower measures of fluid cognition (Labouvie-Vief, Chiodo, Goguin, Diehl, & Orwell, 1995), she suggests that coping strategies are being affected by a decrease in intellectual and/or biological resources. Alternatively, she proposes that it may be the methods employed to tap late-life phenomena that are lacking. Most theories and methods presently used tap phenomena that are more crucial to midlife adjustment, such as personal growth and introspection, critique of social goals, and self-actualization and autonomy. These are tasks that are contemplated while anticipating a substantial remaining life span. Tasks such as "redefining values in the face of limited resources and time, rescaling goals that are no longer in reach, and in general transforming the meaning of personal and social losses" (Labouvie-Vief, 1998, p. 233) are the issues that are relevant to emotional integration in old age.

Socioemotional Selectivity Theory. One condition thought to reflect a change in the emotional status of older individuals is the decrease seen in social interaction as a function of old age. Different theories have been presented to account for this condition. Cumming and Henry (1961) proposed disengagement theory, suggesting that a process of withdrawal between older people and society occurs in preparation for death. Activity theory (Havighurst & Albrecht, 1953; Maddox, 1970) proposed that physical and social obstacles prevent older folks from maintaining social connections. Carstensen (1992; Fredrickson & Carstensen, 1990), on the other hand, has maintained that a narrowing of social interplay occurs over a large part of the lifespan, including childhood, and notes that this occurrence in old age is merely an extension of the lifelong process. She characterizes this evolution as "the result of lifelong selection processes by which people strategically and adaptively cultivate their social networks to maximize social and emotional gains and minimize social and emotional risks" (Carstensen, 1991).

When Fredrickson and Carstensen (1990) tested three age groups (adolescents, middle-aged, and old) to investigate how they tended to categorize potential new social contacts, subjects tended to use three basic dimensions: possible sources of new information, potential for future contacts, or potential for emotional rewards. The adolescent group placed the greatest emphasis on potential for new information and contacts, while the older group almost exclusively categorized others according to potential affective gain.

More recently (1992), in a study using archival and current interviews over a 34-year period, Carstensen investigated six types of relationships in men and women. She found that from early adulthood on, the frequency of interactions with acquaintances and close friends declined, while the frequency of interactions with spouses and siblings increased. At the same time, emotional closeness with relatives and close friends (despite less frequent interactions) increased throughout adulthood. Her rationale (Carstensen, 1991; 1992; Carstensen et al, 1997), from an adaptive standpoint, is that the value of social contact decreases with age. Early in life new and essential information is acquired through exposure to diverse and numerous others, while later in life this information is less likely to be novel, hence is less valuable. In addition, as we start to seek more technical information, it is more effectively acquired through nonsocial means. Finally, in youth, even information that will not be useful in the present may have a potential for utility later in life. As we age and the future becomes more time-limited, so does the value of this type of information.

By contrast, emotional self-regulation and the maintenance of self-image become more adaptive goals as one ages. This is sustained and improved through increased contacts with a select group of significant others who preserve self-concepts. Sufficient shared history is often necessary to validate identity. Moreover, exposure to society includes the risk of being exposed to stereotypes and negative attitudes regarding old age. Thus, even people who have strong, intact identities may expose the self-image to risk by engaging in indiscriminant social interaction. Over the life span, the cost-benefit ratio of casual social interaction decreases, whereas the rewards of intimacy increase. The result of the social adjustments people make in response to this is a minimization of negative emotional experience, and a maximization of positive emotional experience.

Carstensen and Turk-Charles (1994) furthered their investigation by examining the relative salience of emotion in everyday life. They asked subjects to read and recall prose passages. Their subjects were young (20 to 29), middle-aged (35 to 45), older (53 to 67), and elderly (70 to 83) adults. Each subject's recall of the reading material was classified as either neutral or emotional as judged by raters. The authors found that with age, relatively more emotional than neutral information was recalled. Though age decrements were seen in overall recall, mean proportions of emotional stimuli recalled increased as a function of age. The authors suggested that because emotional material increases in significance as a function of the developmental needs referred to above, emotional stimuli become a priority for processing resources as one ages. Importantly, they suggest that the use of nonemotional experimental stimuli across a wide variety of tasks may put older people at a disadvantage.

Carstensen & Turk-Charles (1994) contend that the phenomenon of socioemotional selectivity, though age-related, is not age-caused. They refer to empirical studies that support the notion that for all people facing endings (e.g., young people anticipating relocation versus those not, Fredrickson & Carstensen, 1990; HIV+ versus noninfected gay men, Carstensen & Fredrickson, 1992), regardless of age, emotional experience becomes more salient than other functions such as information-seeking or basic survival functions.

Carstensen (1992; Baltes, M.M. & Carstensen, 1999) notes that her selectivity theory is consistent with P. Baltes' (1987; see above) selective optimization with compensation model, which holds that successful aging happens when people concentrate on objectives that are most valued and let go of less important goals. The compensatory part refers to the reliance on well-learned behavioral repertoires ("crystallized functions") to compensate for functions that have been negatively affected by aging ("fluid abilities"). Carstensen considers her theory "one application of selective optimization with compensation to the social realm" (1992, p.338).

## The Nonverbal Affect Lexicon

Bowers et al. (1993), in their review of studies of emotional perception in both brain-damaged and normal populations, document evidence leading to their theory of the existence of a nonverbal affect lexicon (NAL), a vocabulary of nonverbal emotional signals. This vocabulary is one aspect of what Bowers et al. refer to as the "cold cognitions" (p.433) of emotion. The other is "emotional semantic knowledge," which is appropriately determining the situational circumstances that lead to particular emotions. The common and distinguishing characteristic of these cold cognitions is that they can be removed from the experience of being in an emotional state.

Essentially, Bowers et al. provide a persuasive argument for their theoretical stance. They reiterate the conceptualization of face, voice, and gesture as equivalent to affect phonemes, as proposed by Brothers and Ring (1992) and analogous to the existence of speech phonemes in the verbal system. Another element of their argument is the evidence that exists pointing to similar organization of the proposed NAL and the linguistic system.

One correspondence that may exist between the organization of verbal and nonverbal communication systems is the presence of distinct input and output channels with separate anatomical loci. Prosodic expressive deficits can exist with and without prosodic comprehension deficits (Ross & Mesulam, 1979). There have been cases of patients with deficits in expression and not comprehension that have lesions in the anterior RH (Ross, 1981). Ross has suggested that the anatomical organization of the cortical areas subserving the production and comprehension of emotional speech in the RH may be similar to that of areas subserving propositional speech in the left hemisphere. Left hemisphere speech production areas are located in the anterior part of the hemisphere, while receptive areas lie in the posterior regions. Borod et al. (1996) found dissociations for the perception and expression of lexical emotion in RH brain-damaged adults according to lesion locus, but in a vertical direction. Subcortical lesions were more related to expressive deficits, while cortical lesions were more involved in perceptual deficits.

Bowers and Heilman (1984) initially proposed the concept of the NAL after encountering a patient with a RH subcortical lesion, a large glioma deep in the white matter of the right posterior temporoparietal region. The patient retained the ability to match facial emotional stimuli, but could not accurately label them, implying a disconnection between the facial affect lexicon and the verbal lexicon. The patient's facial lexicon appeared intact (he was able to match facial emotional stimuli within and across specific views), however, access to the lexicon via the verbal route was disrupted. Bowers et al. (1993) compared this condition to the disconnection syndromes seen in the left-hemisphere, only with the source of the visual-verbal disconnection in the minor hemisphere. For example, in the language-based disconnection syndrome seen in alexia without agraphia, the ability to sort written words is preserved, while the ability to read them aloud is lost. This syndrome can occur in left hemisphere lesions analogous to the one described above (i.e., subcortical lesions undercutting the left inferior parietal lobe; see Greenblatt, 1976) and is a visual-verbal disconnection arising from damage to the left hemisphere.

In summary, the argument for an RH-mediated system for emotional communication is strengthened by the similarities that can be identified between the functioning of this system and the LH-mediated verbal system. First, analogous to speech phonemes, affect phonemes exist as inputs to larger and more complex units of emotional communication. Secondly, similar organization in both systems is reflected in evidence for separate input and output modules in emotional processing, and in disconnection syndromes for the appreciation and naming of emotional stimuli seen as a result of brain damage to the right hemisphere. The analogy that can be drawn between the proposed RH-mediated emotional vocabulary and the left hemisphere-mediated linguistic system is highly relevant to the present study. If this analogy is valid, it would follow that the well-documented resistance of the verbal lexicon to aging effects would be duplicated in the nonverbal realm for facial and prosodic emotional signals.

RH Superiority for Emotion

The RH hypothesis of emotion maintains that emotion, regardless of valence, is mediated by the right hemisphere (Borod, 1993). This hypothesis is based on the observation that emotional processing requires strategies for which the right hemisphere is particularly suited, both functionally and structurally (Borod, 1992). Below is a review of studies testing this hypothesis in the decoding or perception of emotional stimuli based on reviews of the literature (Borod, Bloom, & Santschi-Haywood, 1998; Borod & Koff, 1989; Borod, Koff, & Caron, 1983; Borod, Zgaljardic, Tabert, & Koff, in press; Grunwald, 1995).

Facial Perception. Using tachistoscopic techniques, a left-visual field advantage was found for the perception of emotion in cartoon faces (Ley & Bryden, 1982) and photographs of faces (Suberi & McKeever, 1977), independent of the right hemisphere's involvement in facial recognition. McKeever and Dixon (1981), Strauss and Moscovitch (1981) and Ladavas, Umilta, and Ricci-Bitti (1980) also found evidence for RH superiority for facial emotional perception.

More recently, tachistoscopic paradigms have yielded further support for a left-visual field (LVF) advantage in the judgment of intensity of facial emotion (Drebing, Federman, Edington, & Terzian, 1997). They have also found an LVF advantage for: accuracy of identification of facial emotion (Burton & Levy, 1989; Hugdahl, Iversen, & Johnsen, 1993; Moretti, Charlton, & Taylor, 1996), accuracy of matching facial expressions (Mandal & Singh, 1990), and speed of identification of facial emotion (Burton & Levy, 1989; Harrison &

Gorelczenko, 1990). In some cases, this right-hemisphere advantage was observed only for negative stimuli, while no advantage (Harrison & Gorelczenko, 1990; Moretti et al., 1996), or a left hemisphere advantage (Burton & Levy, 1989) was observed for positive stimuli. Further discussion of differential hemispheric findings according to valence follows in the "Valence Hypothesis" section.

The chimeric faces procedure (where two half-faces, depicting different emotional expressions, are spliced together and presented to both visual fields) was used by Levy, Heller, Banich and Burton (1983), and revealed a left hemispace bias for emotional intensity. The stimuli, which were comprised of happy and neutral items, were perceived as happier when processed by the viewer's right hemisphere. More support for RH mediation of facial emotional perception comes from other workers using the chimeric faces paradigm (Borod, Vingiano, & Cytryn, 1989; Jaeger, Borod, & Peselow, 1987; Levine & Levy, 1986).

More recently, workers using free-field viewing to assess hemispheric differences in the appreciation of facial emotion have documented further support for the RH hypothesis (Burt & Perrett, 1997; Burton & Levy, 1991; Christman & Hackworth, 1993; Harris & Snyder, 1992; Luh, Rueckert, & Levy, 1991; Moreno, Borod, Welkowitz, & Alpert, 1990). Best, Womer, and Queen (1994) found differential hemispheric advantages according to valence, with negative facial expressions judged as more intense when presented to the LVF; no hemispheric differences were found in the judgment of positive emotional expressions.

A paucity of studies have found no hemispheric differences in the perception of facial emotion (e.g., Billings, Harrison, & Alden, 1993; Everhart, Harrison, & Crews, 1996; both used tachistoscopic presentation of happy and angry faces).

Prosodic Perception. RH lateralization for the perception of prosodic emotional stimuli has been found in studies using the dichotic listening paradigm, pairing emotionally with nonemotionally intoned sentences (Boles & Pasquarette, 1993; Haggard & Parkinson, 1971; Herrero & Hillix, 1990; Ley & Bryden, 1982; Shipley-Brown & Dingwall, 1988). Using the same techniques, other workers have similarly demonstrated support for the RH superiority of prosodic emotional material using emotionally intoned words (Bryden, Free, Gagne, & Groff, 1991; Bryden & MacRae, 1989; Bulman-Fleming & Bryden, 1994; Morais & Ladavas, 1987), phrases (Strauss & Goldsmith, 1987), and nonsense syllables (Erhan, Borod, Tenke, & Bruder, 1998). Grimshaw (1998) found a left-ear advantage in error rates, but not reaction time, when presenting emotionally intoned words in a dichotic listening task. Other findings suggest right hemisphere mediation of the processing of intonation contours in speech (Blumstein & Cooper, 1974) and nonverbal emotional vocalizations (Bryden & Ley, 1983; Mahoney & Sainsbury, 1987).

Lexical Perception. Using tachistoscopic presentation, Graves, Landis, and Goodglass (1981) found that males processed emotional words more accurately than nonemotional words when they were presented to the left hemifield. (This finding could be explained by gender differences in lateralization; females, in addition to using more bilateral processing in linguistic tasks, exhibit better recovery of language post-LH injury [Lezak, 1995].) More recently, dichotic listening studies have found right hemifield (LH-mediated) biases across genders for perception and recall of positive and negatively intoned words (Ali & Cimino, 1997) and for speed and accuracy in identifying positive and negatively intoned words (Eviatar & Zaidel, 1991; Grimshaw, 1998).

Brody, Goodman, Halm, Krinzman, and Sebrechts (1987) found that affective lexical primes improved response speed relative to neutral primes only when presented to the RH. By contrast, processing speed as measured by reaction time decreased when emotional primes were presented to the LH. These results suggest a tendency for emotionally laden verbal stimuli to facilitate processing in the nondominant hemisphere while disrupting processing in the dominant hemisphere, and may indicate that emotional tone inhibits LH lexical processing.

When Schwartz, Davidson, and Maer (1975) posed emotional questions to subjects, more left-sided lateral eye movements resulted, while nonemotional questions produced right-sided lateral eye movements. Ley and Bryden (1982) found that a presentation of emotional word lists for study prior to participation in dichotic listening and tachistoscopic tasks primed the RH, resulting in improved performance.

Burton and Levy (1989) found differential hemispheric biases according to valence among their female subjects. Reaction times of female subjects to RVF presentations of printed words primed with an emotional face were relatively faster when the facial expression was positive. For LVF presentations, reaction times were differentially improved when negative priming was employed. Van Strien and Morpugo (1992) and Van Strien and Heijt (1995) also found differential priming effects in a tachistoscopic task. These findings will be discussed more fully below in terms of their relevance to the valence hypothesis.

Communication Channels

As noted by Borod (1993), the nature of the relationship among the facial, prosodic, and lexical communication channels has received relatively little study in the context of the perceptual processing mode in normal samples. Studies of normal subjects have suggested associations between the facial and vocal channels in emotional expression (LoCastro, 1972; Mehrabian & Weiner, 1967). One study reported modest associations between facial and vocal emotional perception in normals (Borod et al., 1990). Dissociations of the lexical channel from the facial and prosodic have been found in some cases (LoCastro, 1972), and not in others (Borod et al., 1985). Recently, Borod et al. (2000), in previous work based on preliminary analyses from the same data set as this study, found significant associations among all three communication channels on measures of emotional identification.

Among brain-damaged subjects, moderate facial/vocal associations have been found for emotional perception (Benowitz et al., 1983), expression (Borod et al., 1985), and both expression and perception (Borod et al., 1990). Single-case studies of brain-damaged subjects have reported dissociations between these two channels in the evaluation of emotional stimuli (Bowers et al., 1993). While Bowers et al., hypothesize the existence of two independent NALs, one for faces and one for prosody, these data suggest a unitary system.

Changes in Emotional Communication With Age

Relatively little research has been done on life span changes in the behavioral aspects of emotional processing. Malatesta and Izard (1984) and Malatesta, Izard, Culver, and Nicholich (1987), studied three age groups of women (mean ages 33, 55, and 69) using an emotion-induction paradigm that was used to elicit fear, sadness and anger. No differences were found in expression across age groups, but older subjects were less accurate in perception than the younger groups. Importantly, differences in visuospatial perception were not controlled for. One very interesting and potentially revealing finding for this study is that accuracy of decoding emotional signals varied according to age congruence between encoder and decoder. Malatesta et al. suggest two possible explanations for this. First, they propose that the similarity between encoders and decoders generates more interest and, therefore, leads to a more motivated performance by the decoder. Secondly, they imply that configurational differences (perhaps due to structural facial changes as a result of age) or other subtle differences in the communication of the various age groups cause a decoding advantage for same-aged decoders through familiarity.

Moreno, Borod, Welkowitz, and Alpert, (1993) tested groups of young (21 to 39), middle-aged (40-59), and older (60-81) females, and found no differences in the perception of facial emotion and no evidence of cohort bias. Age effects were seen between younger (17 to 22) and older (65 to 90) men and women in a study by McDowell, Harrison, and Demaree (1994), where the older subjects were less accurate at identifying negative and neutral facial stimuli, while their abilities for identifying positive stimuli remained intact.

Brosgole and Weisman (1995) reported differences among six age groups of subjects (2-11 through 6-11; 7 through 12-11; 13 through 17; 18 through 43; 45 through 64; and, 65 through 83) in the identification and discrimination of facial, prosodic, and musical emotional stimuli. Musical stimuli consisted of ten-second, audiotaped sound bites of musical selections that had been rated as happy, sad, or angry in a previous pilot study. (Only selections with 85% agreement were used.) The selections consisted of jazz and classical arrangements of popular tunes of the 1930s and 40s played by professional jazz groups.

For facial perception, asymptotic performance was seen from age 3 through 34, with progressive declines for the two oldest age groups (45-64; 65-83). For prosodic perception, abilities improved from age 3-12, remained stable until age 43, and declined steadily after age 45. For musical emotional perception, performance was stable from age seven, and a significant increase in errors was seen in the two older age groups (45-64 and 65-83), which did not differ from each other. Importantly, in this study, though visual and hearing acuity were assessed informally, differences in visuospatial and auditory perception were not evaluated and controlled for.

In a study investigating the decoding of body movements and gestures (Montepare, Koff, Zaitchik, & Albert, 1999), older (65-89) subjects were less accurate at identifying emotions than younger subjects (18-22). Grunwald et al. (1999), using control tasks consisting of analogous nonemotional lexical stimuli, found significant age-related decline across groups of young (20-39), middle-aged (40-59) and older (60-85) adults in the perception of lexical emotional stimuli. No differences were seen in the perceived intensity of emotional stimuli across age groups, however, older participants rated nonemotional stimuli as significantly more intense than did younger participants. The authors interpret their intensity findings in the context of theories of adult emotional development theories. In line with differential emotional theory (Izard, 1971), these data support the notion that the intensity of emotional experience remains stable over the life span. Furthermore, as Carstensen's (1992) theory would predict, seemingly neutral stimuli may become imbued with emotional meaning as one ages due to situational changes and the increased salience of emotion.

For emotional expression, studies have shown differences in aging patterns according to whether the expression was posed or spontaneous, and whether accuracy or intensity were being measured. While accuracy of spontaneous facial expression remains stable across adulthood (Levenson, Carstensen, Friesen, & Ekman, 1991; Malatesta, Izard, Culver, & Nicolich, 1987), age-related declines have been seen in accuracy for posed emotional expression in the facial channel (Levenson et al., 1991; Malatesta, Izard, Culver, & Nicolich, 1987; Yecker, Borod, Moreno, Welkowitz, & Alpert, 2000). In studies measuring intensity of emotional expression, no changes have been seen with age for posed facial (Moreno, Borod, Welkowitz, & Alpert, 1990; Yecker et al., 1998). One study (Malatesta-Magai, Jonas, Shepard, & Culver, 1992) found that older adults displayed more intense emotional facial expressions relative to younger adults in a spontaneous condition. (For a review of communication changes with age, see Borod, 2000.)

A recent investigation of lexical expression used a semantic fluency task, comparing three age groups of adults on word production for emotional and nonemotional categories (Tabert et al., 2000). No overall differences in production or errors were seen as a function of age. However, a qualitative evaluation of error-types, intensity, and accuracy ratings showed that older males produced more perseverative errors than younger males, females produced less accurate output as a function of age, and negative words were rated more accurately and intensely than positive words.

<u>The Valence Hypothesis</u>

The valence hypothesis originated with the observation of a tendency for people with LH brain damage to display a preponderance of negative affect, a condition that came to be known as the "catastrophic" reaction (Alford, 1933; Goldstein, 1939). In contrast, patients with right brain damage were seen to exhibit euphoria, or indifference (McGlynn & Schachter, 1989). Bear and Fedio (1977) found different emotional profiles in epileptic patients.

depending on the foci of their seizures. Those with left-sided foci showed more positive affect, while those with right-sided foci displayed a predominance of negative affect. The Wada technique, in which sodium amytal is injected into one of the carotid arteries disabling one hemisphere, is used to test for lateralization of language functions prior to neurosurgery. Using this technique, some authors have shown a mood by hemisphere interaction (Rossi & Rosadini, 1967; Lee, Loring, Meador, & Brooks, 1990), while others have not (Milner, 1967; 1974).

Two versions of the valence hypothesis have been proposed. One assumes left hemisphere mediation of positive emotion and right hemisphere mediation of negative emotion across communication modes of perception and expression (e.g., Sackeim et al., 1982; Silberman & Weingartner, 1986). The other assumes left hemisphere superiority for mediation of expression and experience of positive emotion, right hemisphere superiority for mediation of expression and experience of negative emotion, and right hemisphere dominance for the perception (or appreciation) of emotion for both positive and negative stimuli (Davidson, 1984).

