Perception of Emotion across the Adult Life Span in Three Communication Channels

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Abstract

PERCEPTION OF EMOTION ACROSS THE ADULT LIFE SPAN IN THREE COMMUNICATION CHANNELS

By

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The current study examined age-related differences in emotion perception skills in 116 healthy adults, aged 20-89. Subjects completed identification and discrimination emotion perception tasks involving positive and negative emotion stimuli in three channels of communication: facial, lexical, and prosodic. The emotion tasks were from the New York Emotion Battery (NYEB; Borod, Obler, & Welkowitz, 1992).

Participants were screened for cognitive functioning, psychiatric and neurological history, dementia, and perceptual skills, using procedures from the NYEB, and were matched across age groups for demographic variables. Associations among demographic characteristics (gender, ethnicity, and educational level), nonemotional control tasks from the NYEB, and emotion perception tasks were examined using multiple regression. Age was also included in these analyses in order to directly evaluate the effects of age and the effects of these other variables.

We examined age-related differences in emotion perception, in general, and explored whether age-related differences varied as a function of communication channel and valence in the context of the general decline with age hypothesis, the right hemi-aging hypothesis, and the positivity bias.

In light of research showing that relationships among cognitive functions become more homogeneous, or less specialized, with age, we examined relationships among the three emotion channels within the context of the hemispheric asymmetry reduction with old age (HAROLD; Cabeza, 2002) and dedifferentiation models.

For all three channels of communication, older adults performed worse than younger adults. Years of education predicted performance for lexical tasks only. Age emerged as the most significant predictor of performance on emotion perception tasks, and neither ethnicity nor gender generally emerged as significant predictors of performance. Interrelationships among channels were stronger for older adults (i.e., 70- and 80-year-olds) than for their younger cohorts.

Results are discussed in the context of neuropsychological and psychosocial theories of aging and emotion. The finding that older groups encountered significantly more difficulty with emotion perception tasks is consistent with the general decline hypothesis and aspects of the right hemi-aging hypothesis. There was no positivity bias demonstrated among the older participants. Abilities within participants were more homogeneous in older age groups, suggesting that emotion perception skills become less specialized with age.

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INTRODUCTION

As medical innovations are consistently facilitating higher average life expectancies in the United States, the older population in this country is increasing at a rapid rate. After the population of adults in the oldest age groups grew by 38% in the 1990s, individuals older than 85 years old in 2008 comprised approximately 1% of the population, which equals over 4.2 million people (U.S. Census Bureau Report, 2008). By 2050, it is projected that there will be over 20 million people living in the United States over the age of 85, and that individuals over 85 years old will constitute the most rapidly growing population in America (Roose & Devenand, 2006). This subgroup of the population, like all age groups, has distinct physical, cognitive, and psychological characteristics, which call for scientific investigation.

In terms of psychological characteristics, understanding emotional functioning in healthy adults among various age groups is especially important for two primary reasons. First, understanding emotional functioning in older adults can facilitate medical care and interventions, as well as emotional support, for older individuals. Such knowledge can also help in encouraging adherence to medical regimens. In order to meet the medical and psychological needs of this aging population, it is imperative that we strive to understand the unique emotional experiences, specific emotional needs, and emotional percepts which older individuals have in common, especially if and when these characteristics diverge systematically from those of younger adults.

Second, collecting normative data and creating healthy comparison groups are essential for characterizing and understanding diseases that occur with advanced age, such as the neurodegenerative diseases Alzheimer's disease (AD) and Parkinson's disease (PD). Deficits in emotional processing have been associated with AD (e.g., Taler, Baum, Chertkow, & Saumier, 2008; Testa, Beatty, Gleason, Orbelo, & Ross, 2001), and evidence concerning whether such deficits occur as a direct result of the disease processes in PD suggests an association between the disease and decreased emotion perception (Gray & Tickle-Degnenl; Smith et al., 2010; Zgaljardic, Borod, Foldi, & Mattis, 2003). Normative data on healthy older adults can help rectify such issues.

According to numerous research studies, many developmental changes take place in cognitive, linguistic and emotional processing across the adult life span. The following review of the literature is taken from Borod, Yecker, and colleagues (2004), with updating and some modification. Findings have generally supported age-related decline for a variety of cognitive domains as a function of age, including sustained attention (Filley & Cullum, 1994; Mani, Bedwell, & Miller, 2005), working memory (Logie, Della Sala, MacPherson, & Cooper, 2007; Mutter, Haggbloom, Plumlee, & Schirmer, 2006; Tse, Balota, Yap, Duchek, & McCabe, 2010), visuospatial perception (Benton, Eslinger, & Damasio, 1981), construction (Ben-Yishay, 1971; Bugg, Zook, DeLosh, Davalos, & Davis, 2006), processing speed (Rabbitt et al., 2007), and motor functions (Meudell & Greenhalgh, 1987; Newell, Mayer-Kress, & Liu, 2009). The aging process might contribute to a decline in verbal and linguistic abilities, as well, although there is less consensus in the literature regarding functioning in these domains. Some earlier studies suggested that certain linguistic abilities remain stable across the life span (e.g., Schaie, 1994; Schum & Sivan, 1997), whereas more recent studies have reported age-related decline in verbal fluency (Henry & Phillips, 2006; Kave, 2005; Tabert et al., 2001) and linguistic processing (Borod & Goodglass, 1980; Howieson, Holm, Kaye, Oken, & Howieson, 1993; Kemper, Thompson, & Marquis, 2001).

Age-Related Changes in Emotionality

In addition to the documented changes in cognitive functioning, changes in emotional experience have been identified. However, the nature and course of these changes remain controversial. Again, the following review is adapted from Borod, Yecker, et al. (2004), with updating and some additions. Early research on subjective experience of emotion indicated that in normal adults, clinical diagnoses of depression increase as a function of age (Blazer, 1982; Fogel & Fretwell, 1991; Zung, 1980) and that older individuals are less emotionally responsive than younger individuals (Palmore, 1981). In contrast, more recent research suggests that whereas the incidence of depression does not increase with age in the later years, the quality (i.e., emotional and physical sympomatology) of the depressive syndrome changes with age (Beach & Amir, 2003; Holland, Schutte, Brennan, & Moos, 2010; Newmann, Engel, & Jensen, 1991). In fact, research on subjective experience has suggested that older individuals have reported no significant decline in emotional experience (Feinson, 1985; Lawton, Kleban, Rajagopal, & Dean, 1992; Levenson, Carstensen, Friesen, & Ekman, 1991). More recent studies of normal variability in the subjective experience of emotional processing have actually found that negative emotionality decreases with age, across several ethnic groups in the United States (e.g., Gross et al., 1997).

Perception of Emotion Across the Life Span

An understanding of changes in subjective experience can be enhanced by the study of age-related changes in the ability to perceive emotion. Some general changes have been identified in the perception of emotion in different channels of communication. A channel of communication is a conduit through which humans express emotional information. Communication channels can include, for example, facial (i.e., facial expressions), prosodic (i.e., intonation in speech), lexical (i.e., speech content), gestural, postural, and scenic (Borod, 1993b; Borod, Tabert, Santschi, & Strauss, 2000). This review, here, will focus on the facial, prosodic, and lexical channels of communication.

A burgeoning line of research has begun to disentangle the ability of older adults to perceive basic stimuli, on the one hand, and to perceive emotional signals, on the other. Recent studies have shown that the ability to perceive emotions, as conveyed by various channels of communication, declines with age even when basic perceptual processes remain intact. Specifically, Ruffman, Henry, Livingstone, and Phillips (2008) reported in a recent meta-analysis that anger, sadness, fear, surprise, and happiness were more difficult for older, as opposed to younger, adults to perceive in facial and prosodic channels, and that older adults encountered particular difficulty when matching emotions between the facial and prosodic channels for anger and sadness. However, they found that older adults showed an advantage for perceiving facial expressions of disgust.

Most previous studies of facial perception have revealed a decline in recognition accuracy over the life span (Allen & Brosgole, 1993; Isaacowitz et al., 2007; McDowell, Harrison, & Demaree, 1994; Prodan, Orbelo, & Ross, 2007; Slessor, Phillips, & Bull, 2010). This decline may be associated with changes in strategic implementations (i.e., the way older adults look at faces). Studies have shown that while younger adults tend to look preferentially at the eyes and the upper parts of the face while decoding facial expressions, older subjects spend comparatively more time inspecting the mouth and the lower half of the face. This latter strategy is associated with declines in accuracy for older adults, and is, consequently, considered less efficient (Sullivan, Ruffman & Hutton, 2007: Wong, Cronin-Golomb, & Neargarder, 2005). Sullivan et al. (2007) suggest that this shift is a consequence of frontal lobe atrophy in older adults, which impedes the integration of visual eye fields, effectively interfering with visual scanning ability. Stressor et al. (2010) propose that declines in the integration of gaze direction and the specific expressed emotion interfere with facial emotion perception in older adults, especially for anger and joy.

The perception of affective prosody, which is the identification of emotional content through intonational cues in human speech, seems to be an innate ability (Sambeth, Ruohio, Alku, Fellman, & Huotilainen, 2008). This skill also seems to decline in later life. Older, as compared to younger, subjects have demonstrated a decline in comprehending affective prosody through speech (Dupuis & Pichora-Fuller, 2010; Kiss & Ennis, 2001; Orbelo, Testa, & Ross, 2003), and this decline has been shown to exist independently of age-related hearing loss or cognitive decline (Orbelo, Grim, Talbott, & Ross, 2005).

Research on lexical perception also supports a general decline in accuracy as healthy individuals age for single-word and/or sentence reading (Grunwald et al., 1999; Isaacowitz et al., 2007), although one study (Phillips, MacLean, & Allen, 2002) found that the perception of emotions presented through verbal material in narrated stories did not change as a function of age.

The Positivity Bias

Although the above research might suggest a general decline in emotional perception across the life span, closer examination reveals that the decline might be influenced by the valence of the stimulus presented. Valence refers to whether a stimulus is positive or negative (i.e., pleasant or unpleasant). Basic research on emotions revealed that individuals from a broad range of cultures consistently identify six "basic" emotions in facial expressions: anger, happiness, sadness, fear, surprise, and disgust (Ekman & Friesen, 1975). Research on individuals from the Fore society in New Guinea, who previously had virtually no contact with Western cultures but could identify these emotions in the faces of Westerners, provided further evidence that these emotional expressions are universal (Ekman & Friesen, 1975). This strongly suggests that the emotions themselves are universally and biologically programmed. Subsequent research has supported this theory (Izard, 1994), although controversy pertaining to the "basic" emotions persists. First, there is a lack of consensus regarding which emotions should be included in the categorization of "basic" emotions (each having discrete universal expression, physiological correlates, appraisals, and antecedent events; Ekman, 1999). Second, some investigators posit that emotions vary not in kind, but in intensity and pleasantness (for review, see Ekman, 1999). In any case, there seems to be a pleasantness/unpleasantness dichotomy (Wager, Phan, Liberzon, & Taylor, 2003) or continuum for emotions, although some prefer to capture this distinction as a function of the activation of approach versus avoidance behaviors (Higgins, 1997). The current review will focus on the valence (i.e., pleasantness/unpleasantness) aspect of emotions and will consider discrete emotions (e.g., sadness, disgust, etc.) as having distinct characteristics.

Some research has indicated that as individuals age in the later years of life, the processing of positively valenced emotional stimuli remains relatively intact, compared with that of negative emotional content (Carstensen, 1992b; Kennedy, Mather, & Carstensen, 2004; Kisley, Wood, & Burrows, 2007). This has been termed the "positivity bias" (Kennedy et al., 2004; Lee & Knight, 2009; Mather & Carstensen, 2005).

Facial channel. As individuals reach late life, they appear to encounter progressive difficulty when identifying negative facial expressions, including anger (Calder et al., 2003; Mill, Allik, Realo, & Valk, 2009; Sullivan & Ruffman, 2004), sadness (Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006; Mill et al, 2009; Moreno, Borod, Welkowitz, & Alpert, 1993; Sullivan & Ruffman, 2004) and fear (Calder et al., 2003; Keightley et al., 2006). Older participants have also performed significantly worse than younger participants when matching emotional sounds to faces expressing anger, sadness, and disgust (Sullivan & Ruffman, 2004) and when identifying facial affective valence for negative and neutral facial expressions (McDowell et al., 1994). Research suggests that age-related declines observed for the discrimination and identification of sad expressions are consistent across ethnic groups (MacPherson, Phillips, & Della Sala, 2006). Interestingly, age-related declines in the ability to perceive sadness in expressive faces have been associated with declines in the experience of negative emotion in the same participants (Suzuki, Hoshino, Shigemasu, & Kawamura, 2007).

As would be predicted by the positivity bias, the inverse may be true for the recognition of positive emotions. Older participants have been shown to perform better than younger participants when identifying happiness (Moreno et al., 1993; Werheid et al., 2010). Further, older adults have exhibited attentional and memory biases for faces displaying positive emotions (Mather & Carstensen, 2003; Werheid et al., 2010).

Prosodic channel. There are fewer studies investigating age-related valence effects on the perception of emotion in the prosodic channel of communication. One study (Laukka & Juslin, 2007) found that older adults were worse at identifying negative emotions from musical and prosodic stimuli, but were relatively adept at identifying positive emotions. These effects would provide support for a positivity bias in the prosodic channel.

Lexical channel. In contrast to the above findings regarding valence effects in age-related changes in the perception of facial emotion, studies to date have not revealed a similar pattern in the lexical channel. Older adults, while scoring lower on tasks requiring the identification of lexical emotional content, did not seem to have relative difficulty when identifying positive, as opposed to negative, emotional stimuli (Grunwald et al., 1999). Research on valence effects for remembering words, however, has revealed that there might be a positivity bias (Thomas & Hasher, 2006), in which older adults remember more positive words than negative words. It has been suggested that positively valenced words are more salient than negative words for older adults, and that this saliency can disrupt encoding of negatively valenced stimuli. For example, Piguet, Connally, Krendl, Huot, and Corkin (2008) primed a word-list memory task with positively valenced "distracter" stimuli. They found that following such priming, memory for words could be lured off-track to create false memories of positive words. Taken together, the literature on age-related valence effects indicates that older adults do not demonstrate a consistent bias towards positive stimuli when identifying emotional content, but that there might be a positivity bias for lexical memory tasks.

In addition to the difficulties in accurately identifying negatively valenced stimuli for the facial and prosodic channels, it seems that for older adults, negative stimuli become less salient with age (Carstensen, 1992a, 1992b; Carstensen & Turk-Charles, 1996). When rating the valence of emotionally evocative pictures, older adults tend to rate them more positively than younger participants (Neiss, Leigland, Carlson, & Janowsky, 2009), and they also tend to rate negative pictures as less negative than do younger cohorts (St. Jacques, Dolcos, & Cabeza, 2009). However, this might not be the case for other channels. For example, for the prosodic channel, Fecteau, Armony, Joanette, and Belin (2005) found that older adults rated both negative and positive emotional stimuli as less intense than younger adults.

Although this effect has been termed the positivity bias (Mather & Carstensen, 2005), some researchers are exploring whether older adults experience increases in positive emotionality, or, alternatively, feel a decrease in negative emotionality as they age. St. Jacques et al. (2008) used event-related fMRI data to investigate whether neural signals indicate that older adults experience positive images more positively or negative images more negatively than younger participants. They found that while neural reactivity in response to positive visual images remained extremely constant across the life span, neural responses were attenuated for older, as compared to younger, adults in response to viewing negative images. This suggests that older adults experience positive stimuli in the same manner as younger adults, but that they are less reactive to negative stimuli. One longitudinal study found that negative affect decreased with age (Charles, Reynolds, & Gatz, 2001).

The neurological mechanisms underlying this change are currently being explored. One proposed mechanism involves changes in the neural networks that result in more control over negative emotionality. It appears that over the course of a life span, individuals may develop adaptive control over negative emotional responses. Imaging studies have supported this hypothesis. For example, activation in the left amygdala, in response to perceiving negative facial expressions, appears to decrease in older age (Fischer et al., 2005; Iidaka et al., 2002).

Functional connectivity refers to the association between changes in activation for specific brain regions with activity in other regions within a neural network. The ventral anterior cingulate cortex is implicated in emotional regulatory functions (Drevets, Price, & Furey, 2008; Hornak et al., 2003), and the amygdala underlies the perception of facial expression (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Blair, Morris, Frith, Perrett, & Dolan, 1999; Fischer et al., 2005; Wright, Dickerson, Feczko, Negeira, & Williams, 2007) and the experience of fear (Barrett, Bliss-Moreau, Duncan, Rauch, & Wright, 2007). The amygdala itself remains relatively insensitive to aging processes, but changes in the functional connectivity among the amygdala and other brain regions appear to occur in older age (St. Jacques et al., 2008). The regulation of the amygdala has been explored in the context of emotional memory, because the amygdala enhances memory for emotional material. Memory for negative emotional material may decline in older age (Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004). St. Jacques, et al. (2009) found that increases in functional connectivity between the amygdala and dorsolateral prefrontal regions, as evidenced by fMRI data, were associated with decreased memory for negative emotional stimuli. They posit that augmentations in prefrontal regulatory mechanisms account for the declines in memory for negative emotions, and may reflect more effective emotion regulation in older, as opposed to younger, adults. St. Jacques et al. (2008) revealed that older adults who rate negative pictures as more negative than younger adults exhibit greater functional connectivity between the right amygdala and the ventral anterior cingulate cortex. Specifically, in older adults, increases in the activation of the anterior cingulate cortex were associated with decreases in the activity of the amygdala. This supports the hypothesis that emotional regulation networks may actually strengthen with age in a <u>behaviorally</u> adaptive manner. Nevertheless, the above findings suggest that this process might be associated with impairments in the <u>perception</u> of negative human emotion. This hypothesis is consistent with Mather and Carstensen's (2005) view of the positivity bias, which suggests that reductions in specific perceptual abilities (e.g., the perception of negative emotions) are coupled with increases in emotional regulation.

Emotional Processing: Lateralization

The Right Hemisphere Hypothesis

Age-related effects on the emotional neuropsychological functions discussed above may be related to normal aging processes in the brain. It is therefore helpful to explore the brain regions associated with specific emotional processes. Many functions of the brain are thought to be "lateralized," that is, the neuroanatomical correlates underlying them are localized to predominantly one hemisphere or the other.

Lateralization was first postulated in the nineteenth century when Paul Broca observed two patients suffering from aphasia, both of whose brain injury was localized to the left frontal lobe (Joynt, 1964). According to Parent, Parent, and Leroux-Hugon (2002), Jules Bernard Luys proposed in 1881 that the right hemisphere houses an "emotion center" in the brain (Parent et al., 2002). The left hemisphere is responsible for motor and linguistic functions, while the right hemisphere is dominant for sensory, spatial, and affective functioning (Joseph, 1982).

Research on the right hemisphere hypothesis can be divided into three general categories, according to the population studied and the methodology employed. First, studies on normal participants use either dichotic listening techniques or visual field presentation. These methods capitalize on the fact that sensory afferents from one ear or visual field are processed primarily on the contralateral, or opposite, side of the brain. For example, if a stimulus (e.g., facial expression) is presented in the left visual field, it projects to the right occipital cortex. This method allows investigators to probe sensory processing functions separately for the right and left hemispheres. Secondly, neural imaging techniques, such as functional magnetic resonance imaging (fMRI), produce visual representations of brain activity. The blood oxygenation level-dependent (BOLD) contrast technique utilizes generated magnetic fields to detect relative differences in the release of oxygen from the blood to active neurons (Ogawa, Lee, Kay, & Tank, 1990). Because BOLD is thought to be a correlate, or marker, of metabolic/neural activity, researchers using this technique can test hypotheses regarding the localization of correlates of metabolic/neural activity in vivo, at rest, or while a participant is engaged in a task. Lastly, subjects with lateralized brain damage can reveal the relative contributions of each hemisphere to the processing of stimuli.

Facial channel. Research studies utilizing visual field methods, lateral eye movements, and neural imaging techniques have investigated the processing of facial expressions in normal subjects. Strauss and Moscovitch (1981) reported an advantage for discriminating facial expressions presented in the left hemi-field, and the literature on lateral eye movements has also indicated a bias for processing emotional facial expression in the left-hemispace (Ley & Bryden, 1979; for review, see Borod, Vingiano, & Cytryn, 1989). At least one imaging study found greater activation in the right, as opposed to left, hemisphere while participants viewed emotional faces throughout a diffuse network of regions including the inferior occipital gyrus, fusiform gyrus, superior temporal sulcus, and inferior frontal gyrus (Ishai, Schmidt, & Boesiger, 2005). Parenthetically, activation in the right fusiform gyrus appears to underlie the perception of facial stimuli (Kanwisher, McDermott, & Chun, 1997).

Clinical research involving brain-damaged subjects has generally supported hemispheric asymmetry in the perception of facial emotion, as demonstrated by right hemisphere brain-damaged (RHD) subjects encountering difficulty, relative to left-hemisphere brain-damaged (LHD) subjects, in identifying facial emotional expression (Borod, Koff, Perlman Lorch, & Nicholas, 1986; Borod, Martin, Alpert, Brozgold, & Welkowitz, 1993; DeKosky, Heilman, Bowers, & Valenstein, 1980; Mandal, Borod, et al., 1999). A review of the research on emotional perception in the facial channel has revealed that RHD patients are significantly worse at identifying facial expressions than left-hemisphere brain-damaged (LHD) patients (Borod, Bloom, Brickman, Nakhutina, & Curko, 2002).

Prosodic channel. Dichotic listening tasks, when administered to normal participants, have revealed a left-ear (i.e., right hemisphere) advantage for processing emotion in the prosodic channel (Borod, 1992; Ley & Bryden, 1982; for a comprehensive review of these studies, see Borod, et al., 2001). Imaging studies have also supported right hemisphere dominance for perceiving emotional prosodic cues. Much of this work has focused on the functional neuroanatomical differences between the processing of emotional prosody, on the one hand, and semantic and/or nonemotional intonational cues, on the other. For example, when subjects are attending to prosodic information in a speech sample, activation in the temporal lobe is lateralized to the right (Buchanan, Lutz, et al., 2000); in contrast, when attending to semantic information, temporal lobe activation is lateralized to the left (Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003). Similarly, attention to emotional prosodic stimuli activates the right prefrontal cortex (Gandour et al., 2003; George, Parekh, et al., 1996) and right inferior frontal lobe (Buchanan et al., 2000), in contrast to bilateral activation of the prefrontal cortex as seen when subjects are required to attend to nonemotional linguistic cues (Gandour et al., 2003; George et al., 1996). Additionally, one imaging study revealed that the orbito-frontal cortex was activated bilaterally during emotional prosodic processing, whereas the left inferior frontal gyrus was activated during nonemotional linguistic processing (Wildgruber, Hertrich, et al., 2004).

Studies have revealed that RHD patients encounter significant difficulty when deciphering emotional prosodic cues, but not nonemotional linguistic prosodic cues, when compared with LHD patients (Heilman, Bowers, Speedie, & Coslett, 1984), especially when effortful processing (i.e., perceiving prosodic cues that are incongruent with linguistic cues) of prosodic stimuli is required (Tompkins, 1991). Overall, there is strong evidence to support right hemisphere dominance for emotional prosody perception (for review, see Borod, et al., 2002; cf. Cancelliere & Kertesz, 1990).

<u>Lexical channel</u>. Several studies using tachistoscopic presentation of emotionally laden single words have revealed an advantage for words presented in the left visual field, suggesting that the right hemisphere is particularly suited for the processing of lexical emotional stimuli (Bryden & Ley, 1983; Graves, Landis, & Goodglass, 1981) and that the right hemisphere is sensitive to priming effects in the processing of lexical emotional stimuli (Brody, Goodman, Halm, Krinzman, & Sebrechts, 1987). The hemispheric asymmetry of lexical emotional processing, however, might depend on the type of emotion presented. A comprehensive review of many visual field and dichotic listening studies found that healthy adults demonstrate an advantage for perceiving emotional stimuli presented in either the right or left field, as a function of valence (Borod et al., 2001). Specifically, they revealed that many studies have found that for positively-valenced emotional content, individuals demonstrate an advantage for perceiving stimuli presented in the right, as opposed to left, visual or auditory field. This implicates the left cerebral hemisphere in the processing of positive lexical stimuli. For negative emotions, the right- and left-field advantages found were relatively equal. More valence-dependent findings are discussed in the valence hypothesis section below.

Research on the processing of lexical emotion with brain-damaged patients generally supports the right hemisphere hypothesis. Studies have indicated that, for tasks involving perception and manipulation of emotional verbal content, RHD patients, but not normal controls, treat emotional words differently than nonemotional words (Semenza, Pasini, Zettin, Tonin, & Portolan, 1986) and are more impaired than LHDs or normal controls in the identification and discrimination of single emotional words (Borod, Andelman, Obler, Tweedy, & Welkowitz, 1992) and sentences (Cicero, Borod, et al., 1999). On the other hand, four studies, reviewed by Borod, Bloom, and Haywood (1998), found no effects of lesion side on the perception of emotional lexical material; however, as the authors point out, all four studies included only an emotional condition and, as such, should be considered with caution.

The Valence Hypothesis

One variable that might account for hemispheric specialization for the above emotional perceptual process is the valence of the stimulus (i.e., pleasantness/unpleasantness). Much work in the past several decades has focused on identifying whether hemispheric lateralization is dissociable for pleasant and unpleasant stimuli. The "valence hypothesis" suggests that the right hemisphere is dominant for processing negative emotions, while the left hemisphere is predominantly responsible for processing positive emotions (Borod, 1992; Borod et al., 2000; Heilman, Blonder, Bowers, & Valenstein, 2003).

Facial channel. As the literature reviewed above suggests, the right hemisphere appears to be integral for the processing of facial emotion. Several investigations involving brain-damaged patients have found that the contribution of the right hemisphere to this process might depend on the valence of the stimuli (e.g., Adolphs, Jansari, & Tranel 2001; Borod et al., 1986; Borod, Martin, et al., 1993; Mandal et al., 1991). Additionally, visual-field studies have found left-hemisphere predominance for positive facial expressions, and right-hemisphere predominance for negative facial emotional stimuli. For example, Asthana and Mandal (2001) found that participants rated sad faces as more expressive when presented to the left visual field (right hemisphere). Wedding and Stalans (1985) found that, in an emotional facial identification task, response latency was lowest when positive emotional stimuli were presented to the left visual field. However, the majority of studies considering valence as a variable, as discussed above and by Borod (1992) and Borod, Cicero, et al. (1998), have indicated that both positive and negative facial emotions are processed predominantly in the right hemisphere (see also: Asthana & Mandal, 1998; Moreno, Borod, Welkowitz, & Alpert, 1990; Wedding & Cyrus, 1986).

<u>Prosodic channel.</u> The literature indicates that the right hemisphere mediates the perception of prosodic stimuli, regardless of valence (for review, see Borod, 1992). For example, Borod, Cicero, et al. (1998) found that for RHD stroke patients, positive and negative prosodic stimuli were equally challenging to decipher. Similarly, Bowers, Bauer, and Heilman (1993) reported that their investigations of focal lesion patients have not revealed that valence contributes to RHD patients' ability to decode prosodic emotional cues.

<u>Lexical channel.</u> Early speculation concerning hemispheric asymmetry in the lexical channel found support for the valence hypothesis, as evidenced by priming effects that were visual-field and hemisphere-specific (Van Strien & Morpugo, 1992). In their review of the literature, Borod, Bloom, and Haywood (1998) found that the results of studies investigating emotional lexical perception and valence in healthy adults were

variable. They concluded that this lack of consensus might reflect variable experimental methodologies and discrepancies in the demographics of the samples studied. However, Borod, et al. (2001), in their comprehensive review of emotion perception for the three channels, found that for the lexical channel only, emotional stimuli presented to the right visual field (left hemisphere) were processed more accurately for positive than negative emotions. Overall, support for the valence hypothesis is most consistent for the lexical channel of communication.

Emotional Processing: Neuroanatomical Correlates of Emotion Perception

In the investigation of age-related changes in emotional perception, it is helpful to understand the basic neuroanatomical correlates of emotion perception. Studies of changes in neuroanatomy as a function of age can augment our understanding of age-related changes that might be associated with the neuroanatomical structures involved in emotional processing.

Facial Channel

Lower-level processing of features of the face, like all visual stimuli, takes place in the occipital regions of the brain (Kandel, Schwartz, & Jessell, 2000 p. 537). Facial images are first constructed in the occipital and temporal lobes (Taylor et al., 2008). Then, neural signals representing these images are sent to emotional areas such as the amygdala and orbitofrontal cortex, where they are linked to emotional information (Adolphs, 2002). The higher-level processes that decode specific facial expressions and integrate them with knowledge of emotional content seem to be very site-specific, as discussed below. Research on higher-level processing of facial emotional expression has identified a variety of structures that underlie the processing of specific emotional expressions.

The processing of emotions conveyed by facial expressions has been associated with a variety of structures in the temporal lobe. Imaging studies have revealed that the parahippocampal gyrus is associated with surprised faces (Schroeder, et al., 2004), whereas activation in the basal ganglia has been correlated with expressions of contempt (i.e., globus pallidus and putamen; Sambataro et al., 2006), disgust (i.e., caudate nucleus and putamen; Calder, Keane, Manes, Antoun, & Young, 2000; Sambataro et al., 2006), and surprise, disgust, anger, and fear (e.g., striatum; Henley et al., 2008). Neuroimaging studies have also revealed increased signal in the amygdala during the processing of sadness (Blair et al., 1999; N'Diaye, Sander, & Vuilleumier, 2009), disgust (Kosaka et al., 2002), fear (Calder, Burton, Miller, Young, & Akamatsu, 2001; Phan, Wager, Taylor, & Liberzon, 2002), contempt (Sambataro et al., 2006), and anger (Anderson et al., 2003; N'Diaye et al., 2009; cf. Blair et al., 1999). In their review of the neuroimaging literature on automatic emotional responses, regulation of emotion, and emotional learning, Peper, Herpers, Spreer, Hennig, and Zentner (2006) note that activation of the amygdala may either be elicited or inhibited in response to happy facial expressions. In contrast, Kipps, Duggins, McCusker, and Calder (2007) found that decreases in amygdala volume in Huntington's disease (HD) patients were linearly correlated with diminished ability to identify happiness in facial expressions. Interestingly, one study found that the recruitment of the amygdala in the perception of facial expressions varied by age and emotion (Keightley, Chiew, Winocur, & Grady, 2007). Specifically, in response to happy facial expressions, younger adults recruited a more diffuse network of neural activations that included the amygdala, whereas older adults activated only the ventromedial prefrontal cortex, premotor cortex, and lingual gyrus. Overall, the literature indicates that negative facial expressions are processed in the amygdala, but it remains unclear whether the amygdala is responsible for the processing of positive emotions such as happiness. Although the fusiform gyrus has been primarily implicated in the recognition of familiar faces, Lewis et al. (2003) found that activation of the right fusiform gyrus increased linearly as emotional expressivity was enhanced. The superior temporal sulcus has also been associated with working memory tasks involving the identification of facial emotions (LoPresti et al., 2008).