Some behavioral procedures have supported hemisphere-specific valence asymmetries (Suberi & McKeever, 1977; for review, see Ley & Bryden, 1982). Findings from tachistoscopic studies have offered support for a left visual field advantage for negative stimuli, with no advantage (Harrison & Gorelczenko, 1990; Moretti et al., 1996) or a right-hemifield advantage (Burton & Levy, 1989) for positive stimuli. Best, Womer, and Queen (1994) found differential hemispheric advantages according to valence, with negative facial expressions judged as more intense when presented to the left visual field. They did not find hemispheric differences for judgment of positive emotional expression. Burton and Levy (1989) found differential priming effects according to valence among their female subjects. Faster responses were observed to RVF presentation of printed words primed with an emotional face when the facial expression was positive. When presented to the right hemisphere, reaction times were differentially improved when negative priming was employed. Van Strien & Morpugo (1992) and Van Strien & Heijt (1995) also found differential priming effects in a tachistoscopic task. When negatively valenced words were presented to the RH prior to a letter recognition task, performance improved. Similar gains were seen when positive words were presented to the LH. Other studies partially support the valence hypothesis by finding that one hemisphere was enhanced in the expected direction (i.e., increased RH effect by priming with negatively-valenced words, Richards, French, & Dowd, 1995; enhancement of LH superiority through priming with positive words, Zieher & Zenhauser, 1984; Wexler, Schwartz, Warrenburg, Servis, & Tarlatzis, 1986).

EEG asymmetries showing greater hemispheric arousal depending on the emotional valence of hypnotically induced memories were found by Karlin, Weinapple, Rochford and Goldstein (1979). Schwartz, Ahern, & Brown (1979) found that more lateral eye movements were directed to the left and less to the right in response to negative questions regardless of the type (verbal/visual) of question asked.

Other findings fail to support the valence hypothesis. Bloom, Borod, Obler, and Gerstman (1992), and Bloom, Borod, Obler, and Koff (1990) found no hemispheric valence differences in lexical emotional processing. Others found an LH advantage for processing of both emotional and nonemotional words (Strauss, 1983; Eviatar & Zaidel, 1991), and a RH-left hemi-face superiority for facial expressiveness regardless of valence (Borod, Kent, Koff, Martin, & Alpert, 1988). Many studies of valence and laterality are more supportive of the RH hypothesis (Bowers et al., 1993; Bryden & Ley, 1983; Brody et al., 1987).

Age and valence interactions have been found such that older individuals tend to perceive negative stimuli as more intense (Malatesta et al., 1987). In contrast, some workers have found that older adults are less accurate at identifying negative emotional stimuli (Brosgole & Weisman, 1995; McDowell, Harrison, & Demaree, 1994). In a study investigating the decoding of body movements and gestures (Montepare, Koff, Zaitchik, & Albert, 1999), older (65-89) subjects were less accurate at identifying emotions overall, and this was especially true for negative emotions. Their errors were more likely to reflect neutral misidentifications. The findings of increased errors for negatively valenced items may have something to do with task complexity. If discrete negative emotions are more difficult to differentiate than positive emotions, the added task complexity may have a significant impact on the older individuals' performance. Research in the area of emotional experience (e.g., Carstensen, 1992) has established that older people tend to experience negative emotions less frequently. Carstensen interprets this as increased selectivity (maximizing probability of positive outcomes of social contact, while minimizing negative outcomes). Perhaps this adaptive tendency affects older people's ability to accurately decode negative expressions due to motivational influences.

Conclusions

The general consensus among theorists regarding emotion and adult development is that as individuals age, there is an increase in emotional regulation and in the significance of emotional interaction for adaptive functioning. There is convincing evidence for the existence of a nonverbal affect lexicon analogous to the verbal lexicon regulated by the left hemisphere. The literature supports RH superiority for emotional processing, at least for facial and prosodic perception, while findings for the perception of verbal emotional stimuli are less clear (for review, see Borod, Zgaljardic, Tabert, & Koff, in press).

While isolated single-case studies have revealed separation of the facial and vocal communication channels, nearly all group studies reviewed, in both normal and neurological populations, found at least moderate associations between these channels. For studies investigating three channels (i.e., vocal, facial and lexical), findings have been equivocal.

Finally, the little research that has been done on aging and emotional communication points to age-related changes in perception and posed expression, with stability of spontaneous expression over the age span (for review, see Borod, 2000). Support for the valence hypothesis has been inconclusive. A handful of studies have found differences between older and younger individuals in the judgment of intensity and identification of negative stimuli.

## Gender Differences

### Gender Differences in Cognitive Abilities

Schaie (1994) reports consistent gender differences across various data sets, with men showing superiority in spatial orientation and number, while women are better at tasks reflecting the construct variables of inductive reasoning and verbal meaning. These results are consistent with many years of past research (Deaux, 1984; Maccoby & Jacklin, 1974). Women generally outperform men on tasks with high verbal loadings and psychomotor speed and accuracy, whereas men outperform women on tests of spatial abilities and mathematics (Cohen & Wilkie, 1979; Feingold, 1988; Kaufman, Kaufman-Packer, McLean & Reynolds, 1991). Findings have been mixed on visuospatial analysis and synthesis (Kaufman et al., 1991). Meta-analyses have shown decreases in gender differences in mathematics (Friedman, 1989), however, some consistent gender differences continue to appear, such as a male advantage for mechanical and visual-spatial ability and superiority in psychomotor speed, spelling, and language ability for women (Feingold, 1988; Kaufman, McLean, & Reynolds, 1988). In addition, fairly consistent trends have been seen for men to show more pronounced lateralization effects (Filskov & Catanese, 1986; McGlone, 1977).

A study by Burton, Ryan, Paolo, and Mittenberg (1994) revealed that a factor analysis performed on the WAIS-R data of older adults produced a gender effect. Picture Arrangement loaded on the Performance factor only for men, and on both the Verbal and Performance factors in women. This implies that women use verbal strategies in the execution of this task, whereas men do not. If this is so, possible explanations are: male superiority in visuospatial ability (they do not need to utilize language to efficiently perform the task) or the female tendency towards more interhemispheric communication (they use language to solve this type of problem due to more efficient bilateral connections). This tendency has been documented through the use of functional imaging and neuroanatomical studies. Women seem to use both hemispheres to a greater degree than men for the processing of language (Shaywitz, et al., 1995). The corpus callosum has been found to be proportionally larger in volume in women than men (deLacoste-Utamsing & Holloway, 1982).

Gender Differences in Aging Patterns

When looking at the aging patterns of men and women in the framework of the Gf/Gc split, Schaie (1994) found trends that suggest that women may decline earlier on fluid abilities whereas men do so on crystallized abilities. By contrast, the findings of Kaufman et al. (1988), comparing gender differences on the WAIS-R standardization sample, do not support Schaie's results. Kaufman is skeptical of Schaie's conclusions, citing his failure to apply adequate statistical tests to the data (p.800).

Gender Differences in Emotional Processing

In a meta-analysis of 75 studies comparing men and women on the decoding of nonverbal communication, Hall (1978) found that a predominance of the studies showed a female advantage. The magnitude of the effect was significantly larger for studies in which the visual and auditory modalities were both assessed than those in which only one channel was investigated. Hall indicated that the larger number of instruments used in the dual-modality studies allowed for greater reliability, and, therefore, larger effects. In addition, she stressed that the visual/auditory studies are more ecologically valid. Hall offered both environmental and genetic interpretations of her results, suggesting that social influences motivate women to become better decoders, and that women as mothers develop an acute sensitivity to nonverbal cues as a way of enhancing the survival of offspring.

Other reports in the literature are also supportive of a gender effect, which favors women in the processing of emotional material (Buck, Miller & Caul, 1974; Duda & Brown, 1985; Lafrance & Banaji, 1992). In a study measuring EEG in response to positive sounds, women evidenced heightened activity compared to men (Meyers & Smith, 1987). Grunwald et al., (1999) found significant gender differences when examining lexical emotional perception, such that women rated emotional and nonemotional stimuli more accurately than men and rated emotional stimuli more intensely. Erwin et al. (1992) found that when encoders and decoders were matched for gender, men were more sensitive to sadness in same-sexed stimuli. However, when mixed gender stimulus faces were used, decoding of emotional signals varied according to gender congruence between encoder and decoder. While women were more sensitive to sad emotion in male faces than in female faces, men were adept at emotional recognition when the object of scrutiny was another man's face, but were significantly worse at detecting sadness in a woman's face.

Conclusions

In summary, though the gender gap may be closing, most studies continue to support gender differences with respect to mathematical and visuospatial abilities and tasks requiring verbal ability, psychomotor speed and accuracy. Men usually show superiority on the former two skills, while women tend to be more proficient at the latter. In addition, there is support for a greater degree of lateralization in men, and for a proclivity in women towards greater relative use of verbal strategies, even when confronted with standard visuospatial tasks. Evidence for differential aging patterns of Gf versus Gc in men and women has not been conclusive. In addition, the literature suggests that there are gender differences in emotional processing, such that women are more adept than men at decoding and communicating emotional stimuli.

## Purpose of the Study and Hypotheses

The purpose of this study is to (a.) clarify whether there is a single or multiple emotional processor(s) underlying facial, prosodic/vocal, and lexical/verbal emotional perception by examining the association among the three communication channels, and, b.) to establish the aging pattern of emotional perception in relationship to other nonemotional cognitive variables. Regardless of whether the hypotheses herein are supported or not, this research will be informative and important because emotional processes have not been directly examined from this more holistic perspective, where they are embedded in classical aging theory. The work of Carstensen and its relationship to Baltes' theory of selective optimization (see "Theories of Emotional Development" section) exemplifies the manner in which a theory which has previously been applied to cognitive aging research can be generalized to the socioemotional domain. Hopefully, the present study will provide additional support for the assertion that aging is a multidimensional phenomenon and will clarify the course of a more cognitive aspect of emotional functioning, emotional perception, over the age span.

Evidence for the significant influence of cohort effects can be found in the cognitive aging literature and in the literature on emotional development. For example, Schaie (1996) has noted marked generational shifts in levels of performance on tests of mental abilities, with later-born cohorts showing advantages over earlier-born cohorts at the same ages. Some factors contributing to these differences include improvements in educational opportunities and lifestyles, nutrition and medical care. In the research on emotional functioning, where longitudinal data is sparse, cohort effects have also been detected (e.g., on attachment style possibly due to changes in parenting techniques, Pinkham, 1996). Cohort effects are a methodological problem inherent in cross-sectional analysis, and, thus, must be considered when interpreting the results of this study.

## Primary Hypotheses

### Hypothesis I

Hypothesis I predicts that emotional tasks will be highly associated across communication channels. An exploratory factor analysis including the emotional and nonemotional tasks will be used initially to inspect the factor structure of the battery. It is expected to reveal a single emotional factor common to the three channels as measured by the emotional perception tasks.

### Hypothesis II

Subsequent to testing Hypothesis I, confirmatory factor analyses (CFA) will be used to test the hypothesized measurement model. The first measurement model will hypothesize emotional perception as a part of crystallized intelligence. An alternate model hypothesizes emotional perception as a separate factor from crystallized intelligence. Structural equation modeling techniques will be used to examine the relationships and strengths of the linkages among the factors as well as the effects of age (see "Data Analysis" section below for details).

Correlations will also be used to examine the aging patterns of emotional tasks, while controlling for nonemotional cognitive variables. The magnitude of the correlation coefficients for age with crystallized and fluid measures will be compared to the partial correlation coefficients for emotional perception measures when nonemotional perceptual variables are accounted for. The order of the strength of the age correlations, from highest to lowest, is expected to be as follows: fluid, emotional, and then crystallized. As opposed to linear decline, as is seen in fluid abilities, improvement and stabilization are expected well into adulthood on emotional perception tasks.

Finally, a third approach will be used to examine age differences among the tasks employed. For all relevant emotional variables, analyses of covariance (ANCOVAs) will be performed comparing scores of older versus younger subjects while controlling for nonemotional perception. The groups will be divided in two ways. First, the sample will be divided according to the median split. The younger group (n=50) will contain all subjects less than or equal to 48 years of age, while the older group (n=50) will contain subjects 49 years of age and older). Secondly, to examine whether differences are more likely to occur only among the oldest subjects, the sample will be divided into subjects below 70 years of age (n=82) and 70 years of age and above (n=18).

## Secondary Hypotheses

### The Common Cause Hypothesis

Age effects on emotional processing are expected to be mediated by hearing acuity as would be predicted by Baltes and Lindenberger's (1997; Lindenberger & Baltes, 1994) common cause hypothesis (see pages 16-17 above). This would extend the findings of age-associated links between sensory and intellectual functioning to include emotional perception. This hypothesis will be examined by adding hearing to the regression equations before and after age to determine the extent to which hearing threshold mediates age effects.

Effects of Gender on Decoding of Emotional Stimuli

Females are expected to perform significantly better than males on emotional perception tasks. This superiority is expected to be more robust for negatively relative to positively valenced items due to increased complexity of negative items and ecological factors.

Differential Relationships for Valence as a Function of Age

An age by valence interaction is expected, such that negative age correlations will be more robust for negatively relative to positively valenced items. Due to past findings, increased complexity of negative items, ecological considerations, and possible motivational influences, older individuals are expected to perform relatively worse on negative items than on positive items when compared to younger individuals.

# Methodology

## Subject Characteristics

Healthy young and middle-aged subjects were recruited from hospitals and community centers in New York City, while healthy geriatric subjects were drawn from senior citizens' organizations in the metropolitan area. One hundred subjects, 45 male and 55 female, participated in the study. Subjects ranged in age from 20 through 80, and the ethnic breakdown was 57% Caucasian, 26% African American, 11% Hispanic, and 6 % Asian (see Table 1 for gender and ethnic breakdowns by decade). All subjects were right-handed with no history of conversion from left-handedness (all subjects were screened by self-report and using the Coren, Porac, and Duncan [1979] lateral preference inventory). In addition, all subjects were either native English speakers or had achieved mastery of the English language by the age of seven. No one with a history of substance abuse, neurological disorder, or psychiatric disorder was included in the study.

## Procedures

The description of procedures detailed below is adapted from Borod, Cicero, et al. (1998) for this particular study.

### Screening Measures

All subjects underwent a series of screening procedures to ensure a minimum level of sensory, cognitive, and emotional functioning. All participants were initially screened for demographic and medical background using a comprehensive questionnaire (Borod, Welkowitz, & Obler, 1992). The Schedule for Affective Disorders and Schizophrenia-Lifetime Version (SADS-L; Endicott & Spitzer, 1978), and the Beck Depression

Table 1.
Gender and Ethnic Breakdown of Participants by Decade.

| Decade | Gender | | Ethnicity | | | |
|---|---|---|---|---|---|---|
| | Men | Women | Caucasian | African American | Hispanic | Asian |
| 20 – 29 (N = 17) | 7 (41.2%) | 10 (58.8%) | 9 (52.9%) | 4 (23.5%) | 2 (11.8%) | 2 (11.8%) |
| 30 – 39 (N = 19) | 9 (47.4%) | 10 (52.6%) | 9 (47.4%) | 5 (26.3%) | 3 (15.8%) | 2 (10.5%) |
| 40 – 49 (N = 16) | 5 (31.2%) | 11 (68.8%) | 7 (43.8%) | 5 (31.2%) | 4 (25%) | 0 |
| 50 – 59 (N = 15) | 6 (40%) | 9 (60%) | 10 (66.7%) | 4 (26.6%) | 0 | 1 (6.7%) |
| 60 – 69 (N = 15) | 9 (60%) | 6 (40%) | 10 (66.7%) | 5 (33.3%) | 0 | 0 |
| 70 – 80 (N = 18) | 9 (50%) | 9 (50%) | 12 (66.7%) | 3 (16.7%) | 2 (11.1%) | 1 (5.5%) |
| Total | 45 (45%) | 55 (55%) | 57 (57%) | 26 (26%) | 11 (11%) | 6 (6%) |

Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) were used to screen for psychiatric history. Anyone with history of substance abuse or psychiatric disorder (i.e., fitting DSM-IV criteria) was excluded. The Commands, Complex Ideational Material, and Reading Sentences and Paragraphs subtests of the Boston Diagnostic Aphasia Examination (BDAE; Goodglass & Kaplan, 1983) were used to assess auditory and reading comprehension. Basic attention and memory capacities were tested using the Attention and Memory subtests of the Mattis Dementia Rating Scale (DRS; Mattis, 1988), and Logical Memory I and II subscales of the Wechsler Memory Scale-Revised (WMS-R; Wechsler, 1987). A brief mental status screening test developed by Katzman, Brown, Fuld, et al. (1983), which takes some items from the Blessed Mental Status Test (Blessed, Tomlinson, & Roth, 1968) and others from the Mental Status Questionnaire (Kahn & Miller, 1978), was used to screen for dementia. The Mesulam cancellation tasks (Mesulam, 1985), both verbal and nonverbal, were used as a qualitative screening for visual inattention. The Benton Visual Form Discrimination Test (VFDT; Benton, de S Hamsher, Varney, & Spreen, 1983) was used to detect deficits in basic visual perception, while the Phoneme Discrimination Test (Benton et. al, 1983) assessed auditory perception. Pure Tone Threshold (Beltone Owner's Manual, 1987) was used to screen for significant hearing loss.

General cognitive ability was assessed with the Information and Block Design subtests of the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981). For cutoff scores on all screening measures, see Table 2.

Table 2.

Cutoff Scores for Screening Measures.

| Measure | Cutoff | Measure | Cutoff |
|---|---|---|---|
| BDAE[1] Commands | 3 of 6 points on items 1-3 | WMS – R[2] Logical Memory I & II | 16th %ile for age group |
| BDAE Complex Ideational Material | 4 of 6 points on items 1-6 | Benton Visual Form Discrimination Test | 26 of 32 points |
| BDAE Reading Sentences And Paragraphs | 5 of 10 points | Benton Phoneme Discrimination Test | 19 of 30 points |
| Mattis Dementia Rating Scale – Memory | 22 of 25 points | WAIS – R[3] Information | ACSS[4] – 7 or above |
| Mattis Dementia Rating Scale – Attention | 34 of 37 points | WAIS – R Block Design | ACSS – 7 or above |
| Blessed Information. Orientation. Concentration. And Memory | < 9 errors | Pure Tone Threshold | 500 hz <45[5]<br>1000 hz < 45<br>2000hz < 45 |

[1]BDAE = Boston Diagnostic Aphasia Examination

[2]WMS –R = Wechsler Memory Scale – Revised

[3]WAIS – R = Wechsler Adult Intelligence Scale – Revised

[4]Age-Corrected Scaled Score

[5]Decibels: Mean of right and left ear

Emotional Measures

All subjects were tested on perceptual emotional tasks, examining facial prosodic, and lexical channels, with analogous paradigms (identification, discrimination) and similar difficulty level across channels. (The tasks are included in the NYEB developed by Borod, Welkowitz, & Obler, 1992). Each perception task included three positive (happiness, interest, and pleasant surprise) and five negative (sadness, fear, anger, disgust, and unpleasant surprise) emotions. These emotions were derived from those considered primary by Ekman and Friesen (1975) and Izard (1977); pleasant and unpleasant surprise were included to further study valence. There were two equivalent forms for the discrimination tasks (28 pairs each--14 different trials and 14 same trials) and two random orders for the identification tasks. (For a detailed description of task development, see Borod et al., 1998.)

Facial Perception. Facial stimuli consisted of Ekman and Friesen (1976) slides depicting happiness, sadness, fear, anger, and disgust, and new slides created for pleasant surprise, unpleasant surprise, and interest (Borod, Welkowitz, & Obler, 1992). For discrimination, two slides of different posers with the same or different emotional expressions were presented on a Caramate projector, and participants indicated the same or different emotion orally or by pointing to a printed card. For each pair, each slide was presented for 5 s, with a 1-s interstimulus interval (ISI). There were two equivalent stimulus sets (A,B), each consisting of 28 pairs (14 male and 14 female) and three practice trials. The 56 pairs comprising the stimulus set contained 28 different trials (each of the eight emotions paired with every other emotion) and 28 same trials (each emotion paired with the same emotion three or four times). For identification, slides of different emotional expressions were presented by Caramate, and participants identified the emotion portrayed. Maximum slide exposure was 20 s, and participants named or pointed to the correct response on a 8-1/2 x 11 in (21.6 x 27.9 cm) card, which was centrally placed and vertically listed all eight emotions. Practice was given with emotion labels to ensure the participants' familiarity with their meaning. Four response cards were randomized within and across participants. For the first trial, the examiner read choices aloud as the participant scanned down the card. There were 32 trials (16 male and 16 female posers, balanced across emotions), each emotion appearing four times, and 2 practice trials. There were two randomized stimulus sets for the identification task.

Prosodic Perception. Prosodic stimuli were sentences spoken by actors or actresses in the eight emotional tones. Four neutral sentences were used, chosen for similar grammar, rhythm, and length; comprehensibility; and low emotionality ratings (e.g., "They found it in the room."). For discrimination, two sentences intoned by the same poser with the same or different emotional tone were presented on audiotape. Participants indicated "same" or "different" (see earlier description). For each pair, sentences were presented in normal cadence (about 3 s), with a 1-s ISI. There were two equivalent stimulus sets (A,B), each consisting of 28 gender-balanced pairs. The 56 pairs comprising the entire set contained 28 different trials and 28 same trials, using pairing procedures described previously; there were 3 practice trials in each set. For identification, recordings of emotionally intoned sentences were presented in normal cadence. Participants identified the emotion portrayed from choices on the 8-1/2 x 11 in. (21.6 x 27.9 cm) response cards described earlier. There were 24 gender-balanced trials, each emotion appearing three times, and 2 practice trials. There were two randomized stimulus sets.