In the frontal lobe, the orbitofrontal cortex (OFC) has been implicated in the processing of emotional facial expressions. Research on patients with OFC atrophy secondary to fronto-temporal dementia (FTD) has revealed that reduced volume in the OFC is correlated with decreased ability to recognize facial expressions (for review, see Kertesz, 2006; Viskontas, Possin, & Miller, 2007). FTD is a neurodegenerative disease resulting in atrophy in the frontal and temporal lobes and characterized by dementia, preceded by changes in mood, personality, and social behavior (Darby & Walsh, 2005). In FTD patients, decreases in the ability to identify the following specific emotions have been revealed: fear (Henley et al., 2008), anger, sadness, disgust (Lavenu, Pasquier, Lebert, Petit, & Van der Linden, 1999), and happiness (Minagawa-Kawai et al., 2008). In contrast, one study found that patients with FTD were impaired on a task of facial emotional expression, but not facial identification (Keane, Calder, Hodges, & Young, 2002). The OFC receives projections from the limbic system, specifically from the subthalamic nucleus. LeJeune et al. (2008) posited that the neuroanatomical correlates underlying the recognition of fear include a circuit from the subthalamic nucleus to the orbitofrontal cortex. They found that Parkinson's patients who had undergone deep brain stimulation in the subthalamic nucleus demonstrated a diminished ability to recognize fear (as conveyed by facial expressions), and that this deficit was associated with decreases in glucose metabolism in the OFC.

Other frontal regions associated with the processing of emotional facial expressions include the bilateral inferior frontal gyrus (disgust; Sambataro et al., 2006). Additionally, the right inferior frontal cortex, an area that is a mirror image of Broca's area in the left hemisphere, has been shown to receive increased blood flow during the identification of emotional facial expressions, but not during the judgment of attractiveness (Nakamura et al., 1999). The authors postulate that this region integrates sensory information with stored memories. Specifically, they posit that the right inferior frontal cortex is involved in matching facial expressions to memories of faces or prototypes of expressive faces.

Lastly, the insular cortex seems to subserve the recognition of disgust conveyed by facial expressions (Kipps et al., 2007; Sambataro et al., 2006; Schroeder et al., 2004).

Prosodic Channel

The recognition of emotion from intonational speech seems to recruit a wide range of brain regions, and especially an extensive network of frontal regions (Adolphs, 2002; Ethofer et al., 2006): As noted above, the right prefrontal cortex (Gandour et al., 2003; George et al., 1996) is activated while subjects attend to prosodic information. Other frontal regions involved in processing prosodic emotional stimuli include the right dorsolateral frontal cortex (Wildgruber et al., 2004) and the bilateral orbito-frontal cortex (Hornak et al., 2003; Wildgruber et al., 2004). In fact, it has been suggested that the orbito-frontal cortex integrates a variety of sensory inputs with limbic afferents. In the temporal lobe, lateral temporal areas, including the middle temporal gyrus, have been implicated in the processing of prosodic information (Mitchell et al., 2003). One fMRI study revealed that a diffuse, bilateral network of brain regions, including the caudate nucleus, anterior insula, amygdala, pons, and temporal and prefrontal cortices are involved in the processing of emotional prosodic information (Morris, Scott, & Dolan, 1999).

Lexical Channel

Compared with the prosodic and facial channels, research on the neuroanatomical correlates of emotional perception via the lexical channel has yielded less definitive results. The left orbitofrontal gyrus and bilateral inferior frontal gyri have been shown to be involved in the active processing of emotional, but not neutral, words (Kuchinke et al., 2005). Imaging studies have revealed that the regions subserving the identification of emotions from lexical content may vary as a function of valence. Areas activated during the perception of negative words may include the amygdala and middle temporal cortex, and the rostral anterior and posterior cingulate cortex (Nakic et al., 2006), whereas the bilateral middle temporal and superior frontal gyri seem to respond exclusively to positive emotional words (Kuchinke et al., 2005).

Neural Correlates of Healthy Aging

As healthy adults age, structural and biochemical changes occur in the brain. It is useful to examine these neuroanatomical correlates of aging to determine whether the regions associated with the perception of emotion, as discussed above, are vulnerable to neural aging processes. Imaging studies have elucidated these changes, and many have revealed that the volume of certain regions decreases in late life. Studies have consistently shown that frontal lobe atrophy, especially in the prefrontal cortex (Grieve, Williams, Clark, Paul, & Gordon, 2007), occurs in late life (Meguro et al., 2001). Furthermore, decreases in both white matter in the ventromedial and deep prefrontal regions (Salat et al., 2005) and gray matter in the frontal and parietal regions (Grieve, Clark, Williams, Peduto & Gordon, 2005) have been associated with old age and also with lower cognitive functioning (Grieve et al., 2007). However, these changes might not be inevitable.[1]

The orbitofrontal cortex, as discussed above, seems to be the predominant neural structure underlying the perception of emotion in the facial (Adolphs, 2002; Le Jeune et al., 2008; Viskontas et al., 2007), prosodic (Hornak et al., 2003; Wildgruber et al., 2004), and lexical (Kuchinke et al., 2005) channels. Because emotional perception in all three of these channels appears to decline in late life, as discussed above, one might deduce that the orbitofrontal cortex is particularly vulnerable to the effects of normal aging. Neuroanatomical research on the OFC supports this hypothesis. Age-related decreases in both total volume (Resnick, Lamar, & Driscoll, 2007) and gray matter (McNamara, Liu, Jandacek, Rider, & Tso, 2008) have been revealed in the OFC. Polyunsaturated fatty acids in the OFC also appear to decrease with age, and this effect is accompanied by increases in biosynthetic gene expression that are thought to be compensatory (McNamara et al., 2008). Moreover, these dynamic changes in the structural and chemical composition of the OFC have been associated with impaired functioning on tasks that recruit the OFC (Resnick et al., 2007). Taken together, these data indicate that age-related dynamic changes in the OFC may be associated with poor performance on measures of emotional perception across the three channels of communication discussed in this paper.

Paralimbic and limbic areas have long been considered essential to the processing of human emotion. In terms of age-related structural changes, gray matter seems to be preserved in the amygdala, hippocampus, and cingulate gyrus, relative to frontal and parietal regions (Grieve et al., 2005), although one study found that older adults had reduced grey matter in the anterior cingulate cortex (Vaidya, Paradiso, Boles Ponto, McCormick, & Robinson, 2007). Functional imaging studies have revealed age-related functional changes in limbic regions. Specifically, age has been negatively correlated with blood flow to the rostral and dorsal regions of the anterior cingulate cortex (Vaidya et al., 2007). However, functional connectivity between the right amygdala and ventral anterior cingulate cortex seems to increase with age, an effect that has been associated with greater control over negative emotionality by older adults (St. Jacques et al., 2008; see discussion on the positivity bias, above), although functional connectivity between the right amygdala and posterior (e.g., occipital) brain regions seems to decrease (St. Jacques et al., 2008). Thus, age-related differences in the processing of negative stimuli, which is thought to be mediated by the right amygdala, might reflect differences in the basic perception of negative emotional stimuli (St. Jacques et al., 2009). Overall, it appears that while limbic and paralimbic regions do not exhibit functional or structural declines, the neural networks that recruit limbic structures undergo some degree of reorganization with age. The above findings are relatively new, and provide a fresh perspective from which to view changes to limbic and associated regions.

Several studies examining age-related activity reorganization processes have revealed that there may also be a gradual shift from the activation of subcortical regions (younger adults) to the recruitment of more cortical regions (older adults) during the processing of emotional stimuli, at least for the facial channel. Fischer et al. (2005) found that while perceiving angry faces, younger participants showed greater activation in the right amygdala/hippocampus region, whereas older participants seemed to recruit more cortical areas in the anterior-ventral insula region. Gunning-Dixon et al. (2003) found that in response to viewing emotional faces, older and younger participants activated different cortical regions; younger adults activated primarily the occipital, frontal, and limbic regions, while older adults activated the frontal, parietal, and temporal cortical regions. They also found a shift from subcortical to cortical areas: As younger participants recruited the amygdala and surrounding subcortical temporo-limbic structures, older adults appeared to use more frontal cortical structures. These data provide further support for the hypothesis that the brain undergoes functional reorganization with increasing age.

Neuropsychological Theories of Aging

Considering the above findings on age-related changes in emotion perception and the neuroanatomical correlates of aging, several neuropsychological theories of aging (as explicated in Borod et al., 2004) merit exploration: the right hemi-aging hypothesis, the general decline "dull" hypothesis, and the socioemotional selectivity theory.

The Right Hemi-Aging Hypothesis

The right hemi-aging hypothesis purports that the right hemisphere of the adult brain is more sensitive to aging than the left (for review, see Dolcos, Rice, & Cabeza, 2002). A variety of behavioral approaches has found support for this model.[2] Older, compared to younger, participants are impaired in the processing of emotional visual stimuli presented in the left visual field, and attain lower scores in the visual and spatial (i.e., right hemisphere-mediated) domains than the verbal (i.e., left hemisphere-mediated) domain (McDowell et al., 1994; for review, see Borod et al., 2001). This effect has also been found for nonemotional verbal and visual tasks (Lapidot, 1987). Behavioral studies have found that elderly people, as a function of age, demonstrate a progressive reduction in their ability to identify angry and fearful faces (Calder et al., 2003).

It should be noted that this model emerged from behavioral studies. Evidence from the neuroimaging literature is less consistent in support of the right hemi-aging hypothesis. Age-related atrophy of the right, relative to the left, hemisphere, has been supported by some recent neuroimaging research (e.g., Bonilha et al., 2009). One comparison of the amygdalae in young and elderly subjects found that the right amygdala volume was significantly decreased in old, as compared to young, subjects (Wedig, Rauch, Albert, & Wright, 2005). A similar trend was found for the left amygdala, but the difference did not reach significance. This might suggest that age-related processes are associated with decreases in amygdalae volume, and that specifically, volume is significantly decreased in the right hemisphere. Reduced activity in the right parahippocampal gyrus has been associated with decreased accuracy in perceiving negative, but not positive, facial expressions in older, but not younger, adults (Iidaka et al., 2002).

These results notwithstanding, the neuroimaging literature has not found compelling evidence to support the hypothesis that the right hemisphere, overall, is more vulnerable to aging than the left. Other brain imaging studies tend to support models of aging that involve decreased activation in specific regions, accompanied by increased activation in other regions that is seen as compensatory (see, for example, Malandraki, Sutton, Perlman, & Karampinos, 2010). Additionally, some studies find selective age-related decreases in activation of the left and right hemispheres in the medial temporal lobe (Iidaka et al., 2002). One volumetric imaging study (Shan, Liu, Sahgal, Wang, & Ye, 2005) detected greater volume reductions in the left than right hemisphere in older men.

General Decline and the "Dull Hypothesis"

Cerella (1985) used Brinley plots[3] to show that there is a general "slowing" in cognition as a function of age. This has been labeled the "dull hypothesis" (Perfect & Maylor, 2000), and many researchers have vehemently contested it (e.g., Baddeley et al., 2001). The primary argument is that, although the Brinley plots make simple lines that explain a large amount of variance in the data, they are insensitive to subtle differences in task domain (i.e., they pool together all tasks). Although this model has been highly disputed, Cerella defends this unidimensional view of aging (Cerella, 1994) but acknowledges that it must be substantiated by analyses of multi-dimensional processes. Most proponents of the dull hypothesis now use multivariate analysis to identify one factor to account for all decline (e.g., processing speed). Baddeley and colleagues (2001) challenge the dull hypothesis by noting that tasks involving processing speed all have unique underlying processes necessary for their completion; therefore, processing speed cannot be solely responsible for performance on any single task.[4] In short, the literature does not generally support the theory that one factor underlies general decline with age.

However, there is mounting evidence that, in general, the ability to decipher emotional signals declines in old age. A recent meta-analysis examining perception of emotion for facial and prosodic stimuli and for matching facial with prosodic stimuli found that older participants consistently score lower than younger adults in each modality (Ruffman et al., 2008). The only advantage evinced by the older participants was for the identification of disgust in the facial channel. The authors concluded that their pattern of findings supported the neuropsychological model of general decline in late life.

Socioemotional Selectivity Theory

The socioemotional selectivity theory models social and emotional changes across the life span (Carstensen, 1992b). Specifically, it describes a socially adaptive process of narrowing one's range of social partners as one becomes older. This is a strategic process that unfolds to maximize social and emotional gains while minimizing risks in older age. In one longitudinal study, Carstensen (1992b) found that as early as young adulthood, individuals began narrowing their casual social interactions and focusing on more intimate relationships. Further, she purports that as individuals age, they place progressively more emphasis on the emotional rewards of relationships, as opposed to other benefits such as information acquisition and boosting conceptions of the self. Parallel to placing greater emphasis on emotions, according to this theory, emotionality becomes more salient in older age. In support of this model, Carstensen and Turk-Charles (1994) found that in a memory recall task, emotional material was remembered better than neutral material in older age groups.

This increase in the emphasis on emotional rewards of relationships is associated with a change in the conception of time. According to Carstensen (1992b), individuals with constraints on their lifetime, such as older individuals and younger people with terminal illnesses, concentrate on present-oriented goals rather than future-oriented goals. In other words, they tend to experience life in the present and therefore focus on immediate rewards rather than dwelling on future outcomes. Further, they tend to focus on positive, as opposed to negative, information when predicting future outcomes. Nielson, Knutson, and Carstensen (2008) predicted: "As a result of this shift [in conceptualizing time], older adults tend to focus on the present, favor positive information, and strive for emotional equilibrium" (p. 319). In fact, the authors found that in response to a task that involved losses and gains of small sums of money, older, as opposed to younger, adults experienced similar patterns of positively-valenced emotions in anticipation of a win, but decreased negative emotion when anticipating a loss. Thus, this model is consistent with the positivity bias (discussed above), and would predict that negative emotions become less salient with age as the saliency of positive emotions does not decline.

This model is coherent with the right hemi-aging hypothesis, because as noted above, behavioral studies have indicated that negative emotions are thought to be processed by the right hemisphere (Adolphs et al., 2001; Mandal et al., 1991; Van Strien & Bood, 1997), which might be more sensitive to aging than the left hemisphere (McDowell et al., 1994; Prodan, Orbelo, Testa, & Ross, 2001; Prodan et al., 2007).

Gender Differences in Emotion Perception

There appear to be gender differences in the ability to identify emotional stimuli. For example, research suggests that women are more accurate than men in processing emotional stimuli in the lexical (Grunwald et al., 1999; Kimura & Hampson, 1993), prosodic (Szymanowski et al., 2007), facial (Li, Yuan, & Yin, 2008; Miura, 1993; Montagne, Kessels, Frigerio, de Haan, & Perrett, 2005; Thayer & Johnsen, 2000), and prosodic (Rymarczyk & Grabowska, 2007; Schirmer, Zysset, Kotz, & Yves von Cramon, 2004) channels. This advantage might be particularly prominent for negative emotions, at least for the facial channel. Recent neuroimaging studies have revealed functional neuroanatomical differences between men and women during emotional processing tasks. A meta-analysis of the functional neuroanatomical correlates of emotional processing found that men exhibit greater lateralization of activation during emotional perception tasks as compared to women (Wager et al., 2003). A recent fMRI study found that, while engaging in tasks involving empathic perception and reasoning, women activated the amygdalae with greater activity than did men and recruited more emotion-related areas than men, whereas male activation was located predominantly in cognition-related cortical areas. Therefore, there appear to be differences in emotional processing between the genders at the level of the neural network. However, whether these differences are stronger for some channels (e.g., lexical and facial) than others (e.g., prosodic) is not yet clear. There does not appear to be an indication of specific gender-related changes with age in the literature. Therefore, on an exploratory basis, we will investigate whether gender differences change with increasing age.