Lexical Perception. To develop lexical tasks, 200 words and 100 sentences were generated and then rated by normal participants for category accuracy (eight choices) and emotionality (6-point scale from 0 [not at all] to 5 [extremely]). Item selection was based on accuracy >50% (overall M = 80%), emotionality >2.5, nonredundancy in content and syntax, and clarity/comprehensibility. For discrimination, two printed words, one above the other, representing the same or different emotion, were presented in the center of a white sheet of 8-1/2 x 11 in. (21.6 x 27.9 cm) paper for no more than 20 s. Participants indicated the same or different emotion. There were two stimulus sets (A,B), each consisting of 28 pairs, and three practice trials. An example of a same trial is "grief, regret" pertaining to "sadness," and an example of a different trial is "loving, stench" pertaining to "happiness" and "disgust," respectively. The 56 pairs comprising the entire set contained 28 different trials and 28 same trials, using the pairing procedures described for face. There were two identification tasks. For word identification, three-word vertical clusters (each word representing the same emotion) were presented in the center of an 8-1/2 x 11 in. (21.6 x 27.9 cm) sheet of paper for a maximum of 20 s. Participants indicated (from the eight-option card) the emotion best represented by each cluster. There were 24 test trials (8 [emotions] x 3 [clusters]) and 2 practice trials. There were two randomized stimulus sets. An example of a three-word vertical cluster is "putrid, slime, stench" for "disgust." For sentence identification, 24 different seven-word sentences, displayed in the center of an 8-1/2 x 11 in. (21.6 x 27.9 cm) piece of paper, were presented, and participants indicated the emotion represented. An example of a sentence is "He felt the urge to hit someone," for the anger category. There were 24 test trials (8 [emotions] x 3 [sentences]) and 2 practice trials. There were two randomized stimulus sets.

Nonemotional Measures

Tests administered to achieve a more complete assessment of verbal abilities included a phonemic Verbal Fluency task (i.e., F-A-S; Benton & Hamsher, 1989) and the Mill Hill Vocabulary Test (Raven, 1982). For Verbal Fluency, subjects were given one minute to produce as many words as possible beginning with a specific letter; three trials were administered. The Mill Hill is a 20-item, paper-and-pencil, multiple choice vocabulary test. In addition to these tasks, all participants were tested on nonemotional tasks that control for cognitive and perceptual factors that could potentially confound performance on the various experimental tasks. Within the facial channel, the Facial Recognition Test (Benton et al., 1983) was used to control for nonemotional facial recognition. The Visual Matrices Test (Borod et al., 1993) and the VFDT (Benton et al.) were used to control for visuospatial perception and discrimination. Within the prosodic channel, the Phoneme Discrimination Test was used to control for auditory discrimination. To control for nonemotional aspects of intonation, the Intonation Contours Perception task (Borod, Welkowitz, & Obler, 1992) was used. This task is comprised of four nonsense syllable strings (e.g., pa-da-ka), with three types of intonational stress (i.e., declarative, interrogative, and emphatic; Blumstein & Cooper, 1974); each of the 12 items was presented twice. Participants were required to identify 24 tape-recorded items via a multiple-choice response card that contained a drawing, a verbal label, and a punctuational symbol for each contour. Within the lexical channel, nonemotional lexical control tasks (Borod, Welkowitz, Obler, Whalen, et al., 1992) were used; these tasks are analogous to the emotional lexical experimental tasks in terms of task structure, instructions, and degree of difficulty. The eight nonemotional categories, classified as characteristics of people, are body type, complexion, hair type, intelligence, personality, teeth, vision, and voice type. These nonemotional tasks included a word identification task (e.g., "yellow, crooked, crown" for the teeth category), a sentence identification task (e.g., "He watched the concert until the end" for the vision category), and a word discrimination task (e.g., "scarred, light" for a same item pertaining to "complexion," and "tall, wise" for a different item pertaining to "body type" and "intelligence," respectively). There were two randomized stimulus sets for each of the nonemotional tasks. The overall mean category accuracy rating for these nonemotional tasks was 80.5% (compared to 79.9% for the emotional tasks), and the overall emotionality rating (on a 6-point scale from 0 [not at all] to 5 [extremely]) was 1.25 (compared to 3.32 for the emotional tasks). Ratings were made by healthy adults. (For sample means and standard deviations by decade for all measures, see Tables 3-6.)

Table 3.



Sample Characteristics for Demographics and Screening Measures.

| VARIABLE | Age 20-29 (n = 17) | Age 30-39 (n = 19) | Age 40-49 (n = 16) | Age 50-59 (n = 15) | Age 60-69 (n = 15) | Age 70-80 (n = 18) |
|---|---|---|---|---|---|---|
| Age in Years (20–80) | 24.7 (2.9)[1] | 34.0 (2.9) | 45.4 (3.0) | 54.3 (2.8) | 62.5 (2.5) | 74.4 (3.4) |
| Education in Years (1-22) | 15.4 (1.2) | 15.3 (3.2) | 13.8 (1.6) | 14.5 (2.3) | 14.7 (2.9) | 15.1 (2.3) |
| Hollingshead Scale (1-9) | 6.7 (1.9) | 6.4 (1.6) | 6.0 (1.9) | 6.3 (1.4) | 6.6 (1.4) | 6.8 (1.0) |
| Pure Tone Threshold[2] (-10–45) | 16.6 (11.4) | 16.2 (7.6) | 18.0 (6.3) | 21.0 (8.3) | 20.4 (5.7) n = 14[3] | 25.7 (8.3) |
| Pure Tone Threshold[4] (-10–45) | 10.8 (12.8) | 7.5 (6.0) | 14.2 (5.3) | 15.8 (8.1) | 14.9 (7.8) n = 14 | 22.7 (12.1) |
| Pure Tone Threshold[5] (-10–45) | 8.8 (13.4) | 4.8 (6.5) | 8.4 (5.5) | 17 (12.0) | 14.3 (9.9) n = 14 | 23.9 (13.3) |
| Pure Tone Threshold[6] (-10–45) | 12.1 (12.1) | 9.5 (5.6) | 13.5 (4.2) | 18.0 (8.4) | 16.5 (6.6) n = 14 | 24.1 (10.4) |
| BDAE[7] Commands (0-15) | 14.8 (0.8) | 15.0 (0.0) | 15.0 (0.0) | 14.9 (0.4) | 14.9 (0.4) | 14.9 (0.3) |
| BDAE Complex IM[8] (0-12) | 10.8 (1.3) | 11.1 (1.2) | 11.4 (0.9) | 11.1 (1.0) | 11.2 (0.9) | 11.0 (1.0) |
| BDAE Reading (0-10) | 9.5 (0.9) | 9.5 (0.5) | 9.4 (1.0) | 9.7 (0.6) | 9.7 (0.8) | 9.8 (0.6) |

[1] Mean (Standard Deviation)
[2] R/L mean at 500 hz.
[3] *n* is given only when different from number in top cell
[4] R/L mean at 1000 hz.
[5] R/L mean at 2000 hz.
[6] Mean of three frequencies
[7] BDAE=Boston Diagnostic Aphasia Examination
[8] IM=Ideational Material

Table 4.
Sample Characteristics for Screening and Cognitive Measures.

| VARIABLE | Age 20-29 (n = 17) | Age 30-39 (n = 19) | Age 40-49 (n = 16) | Age 50-59 (n = 17) | Age 60-69 (n = 15) | Age 70-80 (n = 18) |
|---|---|---|---|---|---|---|
| Mattis DRS[1] Attention (0-37) | 36.4 (0.6)[2] | 36.2 (1.1) | 36.8 (0.5) | 36.1 (1.2) | 36.0 (1.1) | 36.1 (0.8) |
| Mattis DRS Memory (0-25) | 24.5 (0.7) | 24.6 (0.8) | 24.1 (1.1) | 24.5 (0.9) | 24.6 (0.7) | 24.3 (1.0) |
| Blessed IOMC[3] (0-24) | | | | | 0.9 (1.2) n = 7[4] | 2.7 (2.8) n = 15 |
| Logical Memory I[5] (0-50) | 28.4 (6.7) | 25.5 (7.0) | 24.3 (6.0) | 26.6 (8.3) | 25.1 (5.2) | 20.7 (4.6) |
| Logical Memory II[5] (0-50) | 24.9 (6.6) | 22.5 (6.3) | 20.6 (6.3) | 23.1 (7.2) | 21.2 (5.3) | 15.6 (5.9) |
| Benton Visual Form DT[6] (0-32) | 29.4 (2.4) | 30.8 (1.2) | 29.7 (3.3) | 29.2 (3.5) | 30.1 (3.0) | 29.2 (2.6) |
| Phoneme DT[6] (0-30) | 28.7 (1.2) | 28.2 (1.8) | 28.1 (1.3) | 27.5 (2.2) | 27.9 (1.7) | 26.6 (1.7) |
| WAIS-R[7] Information (0-29) | 21.2 (6.0) | 20.3 (5.7) | 22.6 (4.5) | 22.8 (4.5) | 22.5 (4.8) | 22.5 (4.7) |
| WAIS-R Block Design (0-51) | 36.9 (8.4) | 29.8 (12.0) | 30.1 (8.5) | 25.8 (9.9) | 22.9 (7.4) | 17.8 (9.1) |
| Cancellation[8] | 114.3 (10.5) | 130.5 (12.1) | 99.2 (16.9) | 103.6 (9.7) | 92.1 (18.6) | 89.2 (18.5) |

[1] DRS=Dementia Rating Scale
[2] Mean (Standard Deviation)
[3] IOMC=Information, Orientation, Memory, Concentration (only administered to subjects >60)
[4] *n* is given only when different from number in top cell
[5] from Wechsler Memory Scale – Revised
[6] DT = Discrimination Test
[7] Wechsler Adult Intelligence Scale – Revised
[8] Mean inverted completion time score of two cancellation tasks, figures and letters

Table 5.

Sample Characteristics for Nonemotional Cognitive Measures.

| VARIABLE | Age 20-29 (n = 17) | Age 30-39 (n = 19) | Age 40-49 (n = 16) | Age 50-59 (n = 15) | Age 60-69 (n = 15) | Age 70-80 (n = 18) |
|---|---|---|---|---|---|---|
| Verbal Fluency[1] | 49.2 (13.4)[2] | 49.1 (13.0) | 46.1 (11.0) | 45.9 (15.6) | 47.3 (10.0) | 39.7 (15.2) |
| Mill Hill Vocabulary (0-20) | 13.3 (1.9) n = 9[3] | 13.9 (3.0) n = 16 | 15.0 (2.1) n = 12 | 15.1 (3.8) n = 12 | 16.7 (1.8) n = 11 | 15.8(3.1) n = 17 |
| Intonation Contours (0-24) | 22.0 (2.7) | 21.0 (3.5) | 21.6 (1.6) | 22.1 (1.8) | 20.3 (3.3) | 21.2 (2.8) |
| Visual Matrices (0-24) | 23.5 (1.0) | 23.4 (1.1) | 23.8 (0.6) | 23.0 (1.6) | 23.7 (0.6) | 22.7 (1.5) |
| Benton Facial Recognition (0-54) | 48.9 (2.4) | 47.0 (3.5) | 47.3 (4.0) | 46.9 (4.6) | 47.9 (4.3) | 46.6 (5.0) |
| Nonemotional Sentence ID[4] (0-24) | 19.7 (2.1) | 19.4 (4.4) | 19.7 (2.1) | 18.5 (2.4) | 19.5 (2.5) | 16.7 (3.8) |
| Nonemotional Word ID (0-24) | 23.2 (0.1) | 22.8 (1.4) | 23.1 (1.4) | 22.9 (1.6) | 22.9 (1.1) | 22.1 (1.8) |
| Nonemotional Word Disc[5] 1 (0-28) | 23.0 (2.6) n = 7 | 22.2 (2.6) n = 9 | 21.9 (1.9) n = 8 | 22.1 (2.1) n = 9 | 22.2 (2.0) n = 8 | 19.4 (2.8) n = 7 |
| Nonemotional Word Disc 2 (0-28) | 23.7 (1.8) n = 10 | 22.8 (2.9) n = 10 | 23.5 (1.6) n = 8 | 21.5 (1.8) n = 6 | 22.0 (3.9) n = 7 | 21.3 (2.8) n = 11 |

[1] Phoneme production with letters "f-a-s"
[2] Mean (standard deviation)
[3] *n* is given only when different than number in top cell
[4] ID=*identification*
[5] Disc=discrimination

Table 6.

Sample Characteristics for Emotional Measures.

| VARIABLE | Age 20-29 (n = 17) | Age 30-39 (n = 19) | Age 40-49 (n = 16) | Age 50-59 (n = 15) | Age 60-69 (n = 15) | Age 70-80 (n = 18) |
|---|---|---|---|---|---|---|
| Emotional Sentence ID[1] (0-24) | 20.9 (2.6)[2] | 19.4 (2.7) | 19.6 (2.8) | 18.7 (2.8) | 19.6 (2.8) | 16.4 (3.6) |
| Emotional Word ID (0-24) | 22.7 (2.0) | 21.8 (2.3) | 22.1 (1.5) | 21.2 (3.0) | 22.1 (1.6) | 19.1 (3.2) |
| Emotional Word Disc[3] 1 (0-28) | 25.8 (2.5) n = 10[4] | 24.6 (3.0) n = 10 | 24.4 (2.3) n = 8 | 23.0 (3.4) n = 6 | 23.3 (1.7) n = 7 | 22.7 (2.7) n = 11 |
| Emotional Word Disc 2 (0-28) | 22.4 (3.3) n = 7 | 21.3 (2.5) n = 9 | 22.4 (2.5) n = 8 | 24.1 (2.9) n = 9 | 23.8 (2.6) n = 8 | 20.7 (3.6) n = 7 |
| Facial Identification (0-32) | 26.5 (2.4) | 24.1 (3.0) | 23.6 (3.1) | 23.5 (3.3) | 22.6 (3.4) | 20.2 (3.2) |
| Facial Disc 1 (0-28) | 22.3 (1.9) n = 8 | 23.1 (1.8) n = 9 | 24.1 (2.3) n = 7 | 22.9 (1.6) n = 7 | 22.2 (2.0) n = 9 | 20.6 (2.1) n = 8 |
| Facial Disc 2 (0-28) | 24.6 (1.0) n = 9 | 24.6 (1.2) n = 9 | 24.6 (1.7) n = 9 | 22.5 (3.7) n = 8 | 21.7 (1.2) n = 6 | 22.9 (2.2) n = 10 |
| Prosodic Identification (0-24) | 17.1 (2.5) | 15.4 (2.7) | 15.0 (2.7) | 13.5 (4.3) | 13.4 (3.3) | 9.2 (4.0) |
| Prosodic Disc 1 (0-28) | 27.4 (0.7) n = 9 | 27.2 (1.0) n = 10 | 27.0 (0.9) n = 9 | 26.9 (0.6) n = 8 | 26.5 (1.9) n = 6 | 26.6 (0.8) n = 10 |
| Prosodic Disc 2 (0-28) | 25.8 (0.7) n = 8 | 25.8 (0.7) n = 9 | 25.7 (1.0) n = 7 | 25.9 (1.5) n = 7 | 24.7 (2.1) n = 9 | 23.9 (1.7) n = 8 |

[1] ID=identification
[2] Mean (Standard Deviation)
[3] Disc=discrimination
[4] *n* is shown only when different than number in top cell

## Data Analysis

Intraclass consistency correlations were computed for the seven emotional test instruments using Cronbach's alpha (see Borod, Pick, Hall, et al., 2000). Internal consistency measures ranged from .50 to .80 for all of the identification tasks, while for one form of each of the prosodic, facial and nonemotional lexical discrimination tasks, values were below .50. Though all discrimination tasks were included in independent group analyses, they were not used for the latent variable analyses[1] or correlational analyses due to the small ns. In addition, caution was used in interpreting results for comparisons of subjects' performance on the discrimination tasks with Cronbach's alpha values below .50.

All perception tasks were scored for category accuracy, 1 (correct) or 0 (incorrect). For identification tasks, the two forms contained the same items, only in reverse order. Therefore, the scores for all subjects, regardless of which form was administered, were analyzed together. For emotional discrimination tasks, alternate forms contained different items, therefore, these forms were analyzed separately. For all tasks,

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[1] Variables of theoretical interest that cannot be directly observed are often referred to as "latent" variables or "factors." Any statistical procedure that uncovers a smaller number of latent variables by studying the covariation among a set of observed variables can be referred to as a latent variable analysis. Exploratory factor analysis, confirmatory factor analysis, and structural equation modeling all can be considered latent variable analyses (Long, 1983).

emotional and nonemotional, raw scores were used as the dependent variables; when tasks were combined to form factors, raw scores were summed. The combinations of scores through summation was deemed the most parsimonious method and the most appropriate because the relevant analyses were correlational, and thus, the use of more complex calculations to combine scores (such as proportions) was not necessary. All independent group analyses involved only individual tasks and, therefore, did not require summation. Procedures used to analyze items according to valence are described below.

Statistical Analyses Specific to Each Hypothesis and Predictions

Primary Hypothesis I

Hypothesis I stipulated that performance on emotional tasks across communication channels would be highly associated. A factor analysis was performed on the total scores from the 4 emotional and the 11 analogous nonemotional tasks employed. "Outlier" measures were eliminated from further analyses, and the factor analysis was repeated. The prediction was that emotional measures would load on the same factor.

Primary Hypothesis II

Hypothesis II predicted that performance on emotional measures would show aging patterns similar to established measures of crystallized intelligence. Thus, they would remain stable across the adult age span when nonemotional cognitive variables were controlled. In order to test Hypothesis II, three approaches were used. Initially, a confirmatory factor analysis (CFA; EQS; Bentler, 1989) was used to test the measurement model. The first model hypothesized three factors. The *crystallized factor*, included WAIS-R Information (Wechsler, 1981), nonemotional verbal perception, and all emotional perception tasks from the NYEB (Borod, Welkowitz, & Obler, 1992). The *fluid factor*, included Block Design (Wechsler, 1981) and Logical Memory I and II (Wechsler, 1987). The *nonemotional perceptual factor* included Visual Matrices (Borod et al., 1993), the Visual Form Discrimination Test (Benton et al., 1983), the Facial Recognition Test (Benton et al., 1983), the Phoneme Discrimination Test (Benton et al., 1983), and Intonation Contours Perception (Borod et al., 1992). The prediction was that this model would provide a good fit of the data, supporting the hypothesis that emotional perception is a crystallized ability. A second CFA was planned in the event of a poor fit to CFA1. This model (CFA2) hypothesized a separate factor on which emotional perception tasks would load.

While the confirmatory model can provide factor loadings and correlations among common factors, estimation of structural parameters requires the application of a structural equation to the common elements or factors. In the next phase of the analyses, a series of structural equation models was initiated. Structural equation modeling is a method to compute the value that each linkage in a causal model should have in order for the model to account for the observed pattern of covariances. The linkages are assigned starting values, which are then modified through a process of iterative data-fitting until the best possible solution is achieved. The resulting path coefficients are interpreted in a manner similar to regression coefficients. Within the structural model, linkages between observed variables and factors comprise the measurement model, while causal linkages among factors comprise the structural model (Mueller, 1996).

For the present study, the structural model was created by adding age to the model, with linkages from age to the latent constructs determined in the CFA described above. In this step, it was possible to look at the influence of age on the factors, as well as interrelationships among factors.

A second test of the primary hypothesis, regarding the nature of the aging pattern of emotional perception, involved computing Pearson product moment correlations between age and fluid abilities, age and crystallized abilities, and age and emotional perception, and comparing the strengths of the correlations. Results from the confirmatory factor analysis determined whether age relations for each of the three emotional communication channels were considered separately or together. (Scores on emotional measures loading on the same factor were summed together; scores on analogous nonemotional measures were combined similarly.) The prediction was that only one dependent measure for emotional perception would be computed, that is, mean performance on emotional (facial/prosodic/lexical) tasks. Partial correlations, controlling for subjects' performance on nonemotional perceptual tasks, were then used for the comparison.

To denote Gf, scores on the Block Design subtest of the WAIS-R (Wechsler, 1974) and on Logical Memory I and II from the WMS-R (Wechsler, 1981) were added together. These tasks measure novel problem-solving and reasoning, and immediate and delayed verbal memory. All represent the relatively knowledge-free mechanics of cognition, and are not significantly enhanced through life experience and cultural exposure. Thus, their designation as fluid abilities is appropriate. Measures typically exemplifying Gc, or crystallized abilities, are those that are enhanced through acculturation and experience, with the most reliable and frequently used being verbally loaded tasks such as vocabulary. Because the Mill Hill Vocabulary Test (Ravens, 1982) was added to the battery after the study was begun, all subjects were not administered this test (n = 74). Therefore, to denote a measure of Gc that included scores from the entire sample, other verbal tasks assessing abilities enhanced through experience and exposure to learning were utilized. Raw scores from the Information subtest of the WAIS-R (Wechsler, 1974) and total word scores from the Verbal Fluency test (F-A-S; Benton & Hamsher, 1989) were added together as one measure of crystallized ability (Gc1). Vocabulary scores were available for only 75% of the current sample, however, because vocabulary is the ability most frequently used to represent Gc, Vocabulary and Information scores were added together to form a second measure of Gc (Gc2). The designation of these tasks as Gc is appropriate because they are known to be highly influenced by acculturation and experience, thus representing the knowledge-saturated "pragmatics" of cognition. The preponderance of empirical data in cognitive aging research reviewed above (see "Aging and Cognitive Changes" section) supports the use of these tasks as examples of fluid and crystallized abilities (e.g., Baltes & Lindenberger, 1997; Kaufman, 1994; Schaie, 1994).

Once the dependent measures of Gc, Gf, and emotional perception were calculated, correlation coefficients were computed for age and Gc, age and Gf, and age and emotional perception (controlling for nonemotional perception). The following order was expected for the magnitude of the strength of the correlations: fluid ability would have the strongest inverse relationship with age; followed by emotional ability; followed by crystallized ability. These predictions were based on the rationale that emotional perception is strengthened through experience, and thus, improves and stabilizes with age, similar to crystallized abilities and unlike fluid abilities.

A third method for examining age effects was the application of ANCOVAs to compare age groups on emotional perceptual task performance while controlling for performance on nonemotional perceptual tasks. As mentioned previously, the sample was divided two ways: at the median age (i.e., 48 and younger, 49 and older) and into a 70+ age group and a less than 70 age group.

## Secondary Hypotheses

### The Common Cause Hypothesis

Age effects on emotional processing were expected to be mediated by hearing as would be predicted by Baltes and Lindenberger's (1997; Lindenberger & Baltes, 1994) common cause hypothesis (see pages 24-25 above). This would extend the findings of age-associated links between sensory and intellectual functioning to include emotional perception. This was examined by adding hearing to regression equations before age, then after age, to determine the extent to which hearing mediated age relations to emotional perception.