Ethnic Differences in Emotion Perception and the In-Group Advantage

Although classic research on emotion expression and perception revealed that there are universal emotions that are recognized across cultures (Ekman, 1972; Izard, 1971), many studies have examined whether our ability to recognize specific emotions varies by ethnicity (e.g., Russell, 1994). Specifically, there may be an in-group advantage for perceiving emotions expressed by individuals of our own ethnicity, as demonstrated by a meta-analysis on emotion recognition both within and across cultures (Elfenbein & Ambady, 2002). More recent studies also support the existence of an in-group advantage. For example, Pinkham, et al. (2008) found that both among patients with schizophrenia and psychiatrically healthy controls, African-American and Caucasian subjects demonstrated an in-group advantage for recognition of facial emotions. Elfenbein, Beaupré, Lévesque, and Hess (2007) examined the mechanism behind the in-group advantage for facial expressions. They proposed that although many emotions are universally recognized, they are expressed in non-verbal "dialects" that are analogous to regional linguistic dialects. Results of the study indicated an in-group advantage for the emotions that were expressed in different "dialects" by individuals from different cultures. Overall, the above evidence calls for close examination of ethnic variables in studies that examine emotional perception.

Interrelationships among Three Channels of Communication

It is enlightening to examine the relationships among the facial, lexical, and prosodic modalities of communication in individuals as they age. Positive correlations among the channels would suggest the existence of a general underlying processor for emotion perception (or, alternatively, that there is a non-emotional neural component that has a negative impact on these processes and others). However, differential findings across channels suggest the existence of separate processors underlying these functions (Borod, 1993a). To date, most research exploring these relationships has found significant correlations between the facial and prosodic channels (e.g., Borod et al., 1990; Massaro, Cohen, & Smeele, 1996). Less strong associations have been shown between these nonverbal channels and the lexical channel (Borod et al., 2000). The implications of separate verbal and nonverbal processors/neural networks for the perception of emotion warrant neuropsychological investigation.

In addition, research on the effects of aging on cognitive processes has revealed that the correlations among different cognitive measures (e.g., linguistic, visual perception, and memory) tasks increase as individuals age (Babcock, Laguna, & Roesch, 1997; Baltes & Lindenberger, 1997; Mitrushina, Fogel, D'Elia, Uchiyama, & Satz, 1995; Mitrushina & Satz, 1991).

The development of what has become the "dedifferentiation hypothesis" has actually spanned over half a century. The idea of the differentiation of specific skills arose early in the twentieth century, when Spearman (1927) posited that differentiation of cognitive abilities is higher for individuals at higher ability levels. Garrett (1946) examined the effects of early developmental processes on the intercorrelations among cognitive domains. He administered a battery of verbal, numerical, and memory tasks to boys and girls aged 9, 12, and 15. Mean intercorrelations for the three age groups were .30, .21, and .18 for boys, and .27, .30, and .10 for girls. In characterizing age-related changes in the correlations among these ages of late childhood, Garrett concluded the following:

> With increasing age there appears to be a gradual breakdown of an amorphous general ability into a group of fairly distinct aptitudes. It seems highly probable that maturation has much to do with this differentiating process, but increasing experience and diverging interests must also contribute heavily. (p. 375).

Thus, the <u>differentiation hypothesis</u> was used to explain the diversification, or specialization, of certain skills or abilities that develop with age during late childhood and into young adulthood. Cattell (1987) described a similar developmental pattern of correlations among cognitive domains. According to Cattell, school age children tend to excel homogeneously across domains, because they are primarily interested in achieving high marks for their work. However, as young adults transition into adulthood during the 20 years following high school, they begin to specialize in certain abilities or skills. Extending this pattern to late adulthood and old age, Li, et al. (2004) examined associations among tasks that measure both fluid and crystallized intelligence (see Cattell, 1987) in 291 individuals between the ages of 6 and 89 years of age. Factor analysis revealed that the extent to which abilities were differentiated was smaller (i.e., more homogeneous) in childhood, late adulthood, and old age, when compared to that of individuals in adolescence and young- and middle-adulthood. These findings support what Li, et al. (2004) term a “dynamic differentiation-dedifferentiation view of intellectual development across the life span” (p. 162). This model may suggest that differentiation, which occurs from childhood to middle–adulthood and dedifferentiation, which occurs in later life, are reflecting the same process in opposite directions.

Conflicting evidence notwithstanding, the dedifferentiation model of cognitive aging has given rise to several interesting hypotheses regarding the nature of certain neuropsychological and aging processes.

One such hypothesis is the Hemispheric Asymmetric Reduction in Older Adults (HAROLD) model, proposed by Cabeza (2002). This model considers the nature of the changes in asymmetry and specialization primarily in the prefrontal cortex. Specifically, it purports that hemispheric asymmetry (i.e., lateralization) and specialization for cognitive processes in the prefrontal cortex decrease with age.

Evidence for the HAROLD model has come from a variety of sources. Brain imaging studies have shown that tasks which require unilateral activation in the brain of younger adults actually activate the brain in the same regions bilaterally in older adults for linguistic ability (Cabeza et al., 1997; Madden, Gottlob, et al., 1999; Madden et al., 1999), visual processing (Grady, Bernstein, Beig, & Siegenthaler, 2002; Payer et al., 2006), and working memory (Payer et al., 2006; Reuter-Lorenz et al., 2000). Decreases in hemispheric asymmetry have been demonstrated in aging populations by functional magnetic resonance imaging (fMRI; Cabeza et al., 2004; Dolcos et al., 2002), event-related potential (ERP; El Yagoubi, Lemaire, & Besson, 2005) electroencephalography (EEG) interhemispheric coherence (Maurits, Scheeringa, van der Hoeven, & de Jong, 2006), and behavioral (Grady, McIntosh, Horwitz, & Rapoport, 2000) studies. A similar pattern of asymmetry reduction in nonemotional facial perception tasks has been found. Grady and colleagues (1994) demonstrated that during visual processing of facial stimuli, activation in the prefrontal cortex appears to be bilateral, whereas in younger adults, the prefrontal cortex is activated in the right hemisphere only.

Recent evidence for the differentiation-dedifferentiation process and HAROLD model has not found compelling support. Tucker-Drob and Salthouse (2008) conducted a study involving 2,227 adults between the ages of 24 and 91. Both novel and traditional factor analysis approaches (scaling latent ability constructs and principle component analysis, respectively) revealed that interrelationships among various cognitive abilities, including fluid reasoning, spatial reasoning, verbal knowledge, processing speed, and episodic memory, did not increase with advanced age. Further, a large-scale study (n = 6,273) found evidence that differentiation provides a well-founded explanation of individual variations in abilities, but that evidence for dedifferentiation in older age is less compelling (Tucker-Drob, 2009). Specifically, they argue that there are fundamental errors in methodology, including entering inherently nonlinear data into linear models and using non-interval data for tests designed for interval data. They applied nonlinear factor analyses on their data and did not find support for the model. In general, recent studies of the differentiation-dedifferentiation model have been mixed, and overall support for this model has waned.

Previous Research in our Lab

Considering the research questions and evidence discussed above, we recently conducted a multidimensional study investigating the ability of 103 right-handed healthy normal adults, ages 20-81, to perceive emotional information. With the intention of characterizing the differences over the life span, we grouped participants into six decades of age, rather than dividing them into larger groups such as “young” and “old.” To address the valence hypothesis, right hemi-aging hypothesis, and socioemotional selectivity theory, we included valence as a variable. In order to test the general decline, or “dull” hypothesis, and to explore relationships among various communication channels, we examined perception through three channels of communication (i.e., facial, prosodic, and lexical) in the same sample. To that end, we sought to determine whether age-related decline in perception (if any) was specific to one or more modalities, overall, and/or in conjunction with valence effects. Lastly, to explore sex differences in the perception of emotion, gender was considered in the analysis.

The participants completed the New York Emotion Battery (NYEB; Borod, Welkowitz, & Obler, 1992), which includes both discrimination and identification tasks for lexical, facial, and prosodic channels. For the identification tasks, participants were required to identify the emotion conveyed out of three positive (happy, interest, and pleasant surprise) and five negative (anger, sadness, disgust, fear, and unpleasant surprise) emotions. For the discrimination tasks, participants were presented with pairs of stimuli and required to state whether the two emotions presented were the same or different. A unique feature of this battery is that each emotional task (e.g., emotional prosodic identification) has a corresponding nonemotional task (e.g., nonemotional prosodic identification). Additionally, the battery includes careful screening for cognitive abilities. Age groups were matched for gender, education, occupation, ethnicity, and general intellectual functioning.

Results of the study (Finley et al., 2008a) revealed a sharp decrease in emotional perception with age in the oldest group (ages 70-81) for the identification tasks. These results were interpreted in the context of the general decline hypothesis, the right hemi-aging hypothesis, and the socioemotional selectivity theory. This effect of decline in the oldest group was most consistent with the general decline hypothesis, as it was robust across channel and valence. The fact that there was no interaction between age and valence suggests that, contrary to the predictions of the socioemotional selectivity theory, older adults did not have an advantage for positive stimuli. Interestingly, women did not exhibit greater skill overall in interpreting emotional stimuli than men, and there was also no interaction between gender and age. Women did, however, score higher than men on prosodic identification tasks, regardless of age.

We also conducted correlational analyses to examine interchannel relationships. Correlations among the three channels increased as a function of age. This finding is intriguing in light of the cognitive literature, as it reveals a pattern strikingly similar to the age-related increases in correlations demonstrated for various cognitive domains. In our study, the median correlations in three age groups in subjects aged 20-81 increased linearly with age from .35, to .40, to .66 in the oldest group, after controlling for nonemotional perceptual factors. Similarly, Baltes and Lindenberger (1997) found that median correlations for performance in young- and old-age groups for a variety of cognitive measures and sensory perception tasks increased from .37 to .71, respectively. The findings for intercorrelations among emotion channels with age may suggest the generalizability of the dedifferentiation model from cognitive to emotional processes. However, it is possible that age is more highly correlated with all abilities in older, as opposed to younger, individuals. If this is true, then the dedifferentiation model may not sufficiently explain true dedifferentiation, but rather simply reflect increasing correlations between abilities and age (Tucker-Drob, 2009).

One unresolved issue with the HAROLD model is whether the decreases in asymmetry represent a de-differentiation process, which is considered maladaptive, or on the other hand, an adaptive form of compensation for declining cognitive abilities in the aging brain. According to the de-differentiation model, specializations developed throughout the earlier years of the life span would decline in older age (Cabeza, 2002). In our sample, increased correlations among three modalities were accompanied by decreases in overall emotion perception accuracy in the oldest age group (Finley et al., 2008b). However, some studies have shown that increased bilaterality, or recruitment of additional neural networks, provides an advantage for older adults that can be seen as compensatory (Minati, Grisoli, & Bruzzone, 2007).

A limitation of our study was that the oldest group comprised individuals in their 70s. Compared to research on the "oldest-old," this age group is relatively young. For example, Isaacowitz and Smith (2003) compared centenarians, who were in the "oldest old" group, with their "young old" group, which comprised adults in their 70s. That we found a sharp decrease in our oldest group (i.e., adults 70-81) compared with younger (but not "young") adults is interesting in light of the oldest-old literature.

Overview of the Current Study

In the current research study, we expanded our sample to include 15 healthy right-handed adults, ages 80-89. The experimental procedures included two main components: First, participants met the same screening requirements and were matched with the other six age groups for education, socioeconomic status, and general intellectual functioning. The collection of data from healthy adults ages 80-89 included the administration of the NYEB. Next, we incorporated this sample into the analysis of previously collected data from adults ages 20-80.

Re-analyzing the data with this oldest age group served two purposes. The first purpose was to examine whether our findings for our study with participants ages 20-79 were anomalous. If the oldest participants achieved similar or lower scores than individuals in their 70s, we would provide support that our results were not anomalous, and that these patterns may be generalized to a broader population. Further, we were interested in examining whether individuals in their 80s performed even worse than those in their 70s. We hypothesized that individuals in this oldest age group would perform significantly worse on emotional identification tasks when compared with younger individuals in each of the six age groups from which data was previously collected (ages 20-79).

The second purpose of the study was to investigate the effects of age, gender, valence, and communication channel on the accuracy of emotion perception. It was hypothesized that adults aged 80-89 would perform significantly worse on negative emotional items than positive items, for stimuli presented in the facial and prosodic (but not lexical) channels, consistent with the positivity bias, right hemi-aging hypothesis, and socioemotional selectivity theory. Second, it was hypothesized that decline in emotional identification would be consistent across communication channels (i.e., the degree to which the ability to identify emotional stimuli in later life would not vary systematically within subjects as a function of channel), consistent with the general decline theory and the right hemi-aging hypothesis. Third, considering research conducted on gender differences in neural aging processes and gender differences in emotional perception, it was hypothesized that close investigation of the data would reveal effects of gender on emotional perception ability as a function of age. Since women have demonstrated an advantage in the perception of emotion (Grunwald et al., 1999; Kimura & Hampson, 1993; Li et al., 2008; Miura, 1993; Montagne et al., 2005; Szymanowski et al., 2007; Thayer & Johnsen, 2000), it was proposed that women in the older age group (80-89) would continue to possess an advantage for processing emotional material when compared to men in that same age group.

The third aim was to determine whether interrelationships among the three communications continue to become stronger with increasing age. It was hypothesized that associations among the three channels would be significantly stronger for individuals in the oldest age group than in the younger age groups, which would provide support for the dedifferentiation model.

METHODOLOGY

Participants

Data was analyzed from two subsets of participants. First, 103 participants aged 20-81 were administered the complete New York Emotion Battery (NYEB; Borod et al., 1992) at Mount Sinai School of Medicine. They were recruited as part of an ongoing research program on emotional perception and expression in healthy and brain-damaged individuals. The research program is headed by Dr. Joan Borod and has been funded over the years by Dr. Borod's NIH and PSC-CUNY research grants. The 103 participants from this first subset are healthy, normal control subjects, as determined by screening measures included in the NYEB (see materials, below). The demographic characteristics of this sample are presented in Table 2.

Second, an additional sample was recruited. This sample consisted of 13 healthy participants between the ages of 80 and 89. There were two individuals from the original sample, aged 80 and 81, who were placed in the 80-89 group. Therefore, there were 15 participants in this oldest group. Attempts were made to match these participants with the other age groups by gender and ethnicity. In the interest of recruiting an ethnically diverse sample, we posted flyers in a variety of neighborhoods throughout the five boroughs of New York City. Flyers were posted at Mount Sinai School of Medicine, in various departments at Queens College (e.g., Africana Studies and Latin American Area Studies), and at nearby assisted living facilities, community "senior" centers, churches, theaters, and libraries. The co-investigators also offered to give presentations at senior centers on the topic of emotion. At Queens College, participants were actively recruited at community events, such as literature readings and chamber music concerts, by a team of graduate and undergraduate students working in Dr. Borod's lab. In order to recruit a healthy "normal" adult sample, investigators contacted the New York Chapter of the Alzheimer's Association to recruit healthy older caregivers. Advertisements were posted in the classified sections of local newspapers, including Queens Courier, Queens Tribune, and New York Daily News. Additionally, advertisements were placed online at the following websites: Craig's List (newyork.craigslist.org), New York Post (nypost.com), Backpage (newyork.backpage.com), Kijiji (newyork.kijiji.com), and classifiedads.com. Both the flyers and the advertisements indicated that we were recruiting individuals in their 80s who have no history of psychiatric or neurological illness and no history of substance abuse. Further, they indicated that participants must have learned English by age nine. Last, e-mails with attached flyers were sent to the local friends and family members of lab members and to the Queens College Neuropsychology doctoral subprogram listserv.