### Gender Effects

When demographic variables were examined for gender effects, men had significantly higher levels of education than women. Therefore, ANCOVAs controlling for education were performed on the emotional perception measures to examine gender differences. Women were expected to perform better overall on emotional tasks. To look at differential effects of gender on emotional perception according to valence, independent group t-tests were performed on all positive and all negative items across tasks. In addition, for each individual task, positive and negative items were tested separately for gender differences. Because some data exist indicating that negative items may be more difficult to identify and differentiate, results were expected to show more prominent female superiority on negatively valenced, as compared to positively valenced, items. To examine differential aging patterns in males and females on emotional cognitive functioning, separate regressions were calculated for males and females with emotional tasks as the dependent variables, and controlling for nonemotional perceptual variables.

Age and Valence

Correlations were computed to detect the strength of the relationships between age and accuracy on negatively and positively valenced items. The inverse relationship between age and accuracy on negatively valenced items was expected to be significantly stronger than that between age and accuracy on positively valenced items. The expectation was that as age increased, accuracy on all items would decrease, however, a more significant decrease was expected in accuracy on negative, as compared to positive, items. This prediction was based on the already established view that differentiation among negative items is a more complex task. Thus, in keeping with the notion of reduced processing efficiency as a function of age, these items were expected to put more strain on the already limited cognitive resources of the older adults, resulting in more diminished performance. One could also speculate that another mechanism contributing to differential age and valence relationships is related to Darwinian theory: it is of relatively lesser significance, phylogenetically, for post-reproductive individuals to sustain rapid and effective responses to negative emotional stimuli for survival. Finally, motivational influences related to stage of life may be operating (e.g., the tendency in older individuals to minimize negativity due to an increasing awareness of time constraints). Separate matrices were computed for males and females correlating age with positively and negatively valenced items to explore the relationships among age, gender, and valence. No specific hypotheses were posited for this analysis.

# Results

In this section, results of the study will be reported. The hypotheses will be reviewed, and results for each hypothesis will be discussed.

## Hypothesis I

Hypothesis I stipulated that emotional perception across communication channels is characterized by a single or unitary, as opposed to multiple or separate, processors. Thus, the prediction related to this hypothesis was that performance across tasks measuring emotional perception within each channel would be highly related. An exploratory factor analysis was calculated to ascertain the degree to which measures of facial, prosodic, and lexical emotional perception loaded on the same factor. In the event of uninterpretable findings, a second analysis was planned, which eliminated "outlier" measures that may have confounded the results. The default number of 25 iterations used by SPSS was employed as the maximum iteration criterion. Factor loadings of .40 and above are considered empirically important (Stevens, 1996), and thus, loadings of .40 and above were accepted for interpretation.

Due to small ns (48 to 52), the Emotional Discrimination tasks were not included in any of the latent variable analyses, but were later examined for age and gender differences using ANCOVAs. Similarly, the Mill Hill Vocabulary Test (n = 74) and the Verbal Fluency task (n = 92) were not used in this initial latent variable analysis, as the groups were smaller than desirable for a structural equation analysis. Bentler (1993) recommends that the ratio of sample size to the number of parameters to be estimated should be, at the very least, 5:1, and preferably much larger, 10:1 or 50:1, if statistical significance tests are to be trusted. The number of parameters to be estimated in these analyses ranges from 14 to 20, therefore, the n of 100, reflecting the entire sample, will need to be included in order for this rule of thumb to be satisfied.

The correlation matrix, means, and standard deviations of the variables involved in this facet of the study appear in Table 7, and the results of the first factor analysis, a principal components analysis with oblique rotation, appear in Table 8. Table 8 shows the unrotated factor loadings, communalities, eigenvalues, and proportions of the variance explained. The number of iterations necessary for a rotated solution exceeded the default level of 25, and hence, only the unrotated factor matrix was used for interpretation. As evidenced by an examination of Table 8, four factors emerged accounting for 64.7% of the variance. The eigenvalues of these factors ranged between 5.75 for Factor 1 to 1.08 for Factor 4, and the proportions of the variance accounted for by the factors ranged between 38.30 for Factor 1 and 7.20 for Factor 4. Loadings on Factor 1, the factor most amenable to interpretation, ranged between .29 for Facial Recognition and .79 for lexical emotional sentence identification. All the measures in the analysis except Facial Recognition displayed substantive loadings on this factor, disclosing a general factor of cognitive processing. A second interpretable factor was Factor 4. Because the two measures loading on Factor 4 require visual discrimination for their successful execution, this factor was interpreted as a visual perception factor. Because no rotations were forthcoming in this analysis, interpretation of the outcomes has to remain at this general level.

Table 7.
Correlation Matrix, Means and Standard Deviations for Raw Scores of Emotional and Nonemotional Cognitive Variables.

(n = 100)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | Mean | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---- | --- | ---- | ---- | ---- | ---- | 21.94 | 5.05 |
| 2 | .334 | --- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 27.18 | 11.10 |
| 3 | .394 | .438 | --- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 25.02 | 6.67 |
| 4 | .369 | .455 | .883 | --- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 21.24 | 6.82 |
| 5 | .226 | .271 | .120 | .101 | --- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 29.91 | 2.25 |
| 6 | .257 | .358 | .261 | .386 | .244 | --- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 27.82 | 1.77 |
| 7 | .101 | .035 | -.016 | -.034 | .199 | .183 | --- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 47.42 | 3.98 |
| 8 | .119 | .300 | .264 | .234 | .440 | .325 | .132 | --- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 23.33 | 1.17 |
| 9 | .520 | .402 | .337 | .277 | .241 | .327 | .195 | .176 | --- | ---- | ---- | ---- | ---- | ---- | ---- | 21.33 | 2.79 |
| 10 | .426 | .214 | .442 | .462 | .202 | .290 | .081 | .178 | .266 | --- | ---- | ---- | ---- | ---- | ---- | 22.79 | 1.40 |
| 11 | -.100 | .173 | .152 | .163 | .182 | .273 | .153 | .242 | .111 | .229 | --- | ---- | ---- | ---- | ---- | 19.04 | 2.77 |
| 12 | .167 | .456 | .313 | .374 | .285 | .331 | .444 | .251 | .339 | .272 | .305 | ---- | ---- | ---- | ---- | 23.40 | 3.56 |
| 13 | .202 | .536 | .379 | .413 | .238 | .475 | .203 | .338 | .351 | .284 | .371 | .577 | ---- | ---- | ---- | 14.03 | 4.03 |
| 14 | .433 | .513 | .457 | .440 | .325 | .384 | .285 | .397 | .480 | .379 | .360 | .604 | .624 | ---- | ---- | 21.46 | 2.60 |
| 15 | .472 | .428 | .476 | .506 | .265 | .458 | .196 | .227 | .393 | .418 | .271 | .555 | .617 | .714 | ---- | 19.07 | 3.18 |

1 = WAIS-R Information
2 = WAIS-R Block Design
3 = WMS-R Logical Memory I
4 = WMS-R Logical Memory II
5 = Visual Form Discrimination
6 = Phoneme Discrimination
7 = Facial Recognition
8 = Visual Matrices
9 = Intonation Contours Perception
10 = Nonemotional Word Identification
11 = Nonemotional Sentence Identification
12 = Facial Emotional Identification
13 = Prosodic Emotional Identification
14 = Lexical Emotional Word Identification
15 = Lexical Emotional Sentence Identification

Table 8.



Unrotated Factor Matrix for Original Data.

| | Factor 1 | 2 | 3 | 4 | Communality |
|---|---|---|---|---|---|
| Crystallized | | | | | |
| Information | .55 | -.41* | .58* | .07 | .80 |
| Fluid | | | | | |
| Block Design | .67* | -.06 | -.05 | .09 | .48 |
| Log Mem I | .68* | -.52* | -.24 | .02 | .79 |
| Log Mem II | .70* | -.50* | -.31 | - .03 | .84 |
| Nonemotional Perception | | | | | |
| Visual Form DT | .43* | .35 | .23 | .60* | .72 |
| Phoneme Disc | .61* | .12 | - .08 | .08 | .39 |
| Facial Recognition | .29 | .56* | .37 | - .34 | .64 |
| Visual Matrices | .48* | .28 | - .15 | .63* | .73 |
| Intonation Contours | .59* | -.08 | .48* | - .02 | .58 |
| Nonemotional Verbal Perception | | | | | |
| NE Word ID | .56* | -.28 | .01 | .02 | .39 |
| NE Sentence ID | .40* | .41* | -.49* | -.06 | .57 |
| Emotional Perception | | | | | |
| Facial ID | .69* | .34 | - .01 | -.32 | .70 |
| Prosodic ID | .75* | .21 | - .21 | -.16 | .67 |
| E Word ID | .83* | .13 | .06 | -.10 | .72 |
| E Sentence ID | .80* | -.03 | .04 | -.21 | .68 |
| **Eigenvalue** | 5.75 | 1.66 | 1.22 | 1.08 | |
| **% of variance** | 38.30 | 11.00 | 8.10 | 7.20 | |
| **Total variance** | 64.70 | | | | |
| **Factor Labels** | General Cognitive Processing | | | Visual Perception | |

*Factor loadings > .40

Given the failure of the first analysis to reach a rotated solution, the various tasks used in the assessment part of the study were examined to determine attributes that may have contributed to the solution failure. The following determinations were made on the basis of this analysis.

1. Nonemotional word identification (NWID) and nonemotional sentence identification (NSID) were developed as analogous tasks to their emotional counterparts. The high degree of similarity might have rendered it difficult for factor analytic techniques to extract the emotional component from other aspects of task performance and thus, contributed to ambiguous findings.
2. Despite the conceptualization of Intonation Contours Perception (ICP) as a nonemotional task, there may be an inherent emotionality in the interrogative and exclamatory conditions of the task, which may have had a confounding effect.
3. Facial Recognition failed to load on the general cognitive processing factor with all other variables. However, it did load positively on the second factor with other tasks of a lexical nature. At the same time, it failed to load significantly on the visual discrimination factor but had a substantial negative loading on this factor. Taken together, these details rendered interpretation of this measure's performance less than definitive.

Given these considerations, the decision was made to perform the second factor analysis excluding these measures (i.e., NWID, NSID, ICP, and Facial Recognition).

The results of the second principal components analysis with oblique rotation appear in Tables 9 and 10. Two factors emerged in this analysis, and they proved to be correlated ($\phi = .39$), leading to the use of the pattern matrix for interpretation of the rotated solution[2]. Table 9 displays the unrotated factor matrix; and Table 10 displays the

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[2] In a factor analysis, when factors are correlated it is necessary to utilize the output matrix that accounts for correlated factors for interpretation purposes. Factor loadings are the correlations of the variables with the factors. When the factors are not correlated, the factor loadings are also the beta weights for predicting the variables from the factors. However, when factors are correlated, the beta weights are different from the correlations between factor and variable. To use an analogy to multiple regression: if dependent variables in a multiple regression are correlated, it is necessary to use the regression weight (as opposed to the Pearson r) as a measure of the relationship between the dependent and the independent variables because (unlike the Pearson r) it takes into account, or controls for, the influence of other variables. In the same way, when factors are correlated in a factor analysis, the pattern matrix (which is an analog for the regression weight) must be used for interpretation because it takes into account, or controls for, the influence of the other factors on factor loadings. Factor correlations of .20 and above are considered significant and require use of the pattern matrix. When factors are uncorrelated, the structure matrix (which is an analog for the Pearson r) can be used for interpretation (Pedhazur, Pedhazur, & Schmelkin, 1991).

Table 9.
Unrotated Factor Matrix for Reduced Data.

| | Factor | |
|---|---|---|
| | 1 | 2 |
| Crystallized Intelligence | | |
| Information | .53* | -.26 |
| Fluid Intelligence | | |
| Block Design | .70* | .01 |
| Log Mem I | .70* | -.55* |
| Log Mem II | .72* | -.53* |
| Nonemotional Perception | | |
| Visual Form | .43* | .58* |
| Visual Matrices | .60* | .16 |
| Phoneme Disc | .49* | .47* |
| Emotional Perception | | |
| Facial ID | .69* | .20 |
| Prosodic ID | .76* | .17 |
| E Word ID | .82* | .11 |
| E Sentence ID | .81* | -.05 |
| **Eigenvalue** | 4.97 | 1.33 |
| **% of variance** | 45.16 | 12.06 |
| **Total variance** | 57.22 | |

*Factor loadings > .40

rotated (pattern) matrix, communalities[3], eigenvalues[4], and proportions of the variance explained. As shown in Table 10, Factor 1, with an eigenvalue of 4.96, explained 45.1% of the variance in the data; and Factor 2, with an eigenvalue of 1.32, explained 12.1% of the variance. Together, the two factors explained 57.1% of the variance. Examination of Table 10 discloses that the crystallized and fluid intelligence items loaded on Factor 1,

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[3] The loadings in the rows of a factor matrix can be squared and summed. The sum of squares for each row indicates the proportion of variance in each variable that the factors can explain. This is known as the communality. The higher the communality the more the particular set of factors explain the variance of the variable (Kline, 1994).

[4] The eigenvalue is the sum of the squared loadings on each factor. The average of the squared loadings of a factor shows the percentage of variance explained by that factor (Kline, 1994). For example, in Table 8, the sum of the squared loadings for Factor 1 is 5.75. When 5.75 is divided by 15 (the number of variables in the factor analysis) the result is .383, thus, Factor 1 explains 38.3% of the variance in the correlation matrix. The larger the eigenvalue, the more variance is explained by the factor. The cutoff for the eigenvalue in terms of its explaining a meaningful proportion of variance is 1. A breadth of empirical work has shown that when factors with eigenvalues of <1 are not considered, just as much of the variance is explained as when they are considered (Pedhazur, Pedhazur, & Schmelkin, 1991).

Table 10.
Rotated (Pattern) Matrix for Reduced Data.

| | Factor 1 | Factor 2 | Communality |
|---|---|---|---|
| Crystallized Intelligence | | | |
| Information | .57* | .06 | .35 |
| Fluid Intelligence | | | |
| Block Design | .43* | .41* | .49 |
| Log Mem I | .92* | -.11 | .78 |
| Log Mem II | .93* | -.08 | .81 |
| Nonemotional Perception | | | |
| Visual Form DT | -.25 | .78* | .52 |
| Phoneme Disc | .24 | .49* | .39 |
| Visual Matrices | -.10 | .72* | .46 |
| Emotional Perception | | | |
| Facial ID | .26 | .58* | .52 |
| Prosodic ID | .33 | .59* | .61 |
| E Word ID | .42* | .57* | .69 |
| E Sentence ID | .56* | .41* | .65 |
| **Eigenvalue** | 4.96 | 1.32 | |
| **% variance** | 45.10 | 12.10 | |
| **Total variance** | 57.10 | | |
| **Factor Labels** | General Intelligence | Perception | |

*Factor loadings > .40

with loadings ranging between .43 for Block Design and .93 for Logical Memory II. Perusal of this table also discloses that the perception items loaded predominantly on Factor 2, with loadings ranging between .41 for lexical emotional sentence identification and .78 for the Visual Form Discrimination Test. The lexical emotional perception measures also loaded on Factor 1, suggesting that while these are measures of emotional perception, they also contain a theoretically suggestive intelligence component. These results, though not conclusive, pointed to a possible separation of the verbal and nonverbal processes of emotional perception. The verbal emotional tasks loaded with intelligence tasks, while the nonverbal emotional tasks loaded with the perceptual tasks. On the basis of these suggestive findings, it was decided to perform a confirmatory factor analysis to more closely examine the processes involved. The hypothesized factor model described below involved the second major hypothesis posed for investigation.

Hypothesis II

Hypothesis II dealt with the relationship of emotional perception to Horn's model of intelligence, which involves two broad constructs, $G_c$, or crystallized intelligence, and $G_f$, or fluid intelligence. The hypothesis stipulated emotional perception to be part of $G_c$. This stipulation is represented in Figure 1 as a confirmatory factor analytic model, using the reduced set of variables from the second factor analysis described above.

Historically, the measure of data fit used for confirmatory factor analysis and structural equation modeling has been the chi square ($\chi^2$) test. However, it is now known that this statistic is heavily influenced by sample size, so that small samples can yield spuriously significant chi square values, whereas in large samples any a priori hypothesis, though only trivially false, may be rejected. For this reason, statisticians have striven to develop more realistic data fit indices. The one least influenced by sample size is the comparative fit index (CFI), developed by Bentler (1989). Because the CFI is generally accepted as the most adequate of the available indices, it was used in this study. A CFI greater than or equal to .90 is indicative of a good fit (Bentler, 1989). The phi ($\phi$) values reported in the text and displayed in the figures below refer to the correlation between two elements in the model when the coefficient is significant beyond the .05 level. When hypothesized models produce linkages whose phi coefficients are not statistically significant, the models are revised to eliminate those hypothesized linkages. The only criterion for whether a phi coefficient is reported is whether it is statistically significant. In the figures below, the straight line with an arrow between two elements signifies a hypothesized functional relationship between them. A curved line between two elements, or factors, is indicative of a statistically significant relationship without implying that one affects the other[5].

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[5] As seen in Figure 1, the Gc factor, which is the common factor or latent variable, is functionally related to each of the observed variables (i.e., Information, Facial ID, Prosodic Id, Word ID, Sentence ID) as indicated by arrows from the latent variables into the observed variables. In other words, Gc affects, or influences performance on each of these task variables. As is shown here, curved lines between latent variables simply represent correlations and do not indicate predictive power of one factor on another. Confirmatory factor analytic procedures are not sufficient to estimate functional relations

The confirmatory factor analysis outcomes are displayed in Figure 1. As shown in this figure, the three-factor model displayed a good fit of the data, CFI = .90. For the crystallized intelligence factor (Gc), the loadings ranged between .47 for Information and .86 for Lexical Emotional Word Identification; for the fluid intelligence (Gf) factor, the loadings ranged between .49 for Block Design and .95 for Logical Memory II; and, for the nonemotional perceptual factor (NEP), the loadings ranged from .52 for Visual Form Discrimination Test to .72 for Visual Matrices. The correlation between Gc and Gf was $\phi$ = .61; between Gc and NEP, it was .74. The correlation between Gf and the NEP factor was .02.

Although this model produced a good fit of the data, the hypothesis in this analysis was tested without taking the effects of age into account. However, previous work has shown that as age increases, fluid intelligence decreases, whereas crystallized intelligence remains stable. To investigate the possible confounding effects of age on the three-factor outcome, the analysis was repeated, including age as an independent variable for Gc, Gf, and NEP. The CFI for this analysis proved to be a low .78, suggesting that age was associated with some of the measures comprising the factors, but not others. This finding required the breaking up of the factors in various ways to explore more closely and in greater detail exactly which of these measures was related to age. This approach required another analysis to incorporate structural relations among the latent

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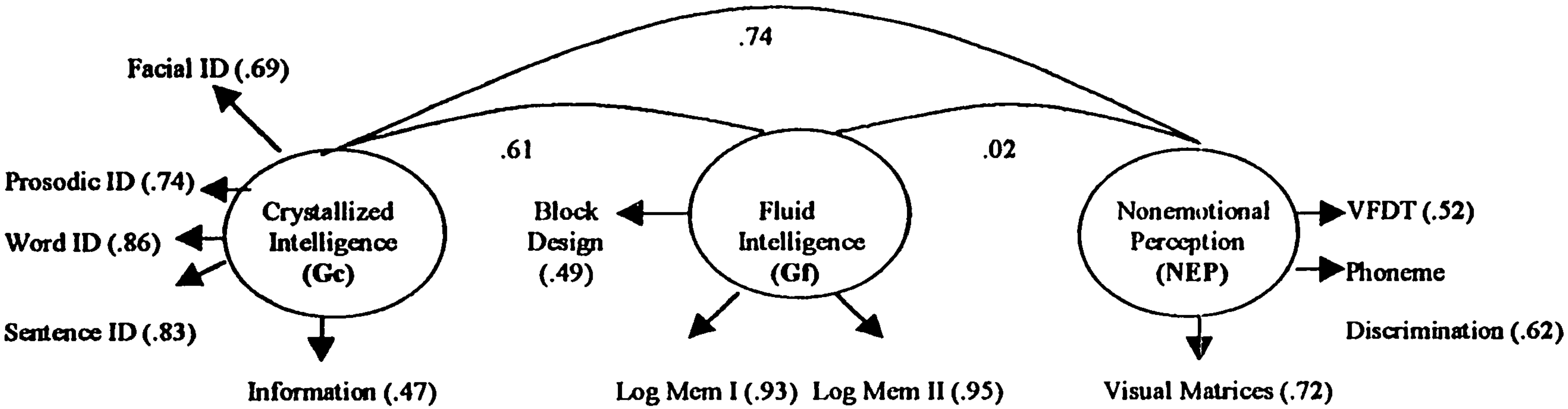
between latent variables; to do this requires application of a structural equation model to the latent variables, or common factors (Long, 1983).

<u>Figure 1.</u> Outcomes for Confirmatory Factor Analysis

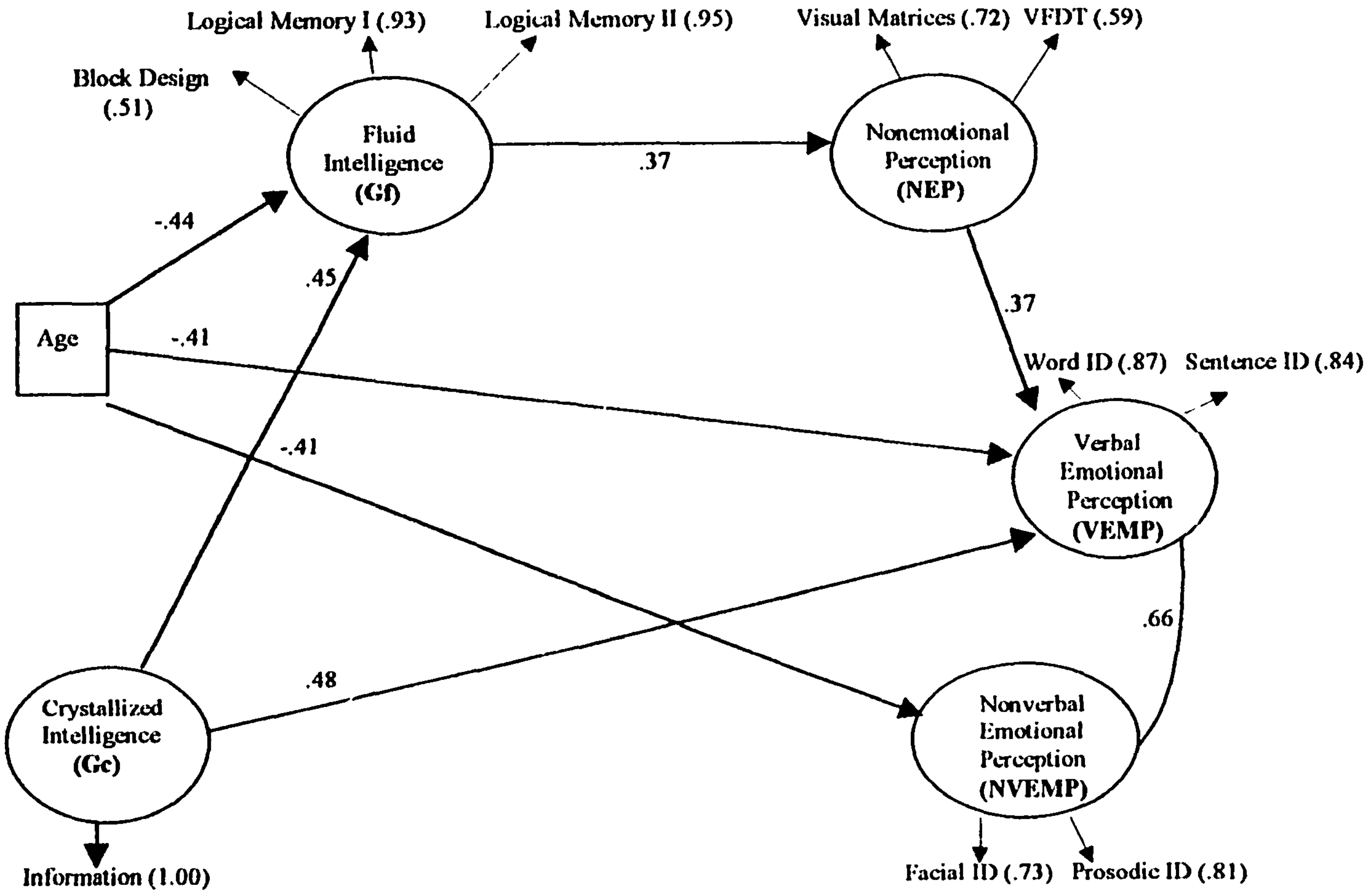



*CFI* = .90

variables. The simpler confirmatory factor analytic approach taken earlier, though it allows structural relations between observed and latent variables, does not allow structural relations between latent variables. The best-fitting path model that emerged, with a CFI of .93, was that appearing in Figure 2. Because Phoneme Discrimination (PHD) was the only nonemotional perceptual variable with a significant age relation, it was removed from the NEP variable and included in the model as a separate auditory perceptual variable with a direct path from age and into NVEMP and VEMP. However, this model did not provide a good fit of the data (CFI =.81). Therefore, PHD was removed from the subsequent and final version of the model. The separation of emotional perception measures from the factor of crystallized intelligence and their division into two factors, verbal emotional perception (VEMP) and nonverbal emotional perception (NVEMP), was also required in order to obtain a good fit of the data.

It became clear from the results of this analysis that the features of emotional perception influenced by crystallized intelligence when age is statistically controlled are verbal, and that nonverbal emotional perception is independent of crystallized intelligence. The relation of age with Gf was $\phi = -.44$; with VEMP, it was $\phi = -.41$, and with NVEMP, it was -.41. Gc proved to be related only to Gf ($\phi = .45$) and to VEMP ($\phi = .48$). VEMP proved to be also influenced by NEP ($\phi = .37$). NEP was in turn influenced by Gf ($\phi = .37$). Finally, the correlation between VEMP and NVEMP was .66 —a noteworthy correlation given the fact that although VEMP proved to be statistically significantly related to crystallized intelligence, NVEMP did not. It is particularly striking, considering

Figure 2. Best-fitting Structural Equation Model




*CFI* = .93

that when age was controlled, no statistically significant relation emerged between either measure of the emotional perception and fluid intelligence.

The analogous nonemotional verbal tasks (NEVP) had not been included in the structural models, as it was felt that the high degree of similarity between task characteristics of these and the emotional verbal tasks would confound a latent variable analysis. As a matter of interest, however, to examine the relations among age, nonemotional verbal perception (i.e., the analogous nonemotional verbal tasks, NEVP) and VEMP, a post hoc analysis was performed adding the two nonemotional verbal identification tasks to the structural model with a direct path from age and into VEMP. As anticipated, this model produced a poor fit to the data (CFI = .68), suggesting that the confounding effects of task characteristics precluded a precise interpretation of factor relations in the context of latent variable analysis.

Post Hoc Structural Analyses

What follows is an overview of statistical procedures applied to the data for post hoc analyses of the primary hypotheses using latent variable techniques. Two important issues will be discussed prior to a description of the results. First, the sequence of analytic procedures used for this part of the study will be clarified. Second, reasons for post hoc analyses using specific groupings of additional dependent variables will be summarized. Despite the less than optimal subject to parameter ratio, these analyses were done for exploratory purposes. The overall intent of the post hoc analyses was to achieve a fuller structural model, one that included more of the task variables in the structural equations. For each of the two analyses, calculations were performed consecutively and became increasingly restrictive (i.e., with respect to inclusion of task variables) until a good-fitting solution was obtained. Following this description of these analyses will be a summary of consistencies and discrepancies among the structural models presented.

Data Analytic Procedures. This phase of statistical analyses also began with an exploratory factor analysis and culminated in a structural equation model. The second step used in the a priori analysis, which included application of a confirmatory factor analysis, was not necessary because this structural equation model included both the measurement model, and the structural model. Similar to the confirmatory factor analysis, the measurement model hypothesized factors made up of the various intelligence and emotional tasks and examined relations between these observed variables and the factors, or latent variables. The structural model hypothesized functional relationships among latent variables (i.e., that one influences, or has an effect, on the other).

The purpose of the exploratory factor analysis was twofold: first, it was a direct test of Primary Hypothesis I, which predicted that performance on emotional tasks across the communication channels would be closely related, thus supporting the notion of a unitary processor for emotional perception across the facial, prosodic and lexical channels. Should the emotional identification tasks load together on an "emotional" factor, the contention that perception of emotion across channels is subserved by a unitary processor would be supported.

The second reason for the exploratory factor analysis was to provide information about relationships among the other dependent variables that could be applied to the structural equations models used to test Primary Hypothesis II, which predicted that emotional perception was a facet of crystallized intelligence. In order to examine the relationships among age, measures of Gc and Gf, nonemotional perceptual measures, and the four identification measures of emotional perception, relevant variables were placed in hypothesized structural models, and these models were subjected to statistical tests to determine whether they provided a good fit of the data. Information from the exploratory factor analyses was used to modify the structural equations when changes were necessary to achieve a better fit of the data. For example, exploratory factor analyses identified ambiguously loading variables and highlighted uninterpretable relationships among disparate variables, both of which directly influenced the structural analysis (more specific examples are discussed below).

For the post hoc analyses, a particular sequence and method were applied to the exploratory factor analyses to ensure the resolution of unrotated factor analyses. Initially, Principal Axis factor analysis was used for extraction, while Promax was the rotation method employed to examine the factor structure of the emotional and nonemotional tasks administered. When solutions were not forthcoming using the default settings for eigenvalues (greater than 1) and iterations (maximum of 25), an attempt was made to increase the number of default iterations to elicit an unrotated solution. When this failed, Cattell's Scree test was applied to the variables as a guide for selecting the correct number of factors to be extracted. Most factor analysts agree that the Scree test is the best solution to selecting the correct number of factors (Kline, 1994). In the Scree test, the data are subjected to a Principal Components factor analysis and a graph is generated consisting of the eigenvalues and the principal components. The cutoff point for each factor is where the line changes slope. In the present study, once the Scree plot was evaluated, the data were again subjected to Principal Axis factoring using Promax rotation procedures with a command to extract the number of factors noted in the Scree plot. In each case, this procedure led to unrotated and rotated solutions. Loadings of .40 and above were considered meaningful.

Each structural equation model started with the same basic structure as the a priori model (see pp. 101-103), positing the same hypothesis regarding relationships among factors. The modifications to the structural equations took the form of adding some variables to the hypothesized factors.

Dependent Variables for Each Analysis. The post hoc analyses were applied to the data to include different groupings of the remaining dependent variables for several reasons. For example, in order to use data from the entire sample of 100 subjects, neither the Mill Hill Vocabulary Test (n = 74) nor Verbal Fluency (n = 92) variables were included in the a priori model tested initially (see Figure 2). However, this first set of variables contained only one measure (Information) that could be designated as Gc. Because it was not one of the measures included in the original battery, only 74 of the 100 subjects had completed the Mill Hill Vocabulary Test (for means and standard deviations, see Table 5). Nevertheless, because vocabulary skill is one of the most dependable and frequently employed ways of assessing crystallized intelligence, it was deemed of interest to include this measure in a structural model, even though the subject to variable ratio would be less than ideal. Thus, the addition of Vocabulary to the Gc factor was tested in the first post hoc structural model (Analysis 1)[6].

Verbal fluency is not a well-established measure of Gc. Findings for age-related decline versus stabilized performance have been equivocal. Most workers have found no evidence for age declines in phonemic verbal fluency (Obler & Albert, 1985; Cronin-Golomb, 1990; Schum & Sivan, 1997). However, a drop in performance with age has been seen when individuals are asked to produce words from a specific category (i.e., semantic verbal fluency, Kozora & Cullum, 1995; Obler & Albert, 1985; Tabert et al., submitted; Tomer & Levin, 1993; Troyer, Moscovitch, & Winocur, 1997). Since the task used in this study was a phonemic word production task, it was considered appropriate for use as an example of Gc. In addition, data from the present study suggest that Verbal Fluency remains stable until age 70, which is a pattern typically observed in Gc abilities (Horn, 1982). (Means and standard deviations of the Verbal Fluency measure for all subjects by decade are displayed in Table 5. As can be seen, means are very similar for each decade until the seventh. Furthermore, age group comparisons summarized below

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[6] A structural model was tested using Information, Vocabulary, and Verbal Fluency to form the Gc factor. This model also included all five variables in the Nonemotional Perceptual Factor (i.e., VFDT, VMAT, PHD, ICP, and FACREC) and Cancellation in the Gf factor. However, because of missing data from the Vocabulary ($n = 74$) and Fluency ($n = 92$) variables, the sample size dropped down to 67, and this model resulted in a very poor fit of the data ($\underline{CFI} = .21$).

revealed no differences between the median split groups on Verbal Fluency scores; however, the 70 and over group produced significantly fewer words than the under 70 group.) Therefore, in order to increase the sample size and retain two variables to represent the Gc factor, another post hoc series of analyses was performed (Analysis 2) with Verbal Fluency (n = 92) replacing vocabulary as a variable in the crystallized factor. Originally, Block Design, Logical Memory I, and Logical Memory II were hypothesized to represent the fluid intelligence factor. However, the addition of the cancellation task (Mesulam, 1989), used as a screening measure for attentional ability (for means and standard deviations, see Table 4), was considered post hoc as a measure of processing speed that might improve the reliability of the fluid factor. Therefore, Cancellation was added to the pool of variables examined post hoc so that this assumption could be tested (Analyses 1 and 2). The Cancellation task requires subjects to locate specific targets among an array of similar stimuli; the verbal form contains various letters, while the nonverbal form contains various geometric shapes. The dependent variable used in this study was seconds to completion. The mean time scores for the two forms was computed, and, in order to maintain consistency with other dependent variables, scores were inverted so that higher scores indicated better performance.

Analysis 1. As mentioned above, an analysis was undertaken to explore the effect of adding the Vocabulary measure to the hypothesized Gc factor, despite the smaller number of subjects who were administered this task. Analysis 1 included the Mill Hill Vocabulary Test in the set of variables to be analyzed (n = 74). A Principal Axis factor extraction was employed, followed by a Promax rotation. Three factors emerged and they proved to be correlated (for Factors 1 and 2; $\phi = .41$; for Factors 2 and 3; $\phi = .31$; for Factors 1 and 3; $\phi = .45$), leading to the use of the rotated (pattern) matrix solution, displayed in Table 11. Factor 1, with an eigenvalue of 5.67, explained 37.78% of the variance in the data; Factor 2, with an eigenvalue of 1.78, explained 11.89% of the variance in the data; and Factor 3, with an eigenvalue of 1.59, explained 10.57% of the variance. Together, the three factors explained 60.24% of the variance. As seen in Table 11, the four emotional identification tasks and Facial Recognition loaded most highly on Factor 1, with loadings ranging from .60 for Facial Recognition and Emotional Sentence Identification to .82 for Facial Emotional Identification. Other tasks loading on this factor included Block Design, Cancellation, Visual Form Discrimination, Visual Matrices and Phoneme Discrimination. These tasks formed a second tier of loadings with smaller values, ranging from .40 for Block Design to .47 for Cancellation. Factor 1 could be interpreted as a perceptual factor. Factor 2 consisted of the Information, Mill Hill Vocabulary, and Intonation Contours Perception (ICP) tasks, with loadings of .82, .68, and .54, respectively. Factor 3 displayed high loadings for the two verbal memory tasks, .83 for Logical Memory I and .89 for Logical Memory II and Facial Recognition (-.43). For Factor 1, the affiliation of the emotional tasks is easily understood due to the emotional component of the tasks as well as their similar construction. The higher loading of Facial Recognition on this factor may stem, in part, from its similarity to Facial Emotional Identification (FID), as both tasks require the processing of facial stimuli.

Table 11.



Results of Factor Analysis on Total Mean Scores for Cognitive and Emotional Variables: Post Hoc Analysis 1.

| Variable | Factors Before Rotation | | | Factors After Rotation | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Crystallized | | | | | | |
| Information | .56* | -.52* | .34 | .00 | .82* | .14 |
| Vocabulary | .47* | -.44* | .28 | .00 | .68* | .12 |
| Fluid | | | | | | |
| Block Design | .64* | .00 | -.17 | .41* | .00 | .35 |
| Logical Memory I | .68* | -.42* | -.41* | .00 | .23 | .83* |
| Logical Memory II | .69* | -.30 | -.54* | .00 | .00 | .89* |
| Cancellation | .31 | .34 | -.31 | .47* | -.39 | .21 |
| NE Perception | | | | | | |
| Visual Form DT | .42* | .11 | .30 | .43* | .25 | -.21 |
| Visual Matrices | .43* | .12 | .00 | .40* | .00 | .00 |
| Facial Recognition | .34 | .32 | .39 | .60* | .15 | -.43* |
| Phoneme Disc | .49* | .15 | .00 | 40* | 00 | .12 |
| Intonation Contours | .58* | -.19 | .30 | .24 | .54* | .00 |
| Emotional Perception | | | | | | |
| Facial ID | .69* | .39 | .00 | .82* | .00 | .00 |
| Prosodic ID | .69* | .40* | -.14 | .80* | -.21 | .15 |
| E Word ID | .81* | .00 | .19 | .64* | .31 | .00 |
| E Sentence ID | .77* | .10 | .00 | .60* | .17 | .16 |
| | | **Eigenvalues** | | 5.67 | 1.78 | 1.58 |
| | | **% variance** | | 37.78 | 11.89 | 10.57 |
| | | **Total Variance** | | | 60.24 | |

| **Factors After Rotation** | **1** | **2** | **3** |
|---|---|---|---|
| **Factor Labels** | Perception | Linguistic | Memory |

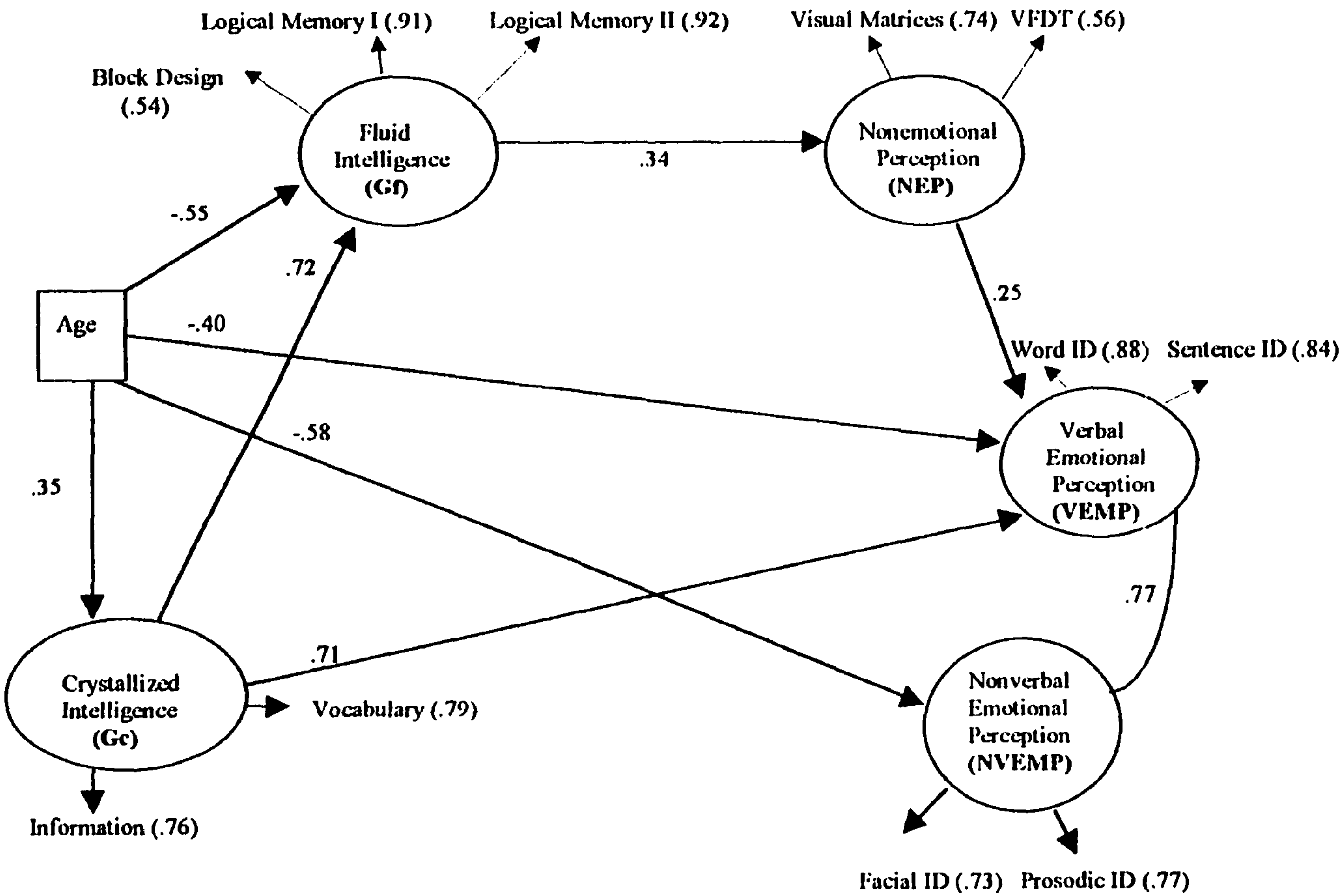
*Factor loadings > .40

Factor 2 could be characterized as a crystallized factor except for the presence of ICP, which is more difficult to interpret. The ability to discern interrogative, exclamatory, and declarative patterns through vocal intonations is linguistic, and therefore Factor 2 could be interpreted as a broad linguistic factor. However, if this were the case it would follow that the lexical emotional tasks and verbal memory tasks would also load on this factor. Therefore, the loading of ICP with these established crystallized tasks remains somewhat ambiguous, suggesting that the task may be potentially confounding. Factor 3 could be interpreted as a verbal memory factor, with the negative loading of Facial Recognition representing the large discrepancy between verbal mnemonic and facial perceptual abilities.

A structural equation model was hypothesized that included all the variables in the factor analysis described above. This factor analysis was comprised of all the tasks originally slated for inclusion with the exception of Nonemotional Word Identification (NWID) and Nonemotional Sentence Identification (NSID). These two nonemotional verbal identification tasks were excluded from the analysis for three reasons. First, they were considered the most ambiguous of the variables due to their similarity in task construction to the verbal emotional tasks. This high degree of similarity would likely render it difficult for latent variable analyses to separate the effects of task parameters from other aspects of task performance. Secondly, when tried post hoc in the first structural model, the model did not provide an adequate fit of the data. Thirdly, it was important to reduce the subject to factor ratio when possible in order to improve the reliability of the analysis. For these reasons, NWID and NSID were excluded from the SEM and from all subsequent latent variable analyses.

The solution for the first structural model for this analysis resulted in an inadequate fit to the data (CFI = .78). Variables were removed from the model sequentially, beginning with ICP, then Facial Recognition. These steps were taken based on the exploratory factor analyses performed previously, which showed ambiguous loadings for ICP and Facial Recognition (see Table 11), as described above. At this point, the fluid factor consisted of four variables; it was determined that one of these would be removed from the model. It was deemed preferable to keep both Block Design, which contains a significant novel problem solving/reasoning component, and Logical Memory, in order to maintain both nonverbal and verbal elements in the measures of fluid ability. Thus, Cancellation was eliminated at this step. Structural equations were recalculated after each of the three tasks were removed, but failed to provide an adequate fit. At this point, because Phoneme Discrimination (PHD) was the only nonemotional perceptual variable with a significant age relation, it was removed from the NEP variable and included in the model as a separate auditory perceptual variable with a direct path from age and into NVEMP and VEMP. This model resulted in a good fit, however, PHD added nothing to the explanation of the variance for either of the emotional factors (i.e., the phi coefficients for the paths from PHD to NVEMP and from PHD to VEMP were not statistically significant). Therefore, PHD was removed from the subsequent and final version of the structural equation model depicted in Figure 3.