Subject matching. Attempts were made to match the new participants with the existing sample for gender, ethnicity, education (years), occupational level (Hollingshead, 1977), and handedness (Porac & Coren, 1979). The aim was to attain an overall sample that had no differences in gender (women vs. men) and ethnicity (Caucasian vs. non-Caucasian) education (years), occupational level (SES), or handedness across the seven age groups (i.e., 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, and 80-89). See Table 3 for a summary of the demographic characteristics of the sample.

Participant reimbursement. Participants who completed the entire experiment received $100. Those who did not complete the testing battery received a prorated sum of $12.50 per hour of participation. For example, an individual who completed the screening measures in three hours, but did not meeting the screening criteria, was reimbursed 3 X $12.50, or $37.50.

Experimental Design and Cohort Effects

The first component of this study's design is mixed-factorial and cross-sectional across the life span, with four independent factors: age group, channel, valence, and gender. Each factor was examined as a main effect, and interactions among the factors were analyzed. The second component is correlational, and examined changes in intercorrelations among the tasks, or channels, as a function of age.

Intrinsic to the cross-sectional design are potentially confounding cohort effects. A cohort is a group of people who share a common characteristic, and this characteristic can introduce possible confounds (McBurney & White, 2007, p. 341). In a cross-sectional design with age as an independent variable, confounds may emerge as a result of everyone in the group sharing a relatively similar time of birth. For example, the style of education received and other socio-cultural influences on development vary systematically between individuals born in 1940 and those born in 1970. Results comparing the cognitive performance of individuals in their 60s and those in their 30s could potentially represent these socio-cultural variables, rather than effects of aging processes. Kuhlen (1940) was among the first to describe possible cohort effects challenging the study of life span cognitive psychology:

> The decrease in IQ with age may be in part attributed to social change, which cannot be adequately evaluated by the usual comparison of age groups. Older people of today had fewer opportunities for education and recreation. The effect

> of automobiles, radios and movies is hard to evaluate. A school year today is not the equivalent of a school year twenty years ago (p. 14).

Controversy remains in the literature concerning the issue of whether age-related changes in cognition can be evaluated using cross-sectional experimental designs. As Salthouse (2009) notes, cross-sectional designs have revealed declines in cognitive skills prior to age 60. In an examination of longitudinal designs, Schaie (2005) found that longitudinal studies tend to reveal stability and even inclines in cognitive abilities across the adult life span until individuals reach their 40s, with no substantial cognitive decline until approximately 60. A comparison of the effects of aging on several cognitive abilities in cross-sectional studies versus those of longitudinal designs (Schaie, 1994) found systematic differences in the results of the two types of designs. Specifically, it was reported that cross-sectional designs revealed linear declines over the life span for tasks involving reasoning, spatial orientation, perceptual speed, and verbal memory, although verbal skills were shown to decline only after the late 60s. In contrast, longitudinal studies revealed increases until age 60 in cognitive abilities in all domains examined except for numeric ability and processing speed, which declined prior to age 60. Notably, these longitudinal studies found that verbal abilities remained stable through the late 80s. Schiae (2005) concluded that longitudinal designs produce more accurate results in their examination of cognitive changes over the life span, because they avoid problematic cohort effects that might overestimate declines in functioning.

While cohort effects[5] might present confounds to the proposed research study, the nature of the tasks in the current study, both control and experimental, would render the study vulnerable to confounding practice effects if administered within a longitudinal design. In fact, Salthouse (2009) reported that longitudinal designs actually can "mask" age-related declines by producing positivity (i.e., enhanced performance) effects associated with test-retest experience. Another reason for employing a cross-sectional study here is that a longitudinal design would be implausible given the amount of time and resources required for such an endeavor.

Nevertheless, given the potential methodological issues intrinsic to cross-sectional designs, especially cohorts effects, attempts were made to limit these effects by balancing salient demographic variables across groups: education, occupational level (i.e., socioeconomic status; Hollingshead; 1977), ethnicity, and gender.

Materials

The materials used in the current study included the screening battery, control tasks, and experimental tasks from the NYEB (Borod et al., 1992), with some additional tests to screen for dementia (to be specified below). For the nonemotional control tasks and the experimental tasks, participants completed both the expression (i.e., requiring the participant to produce, or express, nonemotional and emotional content) and perception (i.e., identifying and discriminating between stimuli) subtests. However, because this study focused on perception, only data from the perception tasks were examined.

Screening battery. A background history form was completed in order to obtain basic demographic data, including ethnic background; language, educational, and occupational history; handedness; and socioeconomic status. All participants had learned English by age seven. This was preferable because, according to the literature, the English language proficiency of individuals who learned English by age seven is indistinguishable from that of native English language speakers (Johnson & Newport, 1989). However, in the interest of maintaining a diverse sample, we considered potential participants who acquired the English language as late as age 10, if they demonstrated high proficiency in the language, as assessed by neuropsychological tests (e.g., Boston Diagnostic Aphasia Examination; Goodglass & Kaplan, 1983).

Next, experimenters took general medical, neurological, pharmacological histories using a semi-structured background history form (Borod et al., 1992). Exclusionary criteria included a positive history of neurological illness such as epilepsy; neurological trauma such as traumatic brain injury or stroke; or congenital illness. Those with a medical history indicating a sensory deficit, or any other condition(s) that would impair performance on control and/or experimental tasks, were excluded. In terms of pharmacological history, participants who were taking psychotropic, sedative/hypnotic, and/or potentially debilitating medications (i.e., those interfering with perceptual, cognitive, affective processing), and/or those meeting criteria for substance abuse (either alcohol or drugs) were excluded. Lastly, a general psychiatric history was taken.

In order to screen for affective disorders, the Schedule for Affective Disorders and Schizophrenia-Lifetime Version (SADS-L; Endicott & Spitzer, 1978) and the Geriatric Depression Scale (Yesavage et al., 1982) were administered. Those with a history of substance abuse and/or psychiatric illness (i.e., meeting criteria for an Axis I or Axis II disorder, according to the DSM-IV) were excluded. Those with a GDS score greater than 9 were excluded, as the GDS manual indicates that a score of 0-9 does not indicate depression, 10-19 indicates mild depression, and a score greater than 20 suggests severe depression (Yesavage et al., 1982).

A battery of neuropsychological tests was administered in order to screen for linguistic, memory, cognitive, and basic perceptual functions. Cutoff scores are listed in Table 1, and screening data for the sample are listed in Table 7 in the Appendix. In general, subjects scoring less than the equivalent of a scaled score of seven on any screening measure were excluded. This cutoff was chosen because scaled scores lower than seven, or below the 16th percentile, indicate performance in the "borderline" or "impaired" range (Spreen & Strauss, 1998). Because our targeted sample will be older than 79 years of age, normative data are not available for all screening measures. When available, normative values were obtained from external normative studies (e.g., the Mayo Older Adults Normative Sample [MOANS] study; Ivnik et al., 1992). Otherwise, we used normative data from the oldest normative group available.

Language comprehension and reading proficiency were assessed with three subtests from the Boston Diagnostic Aphasia Examination (BDAE; Goodglass & Kaplan, 1983): Commands, Complex Ideational Materials, and Reading Sentences and Paragraphs. For memory, immediate and delayed recall was assessed with the Logical Memory I and Logical Memory II subtests of the Wechsler Memory Scale – Revised (WMS-R; Wechsler, 1987). The Information and Block Design subtests of the Wechsler Adult Intelligence Scale (WAIS-R; Wechsler, 1981) assessed general cognitive ability. In order to determine whether participants could perceive control and experimental audio-visual stimuli, visual perception was tested using the Benton Visual Form Discrimination task (BVFD; Benton, Eslinger, & Damasio, 1983), and auditory perception was tested with both the Benton Phoneme Discrimination Test (BPD; Benton et al., 1983) and Pure Tone Threshold (Beltone Special Instruments Division: Owner's Manual, 1987).

To screen for dementia, the Mattis Dementia Rating Scale (DRS; Mattis, 1988) and the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) was administered to the second sample (i.e., participants aged 80-89). The DRS was used to exclude participants on the basis of the following criteria: Highly-educated, Caucasian subjects with a DRS score lower than 133 (Salmon et al., 2002), but meeting all other screening criteria, were referred for further testing, including the California Verbal Learning Test—Second Edition (CVLT-11; Delis, Kramer, Kaplan, & Ober, 2000), in order to rule out dementia. This is the strictest cut-off score reported in the literature for that demographic, achieving a sensitivity of .96 and specificity of .92 (Salmon et al., 2002). Monsch et al. (1995) found that using a cut-off score of 129 in a highly educated, Caucasian sample provided higher levels of specificity (.97) and sensitivity (.98). Therefore, highly educated participants with a score lower than 129 were excluded. Vangel and Lichtenberg (1995) found that a cut-off score of 125 was acceptable for use in an urban population that was not generally highly educated. Therefore, for less-educated participants and non-Caucasian participants, a cut-off score of 125 was applied, but those achieving a score between 125-128 were administered the CVLT-II (Delis et al., 2000) and had to meet all other screening criteria. For the MMSE, participants scoring 26 or lower were excluded, as such scores may indicate possible dementia (Bleecker, Bolla-Wilson, Kawas, & Agnew, 1988). Cut-off scores for screening criteria are summarized in Table 1.

Experimental (Emotional) Measures

Randomization. Although the screening measures and control tasks (excluding the lexical nonemotional control tasks) are administered in a fixed order, the experimental measures are randomized. There are four different orders, which were assigned randomly to participants, both within and across subject (i.e., age) groups.

Emotions. Each emotional stimulus represents one of eight emotions, three of which are positive (happy, interest, and pleasant surprise) and five of which are negative (anger, sadness, fear, disgust, and unpleasant surprise).

Identification tasks. There is one task each for the facial and prosodic channels, and two tasks for the lexical channel. For each identification task, subjects are presented with a card that lists the eight emotions. The participant provides a forced-choice response indicating which of the eight emotions each stimulus represents, and each response is either marked correct (1 point) or incorrect (0 points).

For the facial identification task (FID), participants view 32 slides of faces, each expressing one of eight emotions, one at a time. Stimuli were taken from Ekman and Friesen's (1976) series of facial pictures, which includes 20 slides of people depicting five emotions: happiness, sadness, disgust, anger, and fear. Additional stimuli were taken from slides developed by Borod, et al. (1992). These slides match Ekman and Friesen's (1976) slides in terms of poser gender (9 male and 12 female posers in the combined stimuli set) and age (mean combined age = 38.3), and they include the five aforementioned basic emotions plus facial expressions of interest, pleasant surprise, and unpleasant surprise. Actors and actresses were recruited from the New York City area. They were screened on the following criteria: (a) right-handed adults, (b) high-school educated, (c) native English speaker, (d) no medical/physical problem affecting their face, (e) no history of psychiatric or neurological disorder, and (f) not medicated. Posers were given detailed information on the emotions they portrayed and practiced the expressions extensively. The 256 poses that were generated were randomized and presented to raters for accuracy (for more information on development of stimuli, see Borod et al., 1992). The slides are presented on a Telex Caramate 3000 slide projector.

For the prosodic identification task (PID), participants listen to 24 sentences, each presenting one of four lexically neutral sentences in emotional tones of voice: “They found it in the room.”; “She put it on the tray.”; “He went to walk the dog.”; and “We saw it on TV.” These sentences were generated by the same actors and actresses that produced the facial stimuli, as discussed above (Borod et al., 1992). Sentences are similar in grammar, rhythm, and length, comprehensibility, and low emotionality ratings (mean emotionality on a 5-point scale = 0.33). The clips are played on an audio-cassette tape recorder.

For the lexical identification task, there is a Word Cluster Identification task (WID) and a Sentence Identification task (SID). For the SID task, participants read 24 clusters of three words each. For each cluster, they must choose which of the eight emotions all three words represent, for example, “putrid, slime and stench” (disgust). For the SID task, participants read 24 sentences and decide which of the eight emotions the sentence expresses. For example, “He felt the urge to hit someone” (disgust).

Discrimination tasks. For the discrimination tasks, participants are presented with a list of the eight emotions printed on a piece of paper. They are also presented with two response choices: “Different” or “Same.” Each item consists of two stimuli that represent either the same emotion or different emotions. If the two stimuli represent the same emotion, they respond “Same” and if they represent two different emotions, they respond “Different.”

For the facial discrimination task (FDIS), participants view 28 pairs of slides of people making different facial expressions. The slides were derived from Ekman and Friesen (1976) and from the stimuli set developed by Borod et al. (1992), as discussed previously. The slides are presented on a Telex Caramate 3000 slide projector. Participants choose whether the posers are expressing either the same or different emotional facial expression(s).

For the prosodic discrimination task (PDIS), participants listen to 28 pairs of pre-recorded neutral-content sentences (e.g., “She put it on the tray”), from the stimuli set developed by Borod et al. (1992), as discussed above in the prosodic perception task section. The clips are presented through an audio-cassette tape player. Participants indicate whether each sentence expresses either the same or different emotional tone(s) of voice.

For the lexical (i.e., word) discrimination task (WDIS), participants read 28 pairs of words (e.g., “panic” and “petrified”) and indicate whether they represent either the same or different emotion(s).

Control (Nonemotional) Measures

To control for depression, the Beck Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) was administered. Next, a series of neuropsychological measures was administered to control for age-related changes in relevant domains of cognitive and perceptual functioning. The Benton Facial Recognition Test (Benton, deS Hamsher, Varney, & Spreen, 1983) was administered to control for age-related changes in facial identification and the Visual Matrices Test (Borod et al., 1993) was used to assess basic form perception. The Intonation Contours Task (Borod et al.,

1992) was administered to control for differences in prosodic discrimination. To control for sustained attention, the Letters and Geometric Shapes Cancellation Tasks (Diller, Ben-Yishay, Goodkin, Gordon, & Weinberg, 1974) were administered. The Controlled Oral Word Association Test (FAS; Benton, 1968) and the Animal Naming Test (Goodglass & Kaplan, 1983) assessed verbal fluency.

For the lexical control tasks, Borod et al. (1992) developed a series of nonemotional tasks analogous to the emotional tasks from the NYEB. For each item on these tasks, the participant indicates a forced-choice response, which is either marked correct (1 point) or incorrect (0 points). The tasks include Nonemotional Word Cluster Identification (NE WID), which requires participants to read clusters of three words each and choose which of eight categories they all represent (e.g., Hair Type, Personality, and Teeth); Nonemotional Sentence Identification (NE SID), in which participants read full sentences and choose which category they best represent; and Nonemotional Word Discrimination (NE WDIS), which requires participants to read pairs of words and decide whether they represent the same category or two different categories.