Figure 3. Best-fitting Structural Equation Model, Post Hoc Analysis 1




*CFI* = .94

The final structural model depicted in Figure 3 resulted in a good fit of the data (CFI = .94). The relation of age with Gf was $\phi = -.55$; with Gc, it was $\phi = .35$; with NVEMP, it was $\phi = -.58$; and with VEMP, it was $\phi = -.40$. With age statistically controlled, Gc proved to be related to Gf ($\phi = .72$) and VEMP ($\phi = .71$). VEMP was in turn influenced by NEP ($\phi = .25$). Finally, the correlation between VEMP and NVEMP was .77. The statistically significant linkages seen in this model are comparable to those observed in the a priori structural model with two exceptions. There is an age relation with Gc ($\phi = .35$) not present in the first model that is associated with an increase in vocabulary skills over the age span. In addition, there is a stronger linkage between Gc and Gf ($\phi = .45$ in the a priori analysis, $\phi = .72$ here) and Gc and VEMP ($\phi = .48$ in the a priori analysis, $\phi = .71$ here) in the present model. It may be that vocabulary mediates performance on verbal memory and verbal emotional perception measures more than the factual knowledge reflected in performance on the Information variable.

Analysis 2. Analysis 2 included the Verbal Fluency measure in the set of variables to be factor analyzed (n = 92). Because extraction at the default settings failed to resolve, the Scree test was applied followed by Principal Axis factoring with a Promax rotation, and two factors emerged. These factors were correlated ($\phi = .60$), leading to the use of the rotated (pattern) matrix solution, displayed in Table 12. Factor 1, with an eigenvalue of 5.99, explained 39.94% of the variance in the data, while Factor 2, with an eigenvalue of 1.52, explained 10.14% of the variance in the data; together, the two factors explained 50.07% of the variance. For Factor 1, important loadings were seen for Block Design, the nonemotional perceptual measures (including Facial Recognition, Visual Form

Table 12.



Results of Factor Analysis on Total Mean Scores for Cognitive and Emotional Variables: Post Hoc Analysis 2.

| Variable | Factors Before Rotation | | Factors After Rotation | |
|---|---|---|---|---|
| | 1 | 2 | 1 | 2 |
| Crystallized | | | | |
| Information | .49* | -.14 | .00 | .36 |
| Verbal Fluency | .55* | -.00 | .33 | .29 |
| Fluid | | | | |
| Block Design | .66* | .00 | .44* | .30 |
| Logical Memory I | .68* | -.55* | .14 | .95 |
| Logical Memory II | .73* | -.63* | -.20 | 1.00* |
| Cancellation | .39 | .00 | .29 | -.15 |
| NE Perception | | | | |
| Visual Form DT | .40* | .25 | .52* | -.10 |
| Visual Matrices | .47* | .16 | .48* | .00 |
| Facial Recognition | .30 | .37 | .58* | -.28 |
| Phoneme Disc | .58* | .00 | .45* | .19 |
| Intonation Contours | .55* | .00 | .46* | .15 |
| Emotional Perception | | | | |
| Facial ID | .68* | .29 | .75* | .00 |
| Prosodic ID | .73* | .21 | .69* | .10 |
| E Word ID | .82* | .19 | .74* | .16 |
| E Sentence ID | .79* | .00 | .54* | .34 |
| | | **Eigenvalues** | 5.99 | 1.52 |
| | | **% variance** | 39.94 | 10.14 |
| | | **Total Variance** | | 50.07 |
| | | **Factor Labels** | Perception | Verbal Memory |

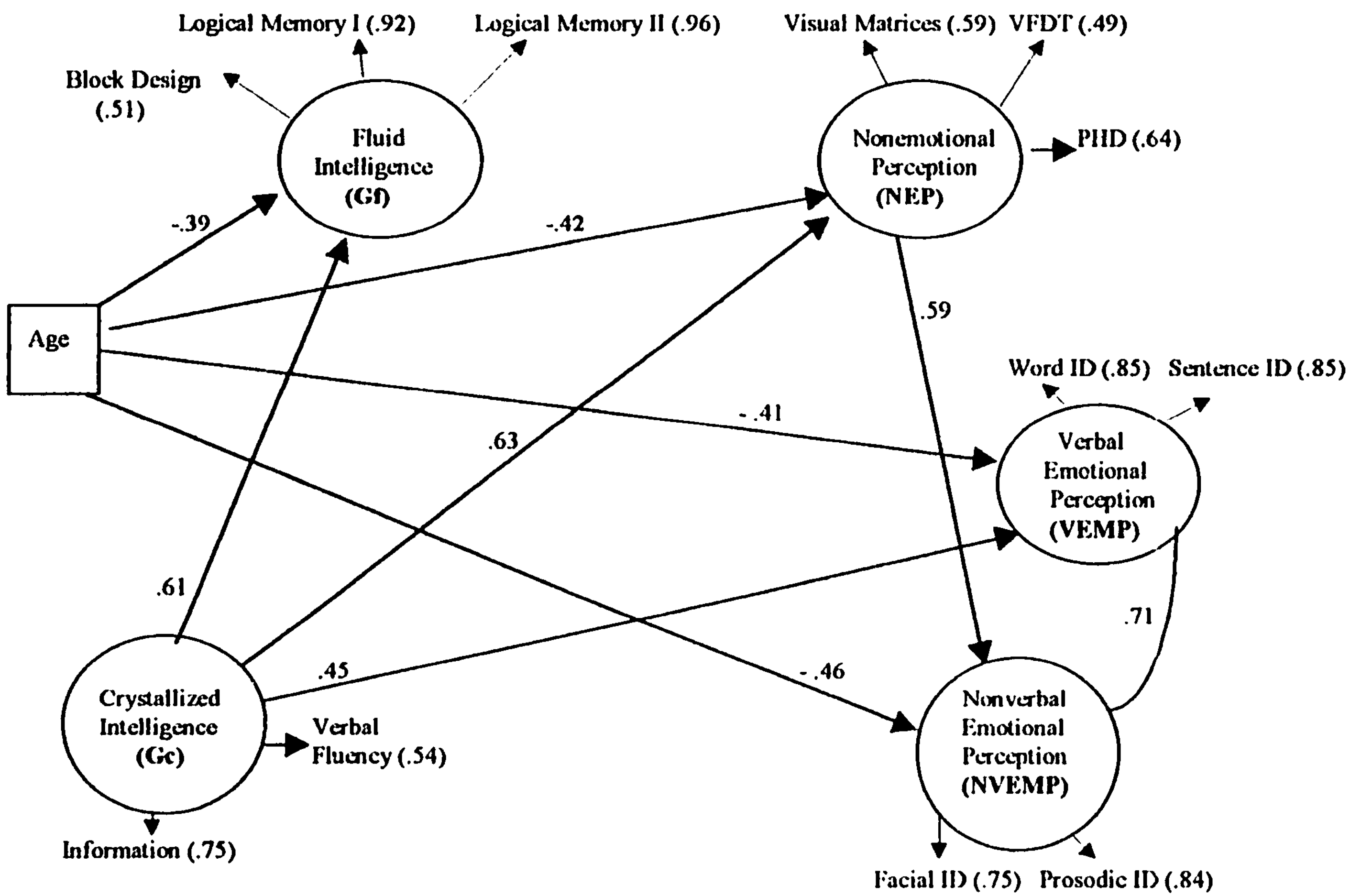
*Factor loadings > .40

Discrimination, Intonation Contours Perception, Phoneme Discrimination, and Visual Matrices), and all the emotional identification measures, with loadings ranging from .44 for Block Design to .75 for Facial Emotional Identification. This factor could be interpreted to represent a perceptual factor. The two Logical Memory subtests showed high loadings of .95 and 1.00 on Factor 2, which can easily be characterized as a verbal memory factor.

A structural equation model including all the variables in the factor analysis described above was hypothesized. The initial model posed resulted in a poor fit of the data (CFI = .84). However, when variables were removed from the model sequentially, based on the same rationale as in the previous analyses, the fit improved with each step. First, ICP was removed from the Nonemotional Perceptual factor, followed by Facial Recognition. Finally, when the Cancellation variable was removed from the Fluid factor, the resulting model (see Figure 4) provided a good fit of the data (CFI = .91).

Here, the measurement model differed from prior structural analyses in two ways: Verbal Fluency, as opposed to Vocabulary, was included with Information in the Crystallized factor, and Phoneme Discrimination was included with VFDT and Visual Matrices in the Nonemotional Perceptual factor (see Figure 4 for variable-to-factor loadings). The structural model also differed from previous analyses, in that a relation of age to the Nonemotional Perceptual factor ($\phi = -.42$) emerged, probably due to the inclusion of PHD in that factor, while the relation of age to VEMP was not statistically significant. As in previous models, relations of age to Gf ($\phi = -.39$) and to NVEMP ($\phi = -.46$) were seen. In addition, a relation of Gc to the NEP factor emerged ($\phi = .63$). This

Figure 4. Best-fitting Structural Equation Model, Post Hoc Analysis 2




*CFI* = .91

may involve abilities common to phonemic verbal fluency and phonemic discrimination that allow for performance on the former to become predictive of performance on the latter. The Gc relation with Gf ($\phi$ = .61) and VEMP ($\phi$ = .45) was retained. However, the relation of Gf to the NEP factor was no longer present. Finally, while NVEMP was influenced by NEP in the current model ($\phi$ = .59), VEMP was not. This was probably a function of the effect of auditory discrimination on prosodic emotional perceptual ability. The two emotional perception factors maintained a strong relation ($\phi$ = .71).

Consistencies Among Exploratory Factor Analyses. For all analyses, only two to three factors were extracted from the data. Noteworthy is the fact that across different combinations of variables and sample sizes, the emotional tasks consistently loaded together on one factor, and displayed moderate to high factor loadings (i.e., .53 to .82). In addition, some variables that loaded with the emotional tasks may have been associated with them based on similarities in task construction and/or task stimuli. The solutions consistently resulted in a perceptual factor that included the highest loadings for emotional variables along with significant loadings of nonemotional perceptual variables.

Consistencies Among The Structural Models. Though each of the best-fitting structural models had some unique aspects with respect to factor relations, several consistencies were observed across models. For example:

1.) All models hypothesized emotional perception as separate from, but related to, the conventional notion of intelligence as represented by the crystallized and fluid factors. (As described above, for the a priori structural model, emotional perception was initially included as part of Gc, but when age was added to the model, it did not provide a good fit.) Though best exemplified as separate due to differential relations with other factors, verbal and nonverbal emotional perception were consistently very highly correlated.

2.) Crystallized intelligence was invariably associated with verbal emotional perception and not with nonverbal emotional perception. Despite this association with abilities that remain stabilized or improve over the age span, a significant relationship was observed between age and both verbal and nonverbal emotional perception in two out of the three models. This suggests that the Gc/VEMP relation was based on characteristics (most likely lexical) other than aging patterns.

3.) In all models, once age was statistically controlled, no relation emerged between either measure of emotional perception and fluid intelligence. This outcome suggests that this relation, which according to Pearson correlations was, for NVEMP and Gf, $\underline{r} = .58$, $\underline{p} < .05$, and for VEMP and Gf, $\underline{r} = .61$, $\underline{p} < .05$, was driven by unmeasured age-related changes occurring in both factors. These age-related changes, which most likely involve alterations in underlying physiology, are common to both fluid abilities and emotional perception, and are causing the measures to appear correlated over time.

Discrepancies Among the Structural Models. When the vocabulary measure was included in the crystallized factor (Analysis 1; see Figure 3), a positive relation between age and crystallized intelligence emerged. In addition, as mentioned above, the linkages of

Gc with VEMP and Gf were stronger than in other models, which probably involves the influence of vocabulary skills on verbal memory and verbal emotional perception.

In Analysis 2, which included Verbal Fluency in the Gc factor and Phoneme Discrimination in the NEP factor, the age relation with VEMP observed in the other models was not statistically significant (see Figure 4). In addition, linkages specific to this model appeared between Gc and NEP (possibly due to shared phonemic aspects of the Verbal Fluency and Phoneme Discrimination tasks) and between NEP and NVEMP (where performance on PHD may have been predictive of performance on the prosodic emotional task). By contrast, no relations surfaced between NEP and VEMP, as seen in the other two models when NEP consisted only of the two visual perception tasks (i.e., VFDT and VMAT). This model included two tasks in the Gc factor, both auditory and visual perceptual tasks in the NEP factor, and an adequate subject to factor ratio. The relationship of NEP to NVEMP (as opposed to VEMP) seems more appropriate than that observed between NEP and VEMP in the other two models, considering that tasks contributing to both NEP and NVEMP draw largely upon both auditory and visual perceptual ability. Finally, the relation between Gc and VEMP is maintained in this model, and, furthermore, as opposed to the other models, both factors have nonsignificant relations with age. This added similarity is noteworthy in the context of the hypothesized association of emotional perception with crystallized intelligence.

Correlational Analyses for Age Relations

To further examine the aging pattern of emotional perception in the context of the Gf/Gc dichotomy, correlational analyses were performed. New variables were created by combining individual task scores through summation, to represent the following: crystallized ability 1 (Gc1), for which Information and Verbal Fluency scores were summed; crystallized ability 2 (Gc2), for which Information and Mill Hill Vocabulary scores were summed; fluid ability (Gf) for which Block Design, Logical Memory I, and Logical Memory II scores were summed; nonemotional perception (NEP2), for which the Visual Form Discrimination Test, Visual Matrices, Facial Recognition, Phoneme Discrimination, and Intonation Contours Perception scores were summed; nonverbal emotional perception (NVEMP), for which facial emotional identification and prosodic emotional identification scores were summed; nonemotional verbal perception (NEVP), for which nonemotional word identification and nonemotional sentence identification scores were summed; and verbal emotional perception (VEMP), for which emotional word identification and emotional sentence identification scores were summed. The rationale for classifications of the Gc and Gf variables is discussed above in the "Statistical Analyses Specific to Each Hypothesis and Predictions" section (pp. 86-87). The rationale for summation as the method of combining scores is discussed above in the "Data Analysis" section (p. 84-85). Separate combinations of variables were used for Gc (i.e., Information + Verbal Fluency; Information + Vocabulary) for comparison purposes and because of missing data from the Vocabulary variable.

Simple Pearson product moment correlations were calculated for age with Gc and Gf. For NVEMP, a partial correlation controlling for NEP2 was calculated to obtain an estimate of the relationship between age and NVEMP with nonemotional perceptual ability taken into account. Similarly, for VEMP, a partial correlation was calculated.

controlling for NEVP to obtain an estimate of the relationship of age to VEMP with nonemotional verbal perceptual abilities taken into account (see Table 13). The order of the magnitude of these values, largest to smallest, was as follows: NVEMP ($r = -.62$, $p < .001$), Gf ($r = -.53$, $p < .01$), VEMP ($r = -.29$, $p < .01$), Gc2 ($r = -.15$, $p > .05$). The correlation coefficient for Gc1 was in the positive direction ($r = .31$, $p < .01$). These values are in the order predicted with the exception of NVEMP, which was expected to show a weaker, as opposed to a stronger, relation with age than fluid abilities. However, whereas both emotional perception variables were expected to exhibit age relations more similar to crystallized intelligence (i.e., positive or insignificant), results indicated significant inverse relationships with age, which is more characteristic of fluid abilities. Interestingly, controlling for NEP did not affect the age relation with NVEMP at all, as the correlation between NVEMP and age was $r = -.62$, $p < .01$. In contrast, the correlation of VEMP with age ($r = -.40$, $p < .01$) was attenuated when NEVP was controlled ($r = -.29$, $p < .01$). This may have to do with the fact that the verbal nonemotional tasks were designed to be highly similar to their emotional counterparts. With control tasks better matched to nonverbal emotional perception, some attenuation of the strength of the age relation may have been seen. Importantly, the magnitude of the values for both NVEMP and VEMP indicates that significant decline in emotional perceptual abilities is seen across the age span, even after the variance attributed to age changes in nonemotional cognitive abilities is taken into account.

Table 13.
Correlations Between Age and Crystallized, Fluid, and Emotional Perceptual Abilities.

| Variable | Age | Control | Partial Correlation |
|---|---|---|---|
| Gc1 | .31* | | |
| Gc2 | - .15 | | |
| Gf | - .53* | | |
| VEMP | - .40* | NVEP | - .29 |
| NVEMP | - .62 | NEP | - .62 |

*p < .01

Group Tests for Age Differences

Prior to examining group differences in individual task performance, independent group t-tests were performed for older and younger subjects on the demographic variables of gender, education, and occupational status. No differences emerged between either the median-split group or the old-younger group on any of these variables (see Tables 14 and 15).

Age effects were examined using independent group t-tests to compare younger and older subjects' performance on nonemotional cognitive tasks, with individual task scores serving as the dependent variables. T-values and p levels for the comparisons are presented in tabular form (see Tables 14 and 15). ANCOVAs, controlling for nonemotional perceptual abilities, were used to compare the younger and older groups on all emotional tasks (see Tables 16 and 17). For all of these between-group analyses, subjects were assigned to groups based on age, with one condition for group assignment splitting the sample at the median age (48.5 years) and the other splitting the sample at age

70 (i.e., under 70, 70 and older). From this point on, these groups will be referred to as the median-split group and the old-younger group, respectively.

For discrimination tasks from the NYEB, including Nonemotional Word Discrimination, Emotional Word Discrimination, Facial Discrimination, and Prosodic Discrimination, each form was administered to approximately half of the subject sample Therefore, separate analyses were performed for each of the two forms of these tasks. Independent group t-tests were performed for the recipients of Forms 1 and 2 for each discrimination task to see whether the groups differed on the demographic variables of age, gender, education, and occupational status. For the Nonemotional Word Discrimination task, significantly more men were administered Form 1 (29 men, 16 women) while significantly more women were administered Form 2 (36 women, 19 men). For the Emotional Word Discrimination task, significantly more women were administered Form 1 (29 women, 16 men), while significantly more men were administered Form 2 (36 men, 19 women). No differences emerged on demographic variables of age, education, or occupational status.

Nonemotional Cognitive Tasks. When scores from the median-split group were compared using individual task scores as dependent variables, superiority among younger adults was seen for Block Design, Logical Memory I and II, Cancellation, Phoneme Discrimination, Nonemotional Sentence Identification, and Nonemotional Word Discrimination (Form 2). Performance on the Mill Hill Vocabulary Test, however, was significantly better in the older group (see Table 14).

Table 14.
Comparisons of Median-Split Groups on Demographic and Performance Variables.

| | **Younger** (n = 50) | | **Older** (n = 50) | | | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | Mean | SD | t | df | p |
| Education | 14.82 | 2.30 | 14.84 | 2.41 | -0.04 | 98 | .966 |
| Occupational Status | 6.30 | 1.78 | 6.68 | 1.30 | -1.22 | 98 | .225 |
| | Males | Females | Males | Females | $\chi^2$ | df | p |
| Gender | 20 | 30 | 25 | 25 | 1.01 | 1 | .422 |

| Variable | Mean | SD | Mean | SD | t | df | p |
|---|---|---|---|---|---|---|---|
| INFO | 21.14 | 5.45 | 22.74 | 4.54 | 1.60 | 98 | .114 |
| BD | 31.94 | 10.32 | 22.60 | 9.84 | 4.63 | 98 | .000** |
| LMI | 26.32 | 6.68 | 23.72 | 6.47 | 1.98 | 98 | .051* |
| LMII | 22.94 | 6.49 | 19.54 | 6.78 | 2.56 | 98 | .012* |
| CANC | 108.07 | 14.71 | 94.77 | 16.86 | 4.20 | 98 | .000** |
| VMAT | 23.52 | 0.95 | 23.14 | 1.34 | 1.63 | 98 | .105 |
| VFDT | 30.02 | 2.07 | 29.80 | 2.44 | 0.49 | 98 | .628 |
| FACREC | 47.64 | 3.44 | 47.20 | 4.49 | 0.55 | 91.81 | .583 |
| PHD | 28.26 | 1.48 | 27.38 | 1.94 | 2.55 | 91.73 | .012* |
| ICP | 21.46 | 2.76 | 21.20 | 2.84 | 0.46 | 98 | .643 |
| NWID | 23.00 | 1.20 | 22.58 | 1.57 | 1.51 | 91.62 | .135 |
| NSID | 19.86 | 1.99 | 18.22 | 3.18 | 3.09 | 82.22 | .003** |

| | **Younger** | | | **Older** | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | N | Mean | SD | N | Mean | SD | t | df | p |
| VOCAB | 35 | 70.29 | 13.00 | 39 | 78.85 | 15.37 | -2.57 | 72 | .012* |
| FLUENCY | 44 | 47.84 | 12.37 | 48 | 44.69 | 14.26 | 1.13 | 90 | .262 |
| NWDS1 | 22 | 22.32 | 2.44 | 26 | 21.54 | 2.86 | 1.09 | 46 | .280 |
| NWDS2 | 28 | 23.32 | 2.16 | 24 | 21.54 | 2.86 | 2.55 | 50 | .014* |

* p < .05; ** p < .01

When scores from the old-younger group were compared, many similar results were obtained. The younger adults achieved significantly higher scores on Block Design, Logical Memory I and II, Cancellation, Phoneme Discrimination, Nonemotional Sentence Identification, and Nonemotional Word Discrimination (Form 1). However, in contrast to what was observed when groups were divided according to the median age, there was a significant difference in performance on the Verbal Fluency task between younger and older subjects. Subjects younger than 70 produced more words to phonemic cues than subjects 70 and over. In addition, the older advantage observed for the median-split group on the vocabulary task was not seen in the over 70 group (see Table 15).

Emotional Discrimination Tasks. When the two median-split groups were compared, younger adults were significantly more accurate than older on five of the six discrimination tasks. Though the younger advantage did not reach significance on the Prosodic Discrimination (Form 1) task, this task's internal consistency was low, with a Cronbach's alpha of < .50. Similar results were seen in the old-younger comparison (see Tables 16 and 17).

Emotional Identification Tasks. Significant differences were observed between subjects from the median-split groups, with younger adults exhibiting better performance on all emotional identification tasks (see Table 16).

Similarly, for the old-younger groups, significant differences were seen on all emotional identification tasks. In all cases, younger subjects showed greater accuracy in identifying emotional stimuli (see Table 17).

Table 15.
Comparisons of Old-Younger Groups on Demographic and Performance Variables.

| | Younger (n = 82) | | Older (n = 18) | | | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | Mean | SD | t | df | p |
| Education | 14.77 | 2.36 | 15.11 | 2.32 | -0.57 | 25.29 | .577 |
| Occupational Status | 6.41 | 1.65 | 6.83 | 1.04 | -1.03 | 98 | .305 |
| | Males | Females | Males | Females | $\chi^2$ | df | p |
| Gender | 36 | 46 | 9 | 9 | .222 | 1 | .794 |
| Variable | Mean | SD | Mean | SD | t | df | p |
| INFO | 21.82 | 5.15 | 22.50 | 4.68 | .52 | 98 | .606 |
| BD | 29.35 | 10.39 | 17.78 | 9.13 | 4.37 | 98 | .000** |
| LMI | 25.98 | 6.69 | 20.67 | 4.64 | 4.02 | 35.55 | .000** |
| LMII | 22.49 | 6.39 | 15.56 | 5.86 | 4.22 | 98 | .000** |
| CANC | 104.12 | 15.65 | 89.15 | 18.46 | 3.56 | 98 | .001** |
| VMAT | 23.46 | 1.06 | 22.72 | 1.49 | 2.01 | 20.92 | .058 |
| VFDT | 30.06 | 2.17 | 29.22 | 2.56 | 0.84 | 98 | .153 |
| FACREC | 47.60 | 3.74 | 46.61 | 5.00 | 0.79 | 21.37 | .438 |
| PHD | 28.10 | 1.67 | 26.56 | 1.72 | 3.53 | 98 | .001** |
| ICP | 21.38 | 2.71 | 21.11 | 3.20 | 0.37 | 98 | .715 |
| NWID | 22.94 | 1.26 | 22.11 | 1.81 | 1.84 | 20.76 | .080 |
| NSID | 19.56 | 2.18 | 16.67 | 3.84 | 3.09 | 19.47 | .006** |

| | Younger | | | Older | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | N | Mean | SD | N | Mean | SD | t | df | p |
| VOCAB | 58 | 73.71 | 14.56 | 16 | 78.75 | 15.65 | -1.21 | 72 | .231 |
| FLUENCY | 74 | 47.77 | 12.56 | 18 | 39.72 | 15.18 | 2.34 | 90 | .022* |
| NWDS1 | 41 | 22.32 | 2.18 | 7 | 19.43 | 2.76 | 3.11 | 46 | .003** |
| NWDS2 | 41 | 22.83 | 2.53 | 11 | 21.27 | 2.80 | 1.77 | 50 | .082 |

* p < .05; ** p < .01

Table 16. 

Emotional Task Performance as a Function of Age (Median-Split Group Comparisons).

**Emotional Identification Tasks**

| | Younger (n = 50) | | Older (n = 50) | | | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | Mean | SD | Control | F | df | p |
| FID | 24.70 | 3.14 | 22.10 | 3.50 | FR,VM,VF | 13.08 | 4, 95 | .000** |
| PID | 15.78 | 2.71 | 12.28 | 4.38 | ICP,PHD | 19.77 | 3, 96 | .000** |
| EWID | 22.10 | 2.01 | 20.82 | 2.96 | NWID | 10.69 | 2, 97 | .000** |
| ESID | 19.98 | 2.66 | 18.16 | 3.40 | NSID | 6.65 | 2, 97 | .002** |

**Emotional Discrimination Tasks**

| | Younger | | | Older | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | n | Mean | SD | n | Mean | SD | F | df | p |
| FDIS1 | 23 | 23.22 | 2.04 | 26 | 21.85 | 1.97 | 4.02 | 4,44 | .007** |
| FDIS2 | 27 | 24.56 | 1.28 | 24 | 22.46 | 2.60 | 7.70 | 4,46 | .000** |
| PDIS1 | 28 | 27.21 | 0.88 | 24 | 26.67 | 1.09 | 1.42 | 4,46 | .250 |
| PDIS2 | 22 | 25.73 | 0.77 | 26 | 24.85 | 1.85 | 4.57 | 3,44 | .007** |
| EWDIS1 | 28 | 24.96 | 2.59 | 24 | 23.00 | 2.41 | 18.01 | 2,49 | .000** |
| EWDIS2 | 22 | 21.72 | 2.55 | 26 | 23.15 | 3.25 | 20.78 | 2,45 | .000** |

Note. For face and prosody, controls for discrimination tasks were the same as those for ID tasks. For EWDIS1, NWDIS2 was the control; for EWDIS2, NWDIS1 was used.

FR=Facial Recognition; VM=Visual Matrices; VF=Visual Form Discrimination Test

ICP=Intonation Contours Perception; PHD=Phoneme Discrimination

**p < .01

Table 17. 

Emotional Task Performance as a Function of Age (Old-Younger Group Comparisons).

**Emotional Identification Tasks**

| | Younger (n = 82) | | Older (n = 18) | | | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | Mean | SD | Control | F | df | p |
| FID | 24.10 | 3.25 | 20.22 | 3.19 | FR,VM,VF | 13.82 | 4, 95 | .000** |
| PID | 15.10 | 3.14 | 9.17 | 4.10 | ICP,PHD | 28.79 | 3, 96 | .000** |
| EWID | 21.99 | 2.12 | 19.06 | 3.24 | NWID | 18.13 | 2, 97 | .000** |
| ESID | 19.98 | 2.66 | 18.16 | 3.40 | NSID | 6.65 | 2, 97 | .002** |

**Emotional Discrimination Tasks**

| | Younger | | | Older | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | n | Mean | SD | n | Mean | SD | F | df | p |
| FDIS1 | 41 | 22.85 | 1.93 | 8 | 20.63 | 2.07 | 4.23 | 4,44 | .006** |
| FDIS2 | 41 | 23.73 | 2.26 | 10 | 22.90 | 2.23 | 3.92 | 4,46 | .008** |
| PDIS1 | 42 | 27.05 | 1.04 | 10 | 26.60 | .84 | 0.62 | 3,48 | .606 |
| PDIS2 | 40 | 25.53 | 1.32 | 8 | 23.88 | 1.73 | 5.61 | 3,44 | .002** |
| EWDIS1 | 41 | 24.39 | 2.66 | 11 | 22.82 | 2.44 | 16.65 | 2,49 | .000** |
| EWDIS2 | 41 | 22.80 | 2.82 | 7 | 20.71 | 3.64 | 12.92 | 2,45 | .000** |

Note. For face and prosody, controls for discrimination tasks were the same as those for ID tasks. For EWDIS1, NWDIS2 was the control; for EWDIS2, NWDIS1 was used.

FR=Facial Recognition; VM=Visual Matrices; VF=Visual Form Discrimination Test

ICP=Intonation Contours Perception; PHD=Phoneme Discrimination

**p < .01

## Secondary Hypotheses

Results for each hypothesis will be discussed separately. Initially, results for examination of the Common Cause Hypothesis as it relates to emotional perception will be reported. Second, results for hypotheses related to gender and emotional perception will be presented. Third, relations among gender, age, and valence will be reported.

### The Common Cause Hypothesis

The Common Cause hypothesis (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994) stipulates that a significant amount of the variance in the relationship of age to cognitive variables can be explained by age differences in sensory functioning. To test this hypothesis as it related to emotional perception, hierarchical regressions were calculated to estimate the reduction of age-related variance for nonverbal emotional perception (NVEMP) and verbal emotional perception (VEMP) accounted for by differences in hearing thresholds.

Table 18 presents the results from the hierarchical regression analyses. The dichotomous age variable alone showed significant relations to each of the emotional measures, accounting for 16 and 39% of the variance. Comparing the age-related variance in Columns 1 and 2 indicates that control of hearing thresholds resulted in only a modest attenuation of age-related variance, 38% for NVEMP and 47% for VEMP. This is in marked contrast to the results of Baltes and Lindenberger. They investigated the degree to which controlling for hearing acuity mediated age effects among five intellectual variables, including perceptual speed, reasoning, memory, knowledge, and fluency. They found that linear and quadratic age trends in intellectual abilities were no longer significantly different from zero after controlling for hearing acuity. The current results do not support the common cause hypothesis as it relates to emotional perception. It is important to note, however, that the present sample is significantly smaller (i.e., 100 subjects versus 687) and covers a much narrower and younger age range than that of the sample from the Lindenberger and Baltes study (25 – 103 years).

Table 18.

Hierarchical Regression for Emotional Measures Controlling for Hearing Threshold.

| | Age Alone | | Age After Hearing | | % Reduction in Variance |
|---|---|---|---|---|---|
| Criterion | B | $R^2$ | B | $\Delta R^2$ | |
| NVEMP | -.24* | .39 | -.21* | .24 | 38 |
| VEMP | -.12* | .16 | -.10* | .09 | 47 |

Note: $\Delta R^2$ = increment in $R^2$, NVEMP = nonverbal emotional perception, VEMP = Verbal emotional perception

*$p < .01$

Gender and Emotional Perception

Prior to examining group differences in emotional perception, independent group t-tests were performed for men and women on the demographic variables of age, education, and occupational status. One difference emerged, with men having significantly higher levels of education than women, $t$ (98) = 2.24 , $p < .05$ (see Table 19). In order to test the hypothesis related to gender and emotion, which stipulated that women would evidence superior decoding abilities on emotional tasks relative to men, ANCOVAs controlling for education were conducted to compare men and women on emotional identification and discrimination variables. Significant differences were observed between men and women on the sentence identification task, where women outperformed men, and on both forms of the word discrimination task, where men performed better than women (see Table 19).

Gender and Valence

To examine the hypotheses related to gender and valence, variables were created grouping items from the emotional identification tasks according to individual task and valence. For example, the variable FACIDP represented the combined score for all positive items on the facial identification task divided by the number of positive items. There were three positive emotions with four items per emotion, so the score was calculated as follows: $(0 + 1 + 1 + 0 + 1 + 0 + 1 + 1 + 1 + 1 + 1 + 1)/12 = .75$. Thus, the values for these variables range from 0 to 1. To detect simple main effects of gender on differentially valenced items, all positive items and all negative items from all four

Table 19. 

Comparison of Gender Groups on Demographics and Emotional Perception Tasks.

| | Men (n = 45) | | Women (n = 55) | | | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | Mean | SD | t | df | p |
| Age | 50.47 | 17.69 | 47.42 | 17.37 | 0.87 | 98 | .389 |
| Education | 15.40 | 2.67 | 14.36 | 1.95 | 2.24 | 98 | .027* |
| Occupational Status | 6.80 | 1.62 | 6.24 | 1.48 | 1.82 | 98 | .072 |

**Emotional Identification Tasks**

| Variable | Mean | SD | Mean | SD | F | df | p |
|---|---|---|---|---|---|---|---|
| FID | 23.40 | 3.68 | 23.40 | 3.49 | 0.65 | 2, 97 | .523 |
| PID | 13.91 | 4.68 | 14.13 | 3.45 | 1.83 | 2, 97 | .166 |
| EWID | 21.58 | 2.74 | 21.36 | 2.50 | 2.93 | 2, 97 | .058 |
| ESID | 18.98 | 3.34 | 19.15 | 3.06 | 6.27 | 2, 97 | .003** |

**Emotional Discrimination Tasks**

| | Men | | | Women | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | n | Mean | SD | n | Mean | SD | F | df | p |
| FDIS1 | 22 | 21.95 | 2.15 | 27 | 22.93 | 2.00 | 2.31 | 2,46 | .111 |
| FDIS2 | 23 | 23.83 | 1.53 | 28 | 23.36 | 2.72 | 1.50 | 2,48 | .233 |
| PDIS1 | 24 | 26.96 | 1.20 | 28 | 26.96 | 0.84 | 0.91 | 2,49 | .410 |
| PDIS2 | 21 | 24.95 | 1.96 | 27 | 25.48 | 1.01 | 0.88 | 2,45 | .422 |
| EWDIS1 | 16 | 24.75 | 2.44 | 36 | 23.75 | 2.75 | 6.55 | 2,49 | .003** |
| EWDIS2 | 29 | 23.17 | 2.99 | 19 | 21.47 | 2.80 | 7.11 | 2,45 | .002** |

**p < .01

emotional identification tasks were combined (e.g., FACIDP + PROSIDP + EWIDP + ESIDP = POS).

Independent group t-tests were performed using the combined valence variables (i.e., POS and NEG) as well as the individual task valence variables (e.g., FACIDP, PROSIDN). No significant differences emerged between males and females on any of the valence variables (see Table 20).

Age and Valence

In order to examine the relations among age and perception of positive and negative emotional stimuli, Pearson correlations were computed among the three variables of age, positive items (i.e., POS), and negative items (NEG). Strong negative correlations were observed for both positive ($r = -.54$, $p < .001$) and negative ($r = -.49$, $p < .001$) items with age (see Table 21).

To examine in greater detail the relationship between age and valence, Pearson correlations were calculated between age and the individual task valence variables described above. Significant negative correlations with age were observed for each variable, ranging from $r = -.27$, $p < .01$, for FACIDP and EWIDP, to $r = -.53$, $p < .001$, for PROSIDP. For FACID and EWID, correlations with age were stronger for negative than for positive items. For PROSID and ESID, correlations with age were stronger for positive than for negative items (see Table 22).

Table 20.
Comparisons of Gender Groups on Emotional Valence Variables.

| | **Males** (n = 45) | | **Females** (n = 55) | | | | |
|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | Mean | SD | t | df | p |
| POS | 2.88 | .518 | 2.95 | .448 | -0.69 | 98 | .490 |
| NEG | 3.06 | .519 | 3.04 | .458 | 0.15 | 98 | .884 |
| FACIDP | .717 | .144 | .723 | .120 | 0.23 | 98 | .819 |
| FACIDN | .740 | .127 | .737 | .141 | 0.10 | 98 | .920 |
| PROSIDP | .496 | .258 | .546 | .208 | 1.06 | 98 | .304 |
| PROSIDN | .615 | .212 | .615 | .155 | 0.01 | 98 | .994 |
| EWIDP | .889 | .148 | .885 | .142 | 0.14 | 98 | .890 |
| EWIDN | .905 | .116 | .892 | .119 | 0.55 | 98 | .582 |
| ESIDP | .780 | .143 | .796 | .138 | -0.56 | 98 | .579 |
| ESIDN | .797 | .159 | .799 | .166 | -0.05 | 98 | .957 |

POS = all positive items across emotional ID tasks
NEG = all negative items across emotional ID tasks

FACIDP = positive items from facial emotional ID
FACIDN = negative items from facial emotional ID
PROSIDP = positive items from prosodic emotional ID
PROSIDN = negative items from prosodic emotional ID
EWIDN = negative items from emotional word ID
ESIDP = positive items from emotional sentence ID
ESIDN = negative items from emotional sentence ID

Table 21.



Intercorrelations Among Age, Positive, and Negative Items for Entire Sample, Men and Women.

Whole Sample ($\underline{n}$ = 100)

| | AGE | POS | NEG |
|---|---|---|---|
| AGE | --- | -.540** | -.499** |
| POS | --- | --- | .631** |
| NEG | --- | --- | --- |

Males ($\underline{n}$ = 45)

| | AGE | POS | NEG |
|---|---|---|---|
| AGE | --- | -.603** | -.583** |
| POS | --- | --- | .760** |
| NEG | --- | --- | --- |

Females ($\underline{n}$ = 55)

| | AGE | POS | NEG |
|---|---|---|---|
| AGE | --- | -.476** | -.428* |
| POS | --- | --- | .499** |
| NEG | --- | --- | --- |

POS = all positive items combined across Emotional ID tasks.
NEG = all negative items combined across Emotional ID tasks.

*p < .01, **p < .001

Table 22.

Intercorrelations Among Age and Differentially-Valenced Items from Emotional Identification (ID) Tasks for Entire Sample.

($\underline{n}$ = 100)

| | AGE | FACIDP | FACIDN | PROSIDP | PROSIDN | EWIDP | EWIDN | ESIDP |
|---|---|---|---|---|---|---|---|---|
| AGE | ------ | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| FACIDP | - .268* | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| FACIDN | - .514** | .365** | ------- | ------- | ------- | ------- | ------- | ------- |
| PROSIDP | - 534** | .323* | .440** | ------- | ------- | ------- | ------- | ------- |
| PROSIDN | - .482** | .158 | .503** | .435** | ------- | ------- | ------- | ------- |
| EWIDP | - .270* | .300* | .424** | .462** | .461** | ------- | ------- | ------- |
| EWIDN | - .340** | .318* | .573** | .387** | .484** | .465** | ------- | ------- |
| ESIDP | - .437** | .336** | .429** | .450** | .340** | .385** | .448** | ------- |
| ESIDN | -.278* | .164 | .544** | .311* | .541** | .510** | .634** | .423** |

Note. *p < .01, **p < .001.

Gender, Age, and Valence

To ascertain whether differences existed between men and women in the relationship of age with valence, separate correlation matrices were computed for men and women among the three variables of age, positive items (POS), and negative items (NEG). For men, both positive and negative items showed high negative correlations with age (for POS, $r = -.60$, $p < .001$; for NEG, $r = -.58$, $p < .001$; see Table 21). Similarly, for women, with age, performance on both positive and negatively valenced items declined (for POS, $r = -.48$, $p < .001$; for NEG, $r = -.43$, $p < .01$; see Table 21).

Separate correlation matrices were also computed for men and women using the variables described above, which grouped items according to individual task and valence. Nearly identical patterns were obtained for men and women. For both groups, two of the four negative variables (facial and prosodic identification), and two of the four positive variables (prosodic and sentence identification) showed significant age-related decline (see Tables 23 and 24). However, the word identification task also showed a significant inverse relation with age for men, but not for women.

The strength of the negative age correlations varied across tasks according to gender. To examine whether any of the differences in correlations were statistically significant, the $z$-test for unrelated correlations was performed (Martinez-Pons, 1999). Only the difference between correlations for the negative prosodic items was significant ($z = -1.61$, $p < .05$). For men, this correlation was $r = -.60$, $p < .001$, while for women, it was $r = -.36$, $p < .01$.

Table 23.

Intercorrelations Among Age and Differentially-Valenced Items from Emotional Identification (ID) Tasks for Men.

($\underline{n}$ = 45)

| | AGE | FACIDP | FACIDN | PROSIDP | PROSIDN | EWIDP | EWIDN | ESIDP |
|---|---|---|---|---|---|---|---|---|
| AGE | ------ | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| FACIDP | - .298 | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| FACIDN | - .475** | .463* | ------- | ------- | ------- | ------- | ------- | ------- |
| PROSIDP | - .604** | .258 | .501** | ------- | ------- | ------- | ------- | ------- |
| PROSIDN | - .603** | .207 | .566** | .508** | ------- | ------- | ------- | ------- |
| EWIDP | - .370 | .178 | .644** | .500** | .617** | ------- | ------- | ------- |
| EWIDN | - .489** | .367 | .607** | .478** | .555** | .589** | ------- | ------- |
| ESIDP | - .412* | .280 | .452* | .544** | .509** | .517** | .471* | ------- |
| ESIDN | -.360 | .195 | .613** | .390* | .658** | .731** | .665** | .622** |

Note. *p < .01, **p < .001.

Table 24.

Intercorrelations Among Age and Differentially-Valenced Items from Emotional Identification (ID) Tasks for Women.

(n = 55)

| | AGE | FACIDP | FACIDN | PROSIDP | PROSIDN | EWIDP | EWIDN | ESIDP |
|---|---|---|---|---|---|---|---|---|
| AGE | ------ | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| FACIDP | -.239 | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| FACIDN | -.550** | .286 | ------- | ------- | ------- | ------- | ------- | ------- |
| PROSIDP | -.458** | .401* | .401* | ------- | ------- | ------- | ------- | ------- |
| PROSIDN | -.359* | .093 | .461** | .340 | ------- | ------- | ------- | ------- |
| EWIDP | -.187 | .426* | .256 | .434** | .289 | ------- | ------- | ------- |
| EWIDN | -.231 | .279 | .550** | .321 | .424* | .363* | ------- | ------- |
| ESIDP | -.455** | .392* | .415* | .349* | .154 | .272 | .437** | ------- |
| ESIDN | -.215 | .138 | .497** | .242 | .434** | .332 | .612** | .264 |

Note. *p < .01, **p < .001.

# Discussion

## Emotional Perception: Fluid, Crystallized, or Distinct?

In this study, an attempt was made to examine emotional perception in the context of the comprehensive Cattell-Horn theory of fluid and crystallized intelligence. This theory relates to Hebb's distinction between Intelligence A and Intelligence B and involves concepts pertaining to the nature-nurture issue, different rates of development, and effects of changes in brain physiology. Fluid ability involves problem solving and reasoning where the efficiency is based on adaptation and flexibility in the face of novel stimuli. Crystallized ability refers to intellectual functioning on tasks calling on previous training, education and acculturation. In the present study, the prediction that emotional perception would be more closely related to crystallized intelligence was based on the assumption that emotional perception is a skill that would likely become more refined as a result of experience and acquisition of social knowledge.

Importantly, the effects of age on the nonemotional cognitive tasks employed were consistent with expectations based on empirical evidence. For tasks tapping areas of fluid functioning such as perceptual organization (e.g., Block Design), verbal memory (e.g. Logical Memory), and processing speed (e.g., Cancellation), younger groups showed superior performance. For verbal tasks representing crystallized functions (e.g., vocabulary, factual knowledge, verbal fluency), however, either no differences were seen (e.g., for Information), superior performance was achieved by the older group (e.g., Mill Hill Vocabulary), or differences were seen only after age 70 (e.g., Verbal Fluency). These results are consistent with the preponderance of research and suggest that the present sample is typical with respect to cognitive aging patterns.