Procedures

Testing sessions took place in Dr. Borod's Emotion Laboratory at Queens College in Flushing and at Mount Sinai Medical Center in New York City. The duration of the experiment ranged from three to eight hours. Participants first completed the screening battery, and if they passed the screening measures satisfactorily, they were invited to participate in the experimental test sessions. Participants generally completed the battery in three to four sessions, each lasting between two and three hours.

Data Analysis

Scoring and Reliability

Each response was scored as either correct (1) or incorrect (0). Because different tasks have different numbers of items (e.g., the prosodic identification task has 24 items and the facial identification task has 32 items), percentage scores were computed for total scores. Percentage scores were then calculated for positive and negative items (for identification), and positive, negative, and mixed items (for discrimination). For identification, scores have been shown to be internally consistent. In a sample of 170 subjects, obtained Pearson product-moment correlations for category accuracy were in the .70s and .80s ($\underline{mdn}_r$ = .77 [Borod, Tabert et al., 2001]). Test-retest coefficients were in the.70s to .90s ($\underline{mdn}_r$ = .79 [Zgaldjardic, Borod, & Sliwinski, 2002]). In this sample, test-retest coefficient values for discrimination ranged between the .60s and .70s ($\underline{mdn}_r$ = .65 [Borod, Tabert, et al., 2001]).

Preparation of the Data

In order to prepare data for analysis, raw scores for the experimental and control tasks from the NYEB (Borod, 1992) were transformed into percentages. For example, a score of 26/28 on a task would be transformed into a score of 92.86%. This step enabled comparisons across tasks and channels. Control tasks that were not from the NYEB were entered as raw scores.

Inspection of the Data

First, histograms and scatter plots were created for each variable for each age group and were systematically inspected for outliers. Means and standard deviations for each task were calculated, and scores falling two standard deviations above or below the mean were identified and further investigated for experimental error.

Tests of Normality and Homogeneity of Variance

The planned hypothesis tests (i.e., Analysis of Variance [ANOVA] and Analysis of Covariance [ANCOVA]) are parametric tests with the following assumptions: the data are on an interval scale; the shape of the population distribution is normality distributed; and variances among the groups are approximately equal (i.e., homoscedasticity). In order to determine whether the normality and homoscedasticity assumptions were met, the Shapiro-Wilk test (Maxwell & Delaney, 1990) and Levene's test for homoscedasticity (Levene, 1960) were performed for each age group on each variable.

Data Transformation

There were several variables that were negatively skewed for the majority of the age groups. In order to transform these non-normal distributions into shapes that more closely approximated normal distributions, log transformations were performed, and the Shapiro-Wilk tests were re-run for each variable by age group.

Subject Matching

The first aim of the study involved extending the research sample from 103 healthy individuals, aged 20-81, to include 13 additional healthy individuals, ages 80-89. Attempts were made to match the existing sample on the following demographics: gender, ethnicity, education, occupational level and handedness. For dichotomous variables (i.e., gender and ethnicity), chi-square analyses were performed across age groups, as defined by decade (e.g., 20-29, 30-39.). Ethnicity was entered as either Caucasian (a value of "1") or non-Caucasian ("2"). For gender, a chi-square analysis was performed for each age group to examine whether the male-to-female ratio remains constant across age groups. Gender was entered as either male ("1") or female ("2").

Considering evidence of in-group advantages for emotion perception (Elfenbein & Ambady, 2002), we were interested in examining whether the Caucasian to non-Caucasian ratios were consistent across groups. A chi-square test was performed to compare the proportion of Caucasian to non-Caucasian participants across age groups. For continuous demographic variables (e.g., education, handedness, and occupational level), two-way ANOVAs were performed in order to assess whether there were significant differences in these variables among the seven age groups.

Nonemotional Control Measures

Seven two-way ANOVAs were run, with age group as the independent variable (IV) and performance as the dependent variable (DV), for six nonemotional control tasks that involve perception in the three channels of communication: facial—Benton Facial Recognition Test (Benton, deS Hamsher, Varney, & Spreen, 1983) and Visual Matrices Test (Borod et al., 1993); prosodic—Intonation Contours Perception (Borod et al., 1992) and Benton Phoneme Discrimination (BPD; Benton et al., 1983); and lexical—Nonemotional Word Cluster Identification, Nonemotional Sentence Identification, and Nonemotional Word Discrimination (Borod et al., 1992). Additionally, to control for depression, a one-way ANOVA was run for scores on the Beck Depression Inventory across age groups.

Effects of Demographic and Control Variables on Emotion Perception

Demographic variables. There is evidence that demographic variables can affect emotion perception for some communication channels, including gender (Grunwald et al., 1999; Kimura & Hampson, 1993; Li et al., 2008; Miura, 1993; Montagne et al., 2005; Szymanowski et al., 2007; Thayer & Johnsen, 2000; Weiner, 2006) and ethnicity

(Brekke, Nakagami, Kee, & Green, 2005). There is evidence that men and women process emotional communications differently for the lexical (Grunwald et al., 1999), facial (Weiner, 2006), and prosodic (Szymanowski et al., 2007) channels. Further, primarily Caucasian models and speakers produced the test stimuli. Although emotional expressions are somewhat uniform in their interpretation across cultures (Ekman & Friesen, 1975), there is evidence for an in-group advantage for emotional processing. In other words, individuals processing emotions that are expressed by someone of their own ethnicity may be better able to perceive the emotions, when compared to the perception abilities of someone from a different culture or ethnicity (for a meta-analytic review, see Elfenbein & Ambady, 2002).

Multiple regression procedures were chosen because of their robustness to distributions that deviate somewhat from the normal curve (Mertler & Vannatta, 2009, p. 172; Tabachnick & Fidell, 1996). Additionally, regression allows us to treat age as a continuous, rather than a categorical, variable. In order to identify the demographic characteristics that contributed to the variance across age groups, blockwise multiple regression procedures were performed for each of the seven tasks: WID, SID, FID, PID, WDIS, FDIS, and PDIS. Because substantive data have been acquired on the potential associations between demographic variables and emotional perception, variables were entered blockwise (Tabachnick & Fidell, 1996).

Control variables. Control tasks were administered as part of the NYEB in order to distinguish between cognitive skills and emotional perception. First, ANOVAs were run on each of the age groups in order to determine whether performance on these measures varied as a function of age. It was also important to explore the amount of variance contributed by each of the control tasks to performance on their analogous experimental tasks. Moreover, control tasks were entered as the first block in each of the multiple regression analyses. It was hypothesized that these tasks, which are closely matched to their emotional counterparts, would contribute significant amounts of variance to each model. The blockwise regression procedures were run with the following control variables entered in the first step: FID – Visual Matrices Test (NYEB) and The Benton Facial Recognition Test (Benton, deS Hamsher, Varney, & Spreen, 1983), WID – NE WID (NYEB; Borod et al., 1992), SID – NE SID (NYEB), PID - Intonation Contours Task (NYEB) and Benton Phoneme Discrimination (Benton et al., 1983), WDIS – NE WDIS (NYEB), FDIS – Visual Matrices Test (NYEB) and The Benton Facial Recognition Test (Benton et al., 1983), and PDIS – Intonation Contours Task (NYEB) and Benton Phoneme Discrimination (Benton et al., 1983). Demographic variables that were hypothesized to contribute large amounts of variance were entered second, followed by the variables that were hypothesized to contribute progressively less variance. Age was entered last for these variables in order to examine the association between age and task performance after controlling for these demographic factors and control measures. Age was entered as a continuous variable. For the lexical tasks, predictors were entered in the following ascending order: control task(s), gender, education, ethnicity, and age. For non-lexical tasks, variables were entered in the following order: control task(s), gender, ethnicity, education, and age.

Age Differences in Emotional Perception

To examine the non-linear patterns of performance among the seven age groups and to investigate whether performance varies as a function of valence, a series of three-way analyses of covariance (ANCOVAs) was performed. One ANCOVA was performed for each of the emotional tasks for which age was a significant predictor after controlling for demographic and control variables (as determined by multiple regression analyses). For each analysis, there was one between-subjects factor (Age Group) and one within-subjects factor (Valence). Performance on each task was the dependent variable. In summary, a total of 7 two-way ANCOVAs were planned: FID, WID, SID, PID, WDIS, FDIS, and PDIS. The main effect of Age Group was used to investigate the pattern of performance among the age groups, and to determine whether declines in the perception of emotion persist in this oldest age group. On a post-hoc basis, the Tukey-Kramer test was used to analyze differences among the age groups. Because the sample sizes were unequal, the Tukey-Kramer test was chosen as a conservative method of post-hoc analysis for samples with unequal ns (Hochberg & Tamhane, 1987, p. 157). The interaction between Age Group and Valence was used to examine hypotheses regarding selective declines in the perception of negative emotional perception with age.

Intercorrelations among Channels by Age Group

Parametric procedures. Correlations were calculated for each task pair to determine whether interrelationships among the three communication channels increase with age. We examined whether participants' patterns of performance became more or less homogeneous with age (i.e., whether specific strengths and weaknesses across communication channels become more or less profound with increasing age). To this end, we computed partial Pearson product-moment correlation coefficients for each age group to evaluate interrelationships among the facial, prosodic, and lexical tasks. We first divided the sample into seven age groups (i.e., 1: 20-29; 2: 30-39; 3: 40-49; 4: 50-69; 5:

70-79; and 6: 80-89). Next, in order to increase power, we performed the analyses after dividing the sample into three age groups (Young: 20-39; Middle: 40-59; and Older: 60-89).

For the identification tasks, five correlations were calculated: Word Identification vs. Prosodic Identification, Sentence Identification vs. Prosodic Identification, Word Identification vs. Facial Identification, Sentence Identification vs. Facial Identification, and Facial Identification vs. Prosodic Identification. For a validity check, the correlations between Word Identification and Sentence Identification were also calculated with the hypothesis that high correlations between these tasks would add to internal validity of the tasks.[7] Significant demographic and control task predictors of task performance, derived from the multiple regression procedures described previously, were partialled out for the corresponding comparisons: FID – Benton Facial Recognition; WID – Education and NE WID; SID – Education and NE SID; and PID – Intonation Contours Perception.

For the Discrimination tasks, three correlations for each group were calculated, each comparing a pair of tasks: Word Discrimination vs. Prosodic Discrimination, Prosodic Discrimination vs. Facial Discrimination, and Word Discrimination vs. Facial Discrimination. Significant demographic and control task predictors of task performance, derived from the multiple regression procedures described previously, were partialled out for the corresponding comparisons: FDIS –Visual Matrices and Education; WDIS – Nonemotional WDIS and Ethnicity; and PDIS – No partials.

In order to simplify the comparisons among the age groups, the correlations were collapsed over specific task by deriving the median correlation for each task type (i.e., Discrimination and Identification), and then comparing the median correlations across age groups using the Fisher's z-test for correlation coefficients. This approach allowed us to examine statistically whether, in general, intercorrelations among the three tasks increased with age.

Nonparametric procedures. Due to the non-normally distributed nature of several of the task variables, Spearman's rho statistics were calculated in order to attain nonparametric measures of correlations among the tasks. Because the Fisher's z-test is designed exclusively for comparing Pearson correlations, the Spearman statistics were compared via visual inspection with the partial Pearson correlations in order to examine the convergent validity of the parametric with the nonparametric tests.

RESULTS

Subject Matching

Demographic characteristics of the sample are presented in Tables 2 and 4. Analyses comparing demographic variables across the seven age groups revealed that there were no significant age group differences for years of education ($F[6, 108] = 0.69$, $p = .661$)[6], socioeconomic status (Hollingshead, 1977; $F[6, 108] = 0.65$, $p = .688$), handedness ($F[6, 108] = 0.63$, $p = .705$), gender ($\chi^2[6] = 3.99$, $p = .677$), or ethnicity (i.e., Caucasian vs. Non-Caucasian; $\chi^2\,[6] = 7.63$, $p = .266$; see Table 3).

Nonemotional Control Measures

Means for scores on nonemotional control tasks by age group are presented in Table 5. The non-emotional control measures and educational level were included as predictors in the multiple regression analyses and as covariates in the ANCOVAs, where relevant. Additionally, analyses of variance were performed on the control tasks and educational level in order to determine whether performance varied as a function of age group. Therefore, tests of normality and tests of differences among the age groups were run for these measures. Shapiro-Wilk tests of normality were performed for the following non-emotional control tasks: Benton Facial Recognition, Visual Matrices, Benton Phoneme Discrimination, Intonation Contours Perception, NE WID, NE WDIS, and NE SID. Results are presented in Table 1 in the Appendix. Following inspection of normality, both parametric (ANOVA) and non-parametric (Kruskal-Wallis) tests were run to determine whether performance varied systematically by age group for each of these measures.

For the Benton Facial Recognition Test, only two out of seven age groups (i.e., 2 and 3) were not normally distributed, which does not constitute a majority of the sample (Lindman, 1974; Manly, 2005, p. 15). The one-way ANOVA revealed that performance on this measure did not vary by age group. For Visual Matrices, Shapiro-Wilk tests of normality revealed that the distribution of scores was not normal for each of the age groups. The one-way Kruskal-Wallis test indicated that performance varied by age group, $p < .05$, such that Age Group 6 performed significantly worse than Age Group 3. Intonation Contours Perception was not normal for five out of the seven age groups. The Kruskal-Wallis test for this measure did not reveal differences in performance as a function of age group. For Benton Phoneme Discrimination, four out of the seven age groups demonstrated non-normal distributions. The Kruskal-Wallis test indicated that performance on this task varied by age group, $p < .05$, such that Group 6 performed significantly worse than Group 1. The NE WID task was non-normally distributed for each age group, and the Kruskal-Wallis test for this measure indicated that there was not an overall signicant effect of age group on this task. Both NE SID and NE WDIS were non-normally distributed, and Kruskal-Wallis tests revealed that there were age-related differences in performance for NE SID, $p < .01$, and for NE WDIS, $p < .05$. For NE SID, Groups 6 and 7 scored lower than the Group 2 ($p < .01$ and $p < .05$, respectively). For NE WDIS, Group 7 performed worse than Group 1.

Inspection of the Data

Scores that were two standard deviations above or below the mean were inspected for experimental errors. No errors in data entry or score transformation were detected. Inspection of the data for outlying scores revealed only eight instances of scores that fell two standard deviations below the mean, and no scores were greater than two standard deviations above the mean. The following eight different participants attained outlying (i.e., lower than two standard deviations below the mean) scores: 1) A 37 year-old Hispanic man with 12 years of education [Low WID]; 2) A 60 year-old Caucasian man with 13 years of education [Low WID]; 3) A 26 year-old Caucasian woman with 14 years of education (Low WID); 4) An 84 year-old Asian woman with 10 years of education [Low SID]; 5) A 24 year-old Caucasian woman with 16 years of education [Low FID]; 6) A 48 year-old Caucasian woman with 14 years of education [Low FID]; 7) A 57 year-old African-American woman with 13 years of education [Low FID]; and 8) A 33 year-old African-American man with 16 years of education. There were no instances in which one person had more than one outlying score. It was subsequently determined that the outliers represented variability in performance, rather than experimental error. They were therefore included in the analysis.

Tests of Normality and Homogeneity of Variance

When the sample was divided into seven age groups by decade and normality was tested using the Shapiro-Wilk test for sample sizes < 50, all tasks were normally distributed for each age group except for Word Identification (WID; See Table 6) and Prosodic Discrimination (PDIS; See Table 7), which were negatively skewed for four and five age groups, respectively. The Facial Identification (FID) task had a non-normal distribution for one age group only, and therefore it was determined that the assumption of normality of the distribution for this task was acceptable, as the majority of the distributions across groups were normally distributed (Lindman, 1974; Manly, 2005, p. 15). When the sample was divided into three age groups (Young=20-39; Middle=40-59;

Older=60-89) the following tasks were not normally distributed for a majority of age groups: WID, FDIS, and PDIS (See Table 8). For the variables that were not normally distributed, attempts to normalize the distributions using natural log transformations and square root transformations for negatively-skewed data failed to normalize any of the variables.