Age-related decline was evident for all emotional perception tasks, whether assessed by examining group differences, age with task correlations, or structural models. The fact that emotional perceptual tasks showed high correlations with other types of cognition affected by age (e.g., fluid abilities; see p. 123) and that these relationships disappear when age is controlled (see Figures 2-4) suggest that there is an underlying process common to all of these abilities that is not being measured. Correlations emerge between the two domains over time as individuals age, because both sets of measures are susceptible to this common process, which causes physiological changes to the brain. In order to clarify these changing associations by further investigating differential relations between fluid and emotional abilities according to age, separate post hoc correlations were performed for the two median split groups. Results revealed that in the older group, 13 of the 16 correlations were significant, while for younger subjects, only nine out of the 16 were significant (see Table 25).

Table 25.
Correlations Between Fluid and Emotional Task Performance for Median Split Groups.

| | Younger (n = 50) | | | | | Older (n = 50) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | FID | PID | EWID | ESID | | FID | PID | EWID | ESID |
| BD | .325* | .476** | .610** | .465** | BD | .425** | .452** | .399** | .274 |
| Canc | .203 | .177 | .228 | .194 | CANC | .357* | .388** | .100 | .244 |
| LM I | .248 | .300* | .523** | .606** | LMI | .280* | .371** | .381** | .326* |
| LM II | .217 | .242 | .416** | .532** | LMII | .395** | .425** | .405** | .424** |

Note. No additional correlations were significant at the .05 level.

**p < .001; *p < .01

As can be seen in Table 25, the cancellation task is uncorrelated with any emotional measure in the younger group. However, this task, which gives a measure of processing speed, becomes correlated with the nonverbal emotional tasks with advancing age. For the younger group, verbal memory tasks are correlated more highly with verbal than nonverbal emotional measures, which is understandable considering both tasks are lexical in nature. However, these tasks become significantly correlated with both verbal and nonverbal emotional variables as a function of age. These results suggest that processing speed, immediate and delayed memory, and nonverbal emotional perception may be similarly affected by the aging process. Block Design is highly correlated with the verbal emotional tasks in the younger group, while for the older group, the relation between Block Design and Emotional Sentence Identification is not statistically significant. Though this is highly speculative, it may be that in younger individuals these tasks are correlated because they are dependent on general intellectual ability. In the older group, their lack of significant association may reflect some preservation of verbal ability concurrent with a decrease in perceptual organization and processing speed capacities.

The results depicted in Table 25 and the interpretation discussed above are consistent with the Common Cause hypothesis espoused by Baltes and Lindenberger (1997; Lindenberger & Baltes, 1994). Though these authors have emphasized the link between deterioration in sensory functioning and decline in cognitive abilities in their work, the basic rationale of the Common Cause theory can be applied here, where an emerging relationship between disparate abilities is seen over the life span. As Baltes and Lindenberger note (1997, p.13), theirs is a "third-variable" hypothesis that stresses the existence of a set of common cause factors that may involve not only changes in brain integrity, but in other physical functions as well.

It is clear from the outcomes of this study that the ability to perceive emotion, across communication channels, is highly sensitive to the changes in brain integrity that cause deterioration. One could speculate that these findings reflect differential aging patterns of right-hemisphere mediated processes, thus giving support to the right hemisphere hemi-aging hypothesis (Sackeim, 1982). Cabeza et al. (1997) suggested that age-related changes in cognitive functioning reflected by task performance and neuroimaging data are caused by changes in connectivity that result in global reorganization of function, such as that seen after brain damage. Because the right hemisphere is known to develop more elaborate connections

(Gur et al., 1980; Tucker et al., 1986), and emotional function requires extensive connectivity not only inter-cortically (neocortical-neocortical) but intra-cortically (subcortical-neocortical) (LeDoux, 1989), it follows that emotional abilities would be extremely vulnerable to the disruption caused by changes in connectivity.

All of the best-fitting structural models to the present data depicted emotional perception as an ability best considered as separate from both of the broad aspects of intelligence (Gf and Gc). When age was statistically controlled, verbal emotional perception was best exemplified as separate from, but related to, crystallized intelligence, and unrelated to fluid intelligence. When age was accounted for, nonverbal emotional perception was best characterized as unrelated to either crystallized or fluid intelligence. Interestingly, when age was treated as a continuous variable and nonemotional cognitive variables were controlled in the partial correlational analyses, the relation between age and nonverbal emotional perception was stronger than that between age and verbal emotional perception. This emphasizes another difference between the two types of emotional perception (see also Figure 4).

Differential age patterns for nonverbal and verbal emotional perception can also be explained in terms of the right-hemisphere hemi-aging hypothesis. If verbal emotional tasks are more bilaterally mediated by virtue of their lexical (LH-mediated) and emotional (RH-mediated) nature (e.g., Borod, Zgaljardic, et al., in press), and nonverbal emotional tasks are assumed to be strictly RH-mediated, the weaker age effects seen among verbal emotional abilities in combination with the overall age-related decline seen in emotional perception could be interpreted as lending support to the right hemisphere hemi-aging hypothesis.

The finding that nonverbal emotional perception is more accurately depicted as separate from verbal affect perception could be interpreted as support for the existence of the nonverbal affect lexicon postulated by Bowers et al., (1993). However, the expectation that the aging pattern of abilities related to this lexicon would correspond with that of the verbal lexicon, and thus remain resistant to age effects, was not confirmed by the present results.

Emotional Intelligence

There are only a handful of intelligence theorists that have formulated structural theories of intelligence that take into account emotional aspects of mental functioning. E.L. Thorndike (1920) originally defined social intelligence as the ability to discern one's own and others feelings, objectives, and behaviors *and* to optimally utilize that knowledge to inform one's actions.

A second theoretician to address an emotional variant of intelligence was Howard Gardner. His theory of multiple intelligences includes two subcategories relevant to emotional functioning (1993). The first is interpersonal intelligence, which is characterized by the individual's ability to notice contrasts in the moods, temperaments, motivations, and intentions of others, even when they are hidden. The second is intrapersonal intelligence, which is reflected in the individual's awareness and understanding of his or her own emotional and motivational life. Both of these abilities serve to effectively guide behavior, allowing one to successfully understand and work with others and oneself. Gardner's theory stresses the broadening of ideas regarding the range of human abilities.

According to Daniel Goleman (1995), emotional aptitude is a meta-ability that determines how well individuals are able to realize potential in all skill areas and thus, to fulfill their raw intellectual promise. Certainly, there are many famous case studies in the neuropsychological literature attesting to the devastation accompanying changes in this meta-ability, which are often caused by damage to the frontal regions of the brain. Goleman's observations are largely based on the work of Salovey and Mayer (1990; Mayer & Salovey, 1993), who originated the term "emotional intelligence." According to these authors, their theory overlaps with Gardner's (1993) intrapersonal intelligence. At the most basic level, they define emotional intelligence as the ability to "perceive accurately, appraise, and express emotion." At the next level is the "ability to access and/or generate feelings when they facilitate thought." Mayer and Salovey characterize the ability to quickly and efficiently generate emotions and emotional thoughts as an emotional fluency akin to verbal fluency (1993, p. 436). They indicate that the ability to move easily from one emotional state to another can be helpful in increasing the range of opportunities available to individuals and the likelihood that they will take advantage of these opportunities. Emotional fluency also facilitates the prioritizing of life tasks. The ability to understand emotion and to employ emotional knowledge is at the third ascending level. This involves being able to discern complex feelings such as simultaneous feelings (e.g., of love and hate) and blends (e.g., awe as a combination of fear and surprise). At the highest level is the ability to regulate emotions to promote emotional and intellectual growth (Mayer & Salovey, 1997). The authors report that emotional intelligence is correlated to other intelligences (Mayer & Geher, 1996), and that if one is intellectually smart, he or she is more likely to be emotionally smart. However, they also highlight the fact that this correlation is not so strong as to indicate the two are measures of the same thing.

In some ways, Mayer and Salovey's model of emotional intelligence fits neatly into both the present findings and the literature on emotional development in adulthood. However, the present results depart somewhat from Mayer and Salovey's premise that emotional intelligence is *part* of cognitive intelligence. The results of the current study clearly show that emotional perception, a basic component of these authors' model, is *related* to crystallized intelligence, but, importantly, *is best conceptualized as a separate entity* from either fluid or crystallized intelligence.

The emotional intelligence model is consistent with Carstensen's socioemotional selectivity theory and Labouvie-Vief's theory of cognitive emotional development. One could interpret Carstensen and Labouvie-Vief's perspectives as implying that the maintenance of basic emotional perceptual abilities is not particularly relevant for the aging individual. According to socioemotional selectivity theory, the relative importance of accuracy in this domain would lessen as a function of age, due to the decreased interaction with strangers and acquaintances and increased rate and quality of interactions with close friends and relatives. From the opposite standpoint, the decreased accuracy in emotional perception that accompanies old age elicits a compensatory response—for example, risking less exposure to situations in which one's powers of interpretation may be less than effective, and therefore promote negative consequences.

Emotional perception is a cognitively oriented (e.g., cold cognition; Bowers et al., 1993) skill that has a particular aging pattern. This aging pattern does not necessarily coincide with that of other aspects of emotional functioning, such as emotional self-regulation and emotional experience (e.g., well-being). It appears that the individual's ability to accurately perceive emotion in facial stimuli, vocal stimuli, and lexical content may deteriorate simultaneously with the acquisition of a greater degree of emotional self-regulation and well-being. Older people's relative inferiority at accurately identifying emotion in faces, voices and language presented in this study does not preclude superiority at identifying the same types of stimuli in the context of their most frequent interactions (e.g., with close friends and relatives). Family members and couples who are together for long periods of time can often sense each other's moods with minimal facial, prosodic, and verbal cues despite the advent of old age. As Carstensen (1992) points out, the requirements for social interactions change over the life span. Whereas younger people seek out new contacts in order to acquire new information, which may be utilized in the present or the future, older people minimize risk and the opportunity for negative consequences by limiting social circles and striving for increased intimacy with significant others. Thus, the ability to discern emotional tone, facial expression, and emotion in lexical content (at least in unfamiliar circumstances as it was measured in this study) becomes less important, superceded by the need for emotional regulation and maintenance of self-image, which is achieved by strengthening existing bonds.

From Labouvie-Vief's (1997) perspective, the acquisition of qualities such as more differentiated emotional experience, better self-monitoring of emotional processes, and reliance on internally generated principles for emotion regulation are key to emotional adaptation and growth. While less mature individuals tend to repress emotion to avoid conflict and look to others for confirmation of their feelings, mature individuals examine their feelings more closely and completely and interpret their emotional lives on the basis of internal, as opposed to external, standards. These are objectives that are obtained through reflective, as opposed to affiliative, means. Though lexical emotional knowledge might come into play in Labouvie-Vief's representation, it is possible that an individual could be expert at subjective description of emotion (e.g., accurately and specifically describing one's own inner feelings) and be lacking in the more objective responses required for accurate performance on tasks such as those administered in this study.

The results of the current study can be interpreted to give support to the intellectual taxonomies of Mayer and Salovey, Goleman, and Gardner, in that they concur with the notion that emotional ability is a component of cognitive functioning that is *related* to more conventional measures of intelligence. However, the current results do not support the conceptualization of emotional perception as a *part* of the conventional notion of intelligence. What the above theorists have in common and what is most valuable about their perspectives is their emphasis on: a.) the significance of emotional intelligence for maximizing potential and achieving life goals, and b.) the importance, to both the individual and society, of prioritizing and formalizing its development.

Verbal and Nonverbal Emotional Perception: Unitary, Related, or Distinct?

Results from exploratory factor analyses showed that emotional identification tasks, across communication channels, consistently loaded together on the same factor with moderate to high loadings (see also Borod, Pick, Hall, et al., 2000). However, this could be, to some degree, an artifact of the similar task construction for the facial, prosodic, and verbal emotional stimuli. The fact that the facial recognition task (which contains no emotional component but uses similar stimuli to the facial emotional perception task) loaded highly with emotional tasks points to the strong influence of task parameters in this analysis. By contrast, results from the structural equations showed that, though closely related, verbal and nonverbal aspects of emotional perception are best typified as separate in terms of their relations with other factors investigated. After accounting for age, nonverbal emotional perception was shown to be unrelated to either fluid or crystallized intelligence. As might be expected, perhaps due to shared lexical attributes, verbal emotional perception was related only to crystallized intelligence. Therefore, overall, the results of this study support the cohesion of the nonverbal elements of emotional perception (i.e., appreciation of facial and prosodic cues) and a degree of separation for the lexical component of emotional perception.

Findings from the correlational analyses also supported the separation of the verbal and nonverbal aspects of emotional perception. When nonemotional cognitive variables were accounted for, nonverbal emotional perception abilities showed a correlation with age corresponding to that of fluid ability ($r = -.62$, $p < .01$), while verbal emotional perception abilities exhibited weaker age relations ($r = -.29$, $p < .01$). Thus, another distinction between verbal and nonverbal emotional perception is that they have differential relationships with age.

The Common Cause Hypothesis—Does it Apply to Emotional Perception?

The Common Cause hypothesis is based on the argument that correlations between measures of sensory and intellectual functioning increase in old age because the performance decline on both measures is a reflection of the physiology of the aging brain. Baltes and Lindenberger (1997; Lindenberger & Baltes, 1994) found that age trends in mental abilities (e.g., perceptual speed, reasoning, memory, knowledge, and fluency) did not differ significantly from zero after controlling for hearing acuity. In fact, these authors found 8.8 fold reductions in age-related individual differences in nonemotional cognitive functioning when they controlled for hearing. Results from the present study show that covarying for hearing thresholds did not significantly mediate the age effect for either of the emotional variables. Importantly, certain restrictions in the present study may have constrained the results. Baltes and Lindenberger tested their hypothesis on a much larger sample size (n = 687) with a much wider age range (25 - 103 years). They strengthened their argument by showing larger effect sizes in the oldest old (70 to 103 years) in whom hearing was more strongly related to individual differences in intellectual abilities. Due to the small number of 70+ individuals in this study (n = 18), it was impossible to undertake this type of comparison.

To determine whether methodological constraints, such as sample size and age, might more likely account for the discrepancy between the results of the present study and that undertaken by Baltes and Lindenberger (1997) another series of regressions were performed. In the Baltes and Lindenberger study, the dependent variables were various intellectual abilities (e.g., a fluid factor, including variables of perceptual speed, reasoning, and memory). The post hoc regression analysis described above was conducted to determine whether an effect size more similar to those obtained by Baltes and Lindenberger would be achieved by calculating a regression on age (with hearing threshold as the covariate), but using a nonemotional measure similar to that used by Baltes and Lindenberger as the dependent variable. If hearing did not mediate age relations with this nonemotional measure, it would be more likely that methodological differences contributed to the discrepancy between the two studies. Regression analyses were conducted on the fluid factor because it contained measures of perceptual speed, reasoning, and memory comparable to those used by Baltes and Lindenberger. When age was regressed on the fluid factor before and after hearing acuity, a 29% reduction in age effects was seen. This is similar to the percent reduction seen for the emotional variables (i.e., 38% and 47%). Therefore, differences between these findings and those of Baltes and Lindenberger are probably more a function of sample characteristics or other methodological differences rather than the distinction between emotional perception (as it relates to sensory functioning) and other forms of cognition.

In conclusion, this study does not extend the findings of Baltes and Lindenberger into the realm of emotional processing. However, replication with a larger sample size, including much older participants and additional measures of sensory functioning, would be necessary to provide an adequate test of the Common Cause hypothesis as it relates to emotional processing.

## Gender Differences in Emotional Perception

The prediction that women would evidence superiority in emotional perceptual tasks was not supported in this study. Minimal differences were seen in emotional perception between men and women. Though women did perform better than men on the Emotional Sentence Identification task, men had higher scores than women on the Emotional Word Discrimination tasks.

Implications for the New York Emotion Battery

As Borod, Tabert, Santschi, and Strauss (2000) indicate, there are a very limited number of instruments available to assess multiple components of emotional processing from a neuropsychological perspective. One important contribution of the current study is to provide preliminary normative data for the emotional perception tasks of the NYEB, as well as additional information regarding the NYEB's usefulness for the measurement of emotional perception in future research. Discriminant validity of the tasks has recently been shown among brain-damaged patients and healthy adults (Borod, Cicero, et al., 1998; Cicero, Borod, et al., 1999).

Many aspects of the present results, examining the accuracy of the performance of healthy normal participants across the age range, support the validity and reliability of the battery. High correlations were observed among the identification tasks, implying predictive validity, in that when a participant performed well on one emotion measure (e.g., facial identification) he or she tended to perform well on another (e.g., word identification; see also Borod, Pick, Hall, et al., 2000). While only minimal differences emerged between men and women on any emotional perception tasks, differences were consistently observed between older and younger age groups, with younger individuals evidencing superior performance.

Importantly, negative age correlations for positively and negatively valenced items were comparable. No differences were seen between men and women with respect to accuracy in identifying positively versus negatively valenced items. Only very minimal differences emerged in patterns of performance with age on positively versus negatively valenced items. These findings suggest that positive and negative items are well-matched in difficulty. Thus, in a case where interpretation of positively and negatively valenced stimuli is differentially affected by a patient's clinical condition, the NYEB should be capable of detecting such differences.

As emphasized in Cicero, Borod, Santschi, et al. (1999), accurately quantifying degree of impairment and identifying specific patterns of emotional communication skills within each channel and mode have important implications for remediation of these skills in brain-damaged patients. It is vital that evaluators and remediators have the means to generate and present a specific skill picture to individual patients, families, and clinicians, assist in increasing awareness and improving daily interactions, develop and designate appropriate treatment modalities, and measure the efficacy of remediation.

## Future Directions – Methodological Considerations

### Task Factors

Importantly, for the verbal emotional tasks employed in this study, analogous nonemotional measures had been constructed which were very closely matched for task features. By contrast, for the nonverbal tasks, measures used as controls were varied and unique in terms of task parameters. For example, some control measures for nonverbal emotional identification tasks did not require verbal labeling, recognition, or identification. With the exception of the Intonation Contours Perception task, these measures (e.g., the Visual Form Discrimination Test and Phoneme Discrimination) tapped more basic perceptual processes requiring matching and sensory discrimination. Thus, they were more appropriately matched to the emotional discrimination, as opposed to the identification, tasks. For future investigations, an effort to develop more appropriate, well-matched control measures for the nonverbal perceptual tasks is recommended, and such tasks may yield different findings.

Methodological improvements could also be made with respect to the measures used to denote fluid and crystallized abilities. There are contradictory lines of thought regarding the appropriateness of designating the WAIS-R Block Design subtest as a measure of Gf. Many studies have supported the more fitting assignment of Block Design to the Gv (Broad Visualization) category due to the visuospatial and motor abilities necessary for efficient execution of the task (for review, see Kaufman, 1994, chapters 2 and 4). Subsequent investigations may consider the use of an instrument such as the Kaufman Adolescent and Adult Intelligence Test (KAIT; A.S. Kaufman & N.L. Kaufman, 1993), which contains a three-subtest Core Fluid Scale shown to measure fluid reasoning and learning ability not tapped well by the Wechsler scales. A more precise measure of fluid intelligence, indexing both verbal and nonverbal fluid ability, might very well lead to alternate findings supporting different interpretations for the relations among variables investigated in this study.

The designation of the Information subtest of the WAIS-R as a measure of Gc has been widely supported. However, a more comprehensive measure of crystallized ability, requiring a wider range of verbal abilities (e.g., a measure assessing vocabulary, a measure assessing social knowledge, such as the Comprehension subtest from the WAIS) and spanning both verbal and nonverbal domains, may yield much more reliable information regarding the association of Gc with emotional perception, both verbal and nonverbal.

It would also be beneficial to expand the range of emotional tasks (e.g., by including some for which the response does not require a lexical, categorical decision-making process) to distinguish the degree to which associations among the emotional tasks across channels are due to task parameters, as opposed to aspects of emotional processing. This could be accomplished through the use of emotional discrimination tasks from the NYEB. Unfortunately, during the current study, data from both forms of discrimination tasks could not be combined because the two forms of the tasks contain different items. As a result, due to the smaller ns, the discrimination measures could not be used in the latent variable analyses.

Another aspect that could be included in future investigations would be that of adding an intervention to see whether older individuals' emotional perception would benefit from training. Evidence from neuroimaging studies suggests that older individuals who perform similarly to younger individuals on memory tasks compensate for physiological changes through the use of alternate strategies that recruit more extensive and different brain regions (Hazlett et al., 1998). It would be interesting to see whether older individuals' performance on emotional perception tasks would benefit from concrete and specific instructional strategies targeted at improving the detection of emotional signals.

Lastly, quantitative measures of health status (e.g., a rating scale), as opposed to more general qualitative screening criteria, would allow for the detection of confounding factors related to differences in physical well-being. The addition of a visual acuity measure would permit a more complete examination of the common cause hypothesis as it relates to emotional perceptual abilities.

Sample Considerations

The inclusion of a broader age range in the subject sample would add greatly to any investigation of the development and maintenance of emotional perceptual abilities over the life span. Such an investigation would benefit from a downward extension to address the initial development and acquisition of such abilities. Though the NYEB was not developed for children, it might be appropriate for use with adolescents. In addition, an upward extension of the subject sample to include the oldest-old age group (e.g., 70-103 years), such as that examined in the Berlin Aging Study (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994), would allow for detection of differences in emotional perception across this latest phase of life. This would also enable a more thorough investigation of the Common Cause hypothesis and clarification of attributes contributing to successful aging.

It is possible that the relations among the factors (e.g., Gc, Gf, NVEMP, and VEMP) examined in the present study could vary according to age group. As individuals age, the relationships among different types of intelligence may be modified in some way. Using a larger sample size, it would be possible to test structural models examining linkages among emotional and nonemotional cognitive factors in younger and older age groups to see whether differential relations appear. An analysis of this nature might also be useful in examining Labouvie-Vief's (1997) cognitive-emotional integration model of adult emotional development, which holds that with higher levels of cognition, more complex and powerful linkages between the systems of emotion and cognition evolve.

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