Log transformations failed to normalize the distributions for tasks that were not normally distributed within groups (i.e., WID and PDIS for seven age group comparisons, and WID, PDIS, and FDIS for three age group comparisons). Because ANCOVAs can be sensitive to the assumption of normality (Manly, 2005, p. 42) both ANCOVAs and nonparametric measures were used for these variables. Although multiple regression procedures are relatively robust for variables that exhibit some deviations from normality (Mertler & Vannatta, 2009, p. 172; Tabachnick & Fidell, 1996), the residuals were plotted for visual inspection of deviations from the normal curve (Micceri, 1989) and for examination of linearity, which is an assumption of multiple regression (Mertler & Vannatta, p. 172; see Appendix for normal P-P plots and normal de-trended P-P plots of the residuals for each task). The plots indicate that residuals for the FID, SID, PID, FDIS, and WDIS tasks are linear and normally distributed. The WID and PDIS tasks show moderate deviations from the normal distribution. Since moderate violations of linearity and normality can often be tolerated (Tate, 1992) because they do not invalidate, but only weaken, multiple regression procedures (Tabachnick & Fidell, 1996), the non-normally distributed variables were included in the multiple regression analyses.

To test for homogeneity of variance across age groups, Levene's test of homoscedasticity was run for all seven age groups across all tasks. Variances for performance were not significantly different across the seven age groups.

Effects of Demographic and Control Variables on Emotion Perception

This series of analyses was performed in order to investigate factors contributing to successful or unsuccessful performance on measures of emotion perception, and to explore possible confounding variables in our experimental analyses. Blockwise multiple regression analyses were performed for all experimental tasks. For all of the following analyses, the percentage of variance accounted for in each model reports the $\underline{R}^2$ statistic, which represents the percentage of variance in the sample. Adjusted $\underline{R}^2$ values, which are meant to describe the population from which the sample was derived, are not reported due to the relatively large size of the sample.

In order to investigate the association between demographic variables (i.e., gender, ethnicity, and education) and cognitive performance, on one hand, and emotion perception abilities, on the other, multiple regression analyses were performed. Predictors were entered blockwise, as opposed to stepwise, because of evidence that certain demographic characteristics may predict performance for specific tasks. Further, it was predicted that for most tasks, the control tasks would predict a significant amount of the variance. In order to analyze the proportion of the variance predicted by corresponding nonemotional control tasks, the nonemotional control measures that corresponded with the emotional variable were entered first, followed by demographic variables. Age was entered last, as a continuous variable, in order to examine the association between age and task performance after controlling for these demographic and cognitive variables. For the lexical tasks, variables were entered in the following order: control task(s), gender, education, ethnicity, and age. Education was entered second for these analyses because the lexical tasks are language-based. Therefore, it was predicted that educational level, which is associated with language learning and comprehension, would contribute a significant amount of variance to participants' performance on the three lexical emotion tasks.. For non-lexical variables, they were entered in the following order: control task(s) gender, ethnicity, education, and age.

We used the results of the multiple regression analyses to investigate the effects of demographic characteristics on emotion perception in separate channels to guide additional analyses and to determine whether age-related differences in performance persisted even after accounting for the proportion of the variance predicted by the control tasks. In terms of guiding additional analyses, we used the final multiple regression models (i.e., "Model 5;" those that included all demographic variables, control measures, and age) to identify the demographic and control variables that contributed a significant amount of variance to performance on each task. Those variables were entered as covariates in our non-linear analyses of age-related differences (i.e., ANCOVAs, as discussed below). This model was chosen to identify the covariates for two reasons. First, from a theoretical standpoint, the ANCOVAs include each of these variables, whether entered directly as individual variables (e.g., age) or indirectly as they might affect individual performance, which is the dependent variable. We were, therefore, interested in identifying the proportions of variance in a model that were most comprehensive. Second, from a statistical perspective, we were interested in maximizing power in the ANCOVAs while simultaneously controlling for confounding variables.

Using the last and most comprehensive model from the regression analyses allowed us to eliminate factors that were not found to contribute significant proportions of variance to performance on the emotional tasks. If we had derived the covariates from all regression models, there would have been more covariates in the ANCOVAs and, therefore, fewer degrees of freedom, which would have decreased power. Moreover, the final models were used in the interest of maximizing power and, thereby, decreasing the chance of committing a Type II error.

Facial Identification. For the FID task, the first model included the Benton Facial Recognition Test and the Visual Matrices test. See Table 9. This model was significant, $F = 10.59$, $p < .001$. The Benton Facial Recognition Test predicted a significant amount of the variance, $t = 4.50$, $p < .001$ but the Visual Matrices test did not, $t = 1.09$, $p = .278$. In subsequent models, no demographic variables were significant except for age, which was entered last, $t = -6.89$, $p < .001$, and accounted for an additional 35.3% of the variance ($R^2 = .353$) in performance (See Table 9).

Word Identification. The NE WID control task predicted a significant amount of the variance in performance on the emotional WID task, $F = 24.79$, $p < .001$, and accounted for 18.1% of the variance. Gender did not predict a significant amount of variance, but education predicted an additional 4.6% of the variance, which was significant, $t = 2.57$, $p < .05$. Ethnicity was entered next and did not contribute a significant amount of variance. Finally, age accounted for an additional 11.1% of the variance, $t = -3.82$, $p < .001$, for a significant total model, $F = 10.22$, $p < .001$. See Table 10 for results of this analysis.

Sentence Identification. For SID, the NE SID task predicted a significant amount of variance, F = 9.13, p < .01. Gender did not account for a significant amount of the variance, but Education, when entered after gender, predicted a significant amount of the variance, t = 4.67, p < .001. When Ethnicity was added to the model, NE SID and Education remained significant. When age was entered last, the NE SID did not account for a significant amount of variance, but Education (t = 4.29, p < .001) and Age (t = -3.22, p < .01) each predicted significant proportions of the variance. See Table 11.

Prosodic Identification. Nonemotional control tasks for PID included Benton Phoneme Discrimination (Benton et al., 1983) and Intonation Contours Perception (NYEB). When entered together, the model was significant, F = 14.34, p < .001. Benton Phoneme Discrimination accounted for a significant amount of the variance, t = 3.10, p < .01. Intonation Contours Perception also contributed a significant amount of variance, t = 2.70, p < .01. Gender, ethnicity, and education did not predict significant proportions of the variance. When age was added to the model, it accounted for an additional 31.0% of the variance, which was significant, t = -4.39, p < .001. After age was added, the percentage of the variance accounted for by Benton Phoneme Discrimination was no longer significant, t = 0.68, p = .497. This final model accounted for 46.4% of the variance and was significant, F = 15.38, p < .001. Results are presented in Table 12.

Facial Discrimination. For the FDIS task, when Benton Facial Recognition and Visual Matrices were entered together, the model predicted a significant percentage of the variance, F = 5.43, p < .01. Both Benton Facial Recognition (t = 2.13, p < .05) and Visual Matrices (t = 2.57, p < .05) contributed significant amounts of variance. Gender and ethnicity did not contribute significant amounts of variance. Education, when added fourth, predicted an additional 5.0% of the variance. Finally, age predicted an additional 13.2% of the variance, which was significant, $t = -4.39$, $p < .001$, for a significant final model, $F = 6.78$, $p < .001$ (See Table 13). In this final model, the proportion of the variance accounted for by the Benton Facial Recognition test was no longer significant.

Word Discrimination. For Word Discrimination, the NE WDIS task predicted a significant amount of variance (i.e., 18.8%) when entered alone, $F = 25.94$, $p < .001$. Gender and education did not predict significant amounts of additional variance. Ethnicity (Caucasian vs. non-Caucasian) did predict a significant amount of the variance in the final model for Word Discrimination, $t = -1.99$, $p < .05$. Interestingly, for this task, age failed to contribute a significant amount of variance when entered last, $t = -1.03$, $p = .304$ (See Table 14).

Prosodic Discrimination. For the emotional PDIS task, Benton Phoneme Discrimination predicted a significant amount of variance, $t = 2.43$, $p < .05$, but Intonation Contours Perception did not, $t = 1.79$, $p = .076$. Gender, ethnicity, and education did not predict significant amounts of variance, but age, when entered last, predicted an additional 3.3% of the variance, which was significant, $t = -2.25$, $p < .05$. The final model was significant, $F = 3.91$, $p < .01$. See Table 15 for results of this analysis.

Age Differences for Emotion Tasks

One two-way ANCOVA was run for each of the six emotional tasks for which age was a significant predictor after controlling for nonemotional control tasks and demographic variables (i.e., according to the multiple regression procedures described previously). Therefore, ANCOVAs were run for the following tasks: FID, WID, SID, PID, FDIS, and PDIS. Although two of the tasks are not normally distributed due to negative skewness (i.e., WID and PDIS), ANCOVAs were run on these tasks for the purpose of comparison, in addition to nonparametric procedures, described below. For each ANCOVA, Age Group was entered as the between-subjects variable, with Valence as the within-subjects variable. Performance on the positive and negative task items was entered as the dependent variable. Covariates were determined by the multiple regression procedures and are listed in Table 16. Adjusted means and standard errors for the ID and DIS tasks are presented in Table 8 in the Appendix.

There were significant effects of age for all of the identification tasks: FID (F[6, 107] = 7.67, p <.01), WID (F [6, 107] = 9.67, p < .01), SID (F [6, 107] = 7.54, p < .01), and PID (F [6, 107] = 3.17, p <.01). For the discrimination tasks, there was a significant main effect of age for FDIS (F [6, 109] = 4.00, p < .01). There was a trend for PDIS (F [6, 109] = 2.14, p = .054). See Table 17 for a summary of these analyses and Table 18 for a summary of means and standard deviations for each age group.

Tukey's HSD post-hoc analyses revealed that for FID, Age Groups 5, 6, and 7 performed significantly worse than Age Group 1. Age Groups 6 and 7 attained significantly lower scores than Age Group 2. Age Group 6 performed significantly worse than Age Groups 3 and 4 (see Table 19). For WID, participants in Age Group 7 performed significantly worse than those in Age Group 1. On this task, individuals in Age Group 6 attained significantly lower scores than those in Age Groups 1, 2, 3, and 5 (see Table 20). Post-hoc comparisons revealed that for SID, Age Groups 6 and 7 performed significantly worse than Age Group 1 (see Table 21). For PID, Age Groups 6 and 7 attained significantly lower scores than Age Groups 1, 2, and 3 (see Table 22). On the FDIS task, Age Group 7 performed significantly worse than Age Group 2 (see Table 23).

Age Group x Valence interactions were examined in order to determine whether age-related differences in emotion perception vary as a function of valence (see Table 24). This interaction was significant for the PID and PDIS tasks, but not for other tasks in other communication channels. Follow-up univariate analyses indicated that the interactions for the two prosodic tasks were in opposite directions. For the PID tasks, two univariate analyses were performed: Age (7) x Performance (Positive Items) and Age (7) x Performance (Negative Items). These analyses revealed age-related differences for positively valenced (F[6, 109] = 3.39, p < .01), but not negatively valenced (F[6, 109] = 1.72, p = .12) items. Pairwise comparisons (LSD) indicated that participants in Age Group 7 (M = 34.95 ± 5.88) scored significantly worse when required to identify prosodic emotional tones than participants in Age Groups 1 (M = 50.81 ± 5.08), 2 (M = 60.85 ± 5.05), 3 (M = 60.10 ± 5.34), 4 (M = 58.46 ± 5.70), and 5 (M = 63.78 ± 5.72). Further, Age Group 6 (M = 40.31 ± 5.50) performed significantly worse than individuals in Age Groups 2, 3, 4, and 5. In contrast, for the PDIS task, the univariate analysis examining negatively valenced items was significant, F(6, 109) = 6.42, p < .001, but those for positively valenced F(6, 109) = 1.68, p = .133, and mixed items F(6, 109) = 1.24, p = .291, were not. See Table 25. For the negatively valenced items, post-hoc analyses (LSD) indicated that participants in Age Group 7 (M = 87.62 ± 1.50) attained significantly lower scores than those in Age Groups 1, (M = 98.06 ± 1.34), 2 (M = 98.06 ± 1.34), 3 (M = 96.93 ± 1.41), 4 (M = 97.47 ± 1.50), 5 (M = 94.10 ± 1.50), and 6 (M = 96.29 ± 1.46).

A series of Kruskal-Wallis tests was performed for non-normally distributed tasks (i.e., WID and PDIS; Kruskal & Wallis, 1952). For each of the tasks, separate analyses were performed for positive and negative items (WID) or positive, negative, and mixed items (PDIS). For WID, because of the association between education and performance on lexical emotional perception tasks (Yip, 2006) and results from the multiple regression analyses that identified education as a significant predictor of performance, separate analyses were performed for participants with different levels of education. Because the median education level is 15 years for 115 subjects in the sample (education was unknown for one subject), age groups were divided into higher education (≥16 years; $\underline{n}$ = 48) and lower education (<16 years; $\underline{n}$ = 67), and these groups were analyzed separately for subjects with high education (≥ 16 years) and those with lower education (<16 years). Pairwise comparisons (Dunn, 1964) were calculated to determine specific differences among the seven age groups.

In summary, for the WID task, four Kruskal-Wallis tests were performed: higher education – negative valence; higher education – positive valence; lower education – negative valence; and lower education – positive valence. For the PDIS task, groups were not divided by highest education level attained because education has not been shown to exert significant effects on this task (Poole, Tobias, & Vinogradov, 2000). Three Kruskal-Wallis tests were performed for this task, one for each level of valence: negative, positive, and mixed.

Performance on the WID task varied significantly among the seven age groups, χ^2 (6, 107) = 22.89, $\underline{p} < .01$. Pairwise comparisons revealed that for this task, Age Group 6 performed significantly worse than Age Groups 3 ($\underline{p} < .05$) and 1 ($\underline{p} < .01$). For the PDIS task, performance was significantly different among the age groups, $\chi^2 = 12.88$, $p < .05$, such that Age Group 6 performed worse than Age Group 1.

Separate Kruskal-Wallis tests were performed on the non-normally distributed tasks for the different levels of valence. Results are presented in Table 26. The WID analyses were performed separately for participants with higher (≥16 years) and lower (<16) educational attainment. See Table 11 for results of these analyses. For the highly educated participants, analyses for both levels of valence were significant: Negative WID $\chi^2 = 18.72$, $p < .05$ and Positive WID $\chi^2 = 15.61$, $p < .05$. For the less educated participants, Negative WID varied across age groups ($\chi^2 = 13.38$, $p < .05$), but Positive WID did not ($\chi^2 = 8.45$, $p = .207$). A similar pattern was revealed for the PDIS analysis, in which the Negative task items were significantly different across age groups, $\chi^2 = 16.00$, $p < .05$, but the Positive items ($\chi^2 = 8.42$, $p = .209$) and the Mixed items ($\chi^2 = 6.98$, $p = .322$) were not.

Intercorrelations among Channels by Age Group

Six correlational analyses were computed for the Identification tasks, partialling for appropriate demographic variables and control tasks. See Table 16 for a summary of these variables. Median correlations were derived from five comparisons: FID vs. WID, FID vs. SID, FID vs. PID, WID vs. PID, and SID vs. PID. Comparisons were made between WID and SID on an exploratory basis and to check for validity, but since these tasks are within the same channel, they were not included in the derivation of median scores.

Seven age groups. Median scores for Identification tasks for the seven age groups, in ascending order (i.e., Age Group 1 to Age Group 7), were: .335, .234, .306, .201, .622,

.623, and .651 (see Table 27). These scores were compared using the Fisher's z Test for Pearson r (see Table 29). Although it appears that the correlations become greater in the older age groups, none of the comparisons was significant. Because some of the variables entered in the correlations were not normally distributed, Spearman r correlations were calculated in order to check the validity of the parametric analyses. The median Spearman's r correlations for each age group were derived: .197, .279, .359, .367, .636, .571, and .648 (See Table 27).

For the Discrimination tasks, three partial correlational analyses were performed. Table 16 presents a summary of demographic variables and control tasks that were partialled out of the analyses. Median correlations were derived from these comparisons: FDIS vs. WDIS, FDIS vs. PDIS, and WDIS vs. PDIS. Median scores for Discrimination tasks for the seven age groups, in ascending order (i.e., Age Group 1 to Age Group 7), were: .447, .096, .302, .081, .311, .134, and .311 (See Table 28). These scores were compared using the Fisher's r-to-z transformation. None of the resulting z scores were significant (See Table 29). Because some of the variables entered in the correlations were not normally distributed, Spearman r correlations were calculated in order to check the validity of the parametric analyses. The median Spearman's r correlations for each age group were derived: .420, .336, .234, .268, .250, .392, and .198 (See Table 28).

Three age groups. In order to increase power, groups were again combined into three age groups: Young (20-39), Middle (40-59), and Older (60-89). Identical analyses were performed with these groupings. Median scores for Identification tasks for the three age groups, in ascending order, were: .312, .373, and .701 (see Table 30). Fisher's z-tests revealed that the Older group had significantly greater intercorrelations among the channels than did the Middle ($z = -2.01$, $p < .05$) and Young ($z = -2.38$, $p < .01$) groups (see Table 32). The Middle and Young groups were not different from each other. Analogous Spearman’s r correlations were: .301, .416, and .709 (see Table 30). Median scores for the Discrimination tasks for the three age groups, in ascending order, were: .237, .164, and .191 (see Table 31). Fisher’s z-tests revealed that none of the comparisons between each pair of groups was significant, as presented in Table 32.

DISCUSSION

Summary

Results of the current study indicate that in our sample of active, community-dwelling healthy adults, older individuals (ages 70-89) are less accurate in identifying emotional expressions in the facial, lexical, and prosodic channels. Age predicted performance after controlling for demographic and control variables in all tasks except Word Discrimination. Education also emerged as a predictor of performance for all lexical tasks and for Facial Discrimination. Neither gender nor ethnicity predicted performance on emotion perception tasks. Differences in performance among the age groups did not vary as a function of valence. Intercorrelations among the channels of communication increased in the older age groups (i.e., ages 60-89) for emotion identification.

Predictors of Emotion Perception Abilities

Associations between demographic characteristics and performance on emotion perception tasks were analyzed using multiple regression techniques that controlled for cognitive/perceptual performance. Age was entered last in order to examine the proportion of the variance in performance that could be explained by age after controlling for demographic and cognitive/perceptual variables.

Gender, ethnicity, and education level were examined. Results indicated that gender did not predict performance on any emotional perception task. This findings runs counter to our hypothesis that predicted an association between gender and emotion perception. However, this result is consistent with an aim of the development of the

NYEB, which sought to balance male and female stimuli in order to minimize gender effects. Additionally, stimuli were rated by both male and female judges.

In terms of ethnicity, recent evidence for an in-group advantage for the perception of emotional expressions has been mixed. The current study examined the ability of Caucasian, Hispanic, African-American, and Asian individuals to identify expressions produced by Caucasian posers/speakers. Given research that suggests the presence of an in-group advantage for faces (e.g., Pinkham et al., 2008) and prosody (e.g., Elfenbein & Ambady, 2002), ethnicity was entered as a dichotomous variable with two levels: Caucasian and non-Caucasian. Results indicated that, contrary to the in-group advantage hypothesis, ethnicity was not associated with performance on emotion perception tasks for the facial and prosodic channels. Interestingly, ethnicity did emerge as a significant predictor of performance on the WDIS task such that Caucasian participants responded significantly more accurately than did Non-Caucasian participants. The Spearman rank-order correlation between ethnicity and Emotional Word Discrimination was -.204, $\underline{p}$ = .029. Of note, the correlation between ethnicity and Nonemotional Word Discrimination was not significant, $\underline{r}$ = .093, $\underline{p}$ = .325. This result was unexpected because we did not hypothesize that discrimination of words written on a page would involve an ethnic component. It is possible that the words carry cultural meaning that was previously undetected, indicating that some lexical stimuli are processed differently by individuals from different cultures. Future research should look at differences between specific ethnic groups, rather than treating ethnicity as a dichotomous variable, in order to better inform our understanding of emotion perception across cultures.

As expected, educational level predicted performance for all lexical tasks. This finding indicates that emotion research should consider educational level as a possible confounding variable and should be addressed accordingly. The current study approached individual variability in educational level by balancing/matching the age groups on this variable and by covarying for educational level in our inferential procedures (i.e., ANCOVAs and correlations). Similarly, cognitive/perceptual control measures predicted performance in all but one emotion perception task (i.e., PDIS, possibly because of the low ceiling effect on that task), indicating that even after implementing cognitive/perceptual screening measures, cognitive and perceptual performance should be taken into account when analyzing emotional perception abilities.

As hypothesized, age emerged as the most consistent and robust predictor of emotion perception performance, even after controlling for other demographic and control variables. In fact, age predicted a significant proportion of the variance in performance for all but one emotion perception task (i.e., WDIS). In summary, age predicts emotion perception abilities more than gender, ethnicity, and educational level. This observation constitutes a substantial finding and indicates the need for further research on the mechanisms and implications of the association between age and emotion perception skills. For example, it would be important to delineate healthy aging associated with declines in emotion perception from pathological processes that are prevalent in older populations, such as occur with dementia. Additionally, recent studies on deception have shown that older individuals may be particularly vulnerable to intentional deceit (Stanley & Blanchard-Fields, 2008) and that this may be associated with declines in recognition of stimuli that communicate emotion (Frank & Ekman, 1997).

Which Age Groups Demonstrate Declines?

One aim of this study was to examine whether emotion perception declines with age, and to define the trajectory of this change. We examined cohorts between the ages of 20 and 90 by dividing the sample by age group, as defined by decade of age (e.g., 20s, 30s, 40s, etc.), in order to identify specific cohorts that have difficulties identifying emotional expressions. When the age groups were divided by single decades, age exerted a significant effect on performance for all tasks, both identification and discrimination, in all channels of communication, with the exception of the word discrimination task. This provides compelling evidence that older cohorts are less adept at identifying and discriminating emotional expressions. Specifically, results indicate that emotion perception skills remain relatively stable among individuals in their 20s, 30s, 40s, 50s, and 60s. However, there was a significant change in emotion perception abilities in the 70-79 year-old cohort such that these older participants responded with significantly less accuracy. Although it might be hypothesized that emotion perception skills continue to decline in older groups, the 80-89 year-old group attained scores that were not significantly different from the 70-79 year-old group. Results suggest that older individuals are less able to accurately identify emotion expressions, but that this change does not occur until individuals are in their 70s, and may remain stable in octogenarians that are healthy and active community members. This latter finding is discussed, below, in the context of "selective survival."

Valence

Data were analyzed both all together and separated by valence (e.g., positive and negative, or positive, negative, and mixed). We were interested in whether older adults show selective difficulties in perceiving negative (i.e., anger, fear, sadness, unpleasant surprise, and disgust), as opposed to positive (i.e., happiness, interest, and pleasant surprise), emotional expressions. Results indicated that the effect of age on performance did not vary by valence for facial and lexical expressions. For the prosodic channel, however, there were interactions between age and valence. Specifically, older participants were less adept at identifying emotional tones for positive, but not negative, task items for the Prosodic Identification task. In contrast, for the Prosodic Discrimination task, they were less able to discriminate negative, as opposed to positive, items. This result may be an artifact of the research design. Specifically, the PID task posed significant difficulty for participants of all ages, and positive emotional items may have been especially difficult to identify for the oldest participants. The PDIS task, on the other hand, was an easy task for which there was a ceiling effect. Nonparametric analyses of the PDIS task confirmed that older individuals had selective difficulty with negative items but not with positive items. This finding may indicate a discrete difficulty for older adults in their ability to discriminate among negative emotional tones, but should be considered with caution, as the analogous Identification task demonstrated the opposite pattern (i.e., older individuals encountered difficulty with positive, but not negative, items).

Neuropsychological Models of Aging

Right hemi-aging hypothesis, valence hypothesis, and positivity bias.

The right hemisphere hypothesis purports that the right hemisphere mediates affective processing, including the perception of emotional expressions (e.g., Borod et al., 1986, 1993, 2002; DeKosky et al., 1980; Gandour et al., 2003; Ishai et al., 2005; Joseph, 1982; Ley & Bryden, 1982, Mandal et al., 1999; Parent et al., 2002). Therefore, the right hemi-aging hypothesis, which proposes that the right hemisphere ages more quickly than the left, would predict declines in emotional perception in older individuals. Results of the current study indicate that older individuals have greater difficulty perceiving emotions than younger cohorts, suggesting that the right hemisphere is vulnerable to detrimental effects of aging on the brain. However, direct statistical comparisons were not made between the cognitive and affective measures and is a limitation of the current project. Such comparisons should be made in future research.

The positivity bias hypothesis proposes that older adults have an advantage for processing and perceiving positive, as opposed to negative, emotional material (e.g., Calder et al., 2003; Keightley et al., 2006; Mill et al., 2009; Moreno et al., 1993; and Sullivan & Ruffman, 2004). We examined differences in processing for positively versus negatively valenced items in order to determine whether there was support for the positivity bias and/or right hemi-aging model. If both the positivity bias and the right hemi-aging hypothesis were true, older individuals would be expected to have greater difficulty with negative, as opposed to positive, emotional expressions. The current study did not indicate that older adults encountered selective difficulties with negative, as opposed to positive items, therefore limiting the scope of the evidence for the right hemi-aging hypothesis and providing support against the positivity bias.

Socioemotional selectivity theory. This theory would also predict that positive, as opposed to negative, emotional content is more salient (and, hypothetically, easier to identify) for older participants. We found only very limited evidence for this (i.e., results of the PDIS task; see above). This lack of compelling support for our hypothesis does not, however, provide evidence against the socioemotional selectivity theory, because the theory itself focuses on experiential, and not perceptual, phenomena.

General decline. The current study found compelling evidence that emotion perception declines with age for the facial, lexical, and prosodic channels of communication. This supports the “general decline” hypothesis. It should be noted that other channels of communication (e.g., gestural) were not examined in the current study, and therefore the generality of the proposed decline is limited to these three channels of communication. It should also be noted that many opponents of the “general decline,” or “dull” hypothesis have underscored processing speed as driving “general” declines in cognitive skills. Scores for the current study, however, do not likely reflect processing speed, as none of the tasks were timed.

Intercorrelations among the Channels

For the identification tasks, intercorrelations were greater for the Older age group than those for the Young and Middle age groups. This finding provides some evidence that emotion perception skills are more homogeneous, and less specialized, in older individuals. There were no discernible patterns among the age groups for intercorrelations among the discrimination tasks. One primary difference between identification tasks and discrimination tasks is that successful performance on identification tasks requires more skill in recognizing emotional expressions than that required for discrimination tasks. For discrimination tasks, relative to identification tasks, it is easier to determine the correct response without relying solely on emotional cues. This might suggest that the discrimination tasks were less sensitive to age-related changes in emotion perception.

De-differentiation. Researchers have proposed that whereas in early development, skills become differentiated (i.e., specialized) as children age (Cattell, 1987), in later development, skills become de-differentiated (i.e., less specialized; Li et al., 2004). Our results support this proposed process of de-differentiation of skills in older age.

It should be noted that when using correlational statistics to study aging, the nature of aging could produce artifacts that appear to be experimental effects. Specifically, as individuals reach older age, performance on various measures of ability become more correlated with the age variable. It has been speculated that, in younger adults, variance in performance is more strongly related to individual differences (e.g., genes, experience, and education) than to age. Further, in older age, cognitive abilities are thought to decline in a degenerative way that is associated with the age variable more than with individual differences, especially when compared with their younger cohorts (A.M. Brickman, personal communication, April 25, 2010).

This means that our results that support the de-differentiation model might be an artifact of the design such that older participants' scores are more highly correlated with age, and therefore more correlated with performance on all other tasks. The design was limited in that it was difficult to disentangle correlations with age from correlations among the tasks. Future studies with larger ns (and therefore more power) might achieve this by partialling for age when examining correlations among domains in various age groups.

Hemispheric asymmetry in older age (HAROLD) model. The HAROLD model predicts that hemispheric asymmetry is reduced in older adults. It has been postulated that this reduction in asymmetry might be associated with age-related de-differentiation processes in older adults. If increased intercorrelations among the channels do indicate de-differentiation processes with age (methodological considerations, discussed above, notwithstanding), then our data might provide support for this model. However, it is beyond the scope of this behavioral study to describe age-related changes in cerebral hemispheric asymmetry.

Implications for Social Functioning

Social skills. Declines in recognizing emotional expressions in others can pose a significant challenge for social functioning and adjustment. Research indicates that compromised emotion recognition is associated with deficient social skills in individuals with autism (Baron-Cohen, 1988), traumatic brain injury (Dimoska, McDonald, Pell, Tate, & James, 2010), multiple sclerosis (Krause et al., 2009), anorexia nervosa (Harrison, Sullivan, Tchanturia, & Treasure, 2009), Down syndrome (Hippolyte, Barisnikov, Van der Linden, & Detraux, 2009), epilepsy (Farrant et al., 2005), and learning disorders (Bauminger, Edelsztein, & Morash, 2005). Moreover, age-related declines in recognizing emotional expressions may have implications for social functioning in older individuals. Specifically, older individuals might be more vulnerable to deception (Stanley & Blanchard-Fields, 2008) in association with declines in emotion recognition abilities (Frank & Ekman, 1997). Further, evidence for the positivity bias in older adults suggests that they are less likely to recognize negative emotionality. Social cognition theories (see, for example, Harvey & Penn, 2010) would also predict that these difficulties with monitoring nonverbal communication during conversations could lead to poor social outcomes.

Additional Considerations

Selective survival. This study utilized rigorous screening measures to distinguish the variability in performance due to cognitive, perceptual, and medical declines on the one hand, and normal healthy aging, on the other. It is particularly important to implement these screening procedures due to the prevalence of overt or covert illness in older adults and the effects that many non-emotional factors may have on the perception of our experimental stimuli. However, implementation of rigorous screening procedures naturally results in a cohort of unique participants that have been labeled "selective survivors:" individuals with genetic advantages and different developmental trajectories than much of the older population (Hassing, Wahlin, & Backman, 1998). This phenomenon may produce a sampling bias such that individuals in their 80s that are fit enough to travel and endure eight hours of testing are different in some way (e.g., genetically) from those that are in their 70s. However, individuals who survive long enough to be included in this age group may all be considered "selective survivors." When conceptualized in this way, our sample may be generalizable to the older population, because they are all, in one way or another, "selective survivors."

Some aging and cognition studies that implement rigorous screening procedures indicate that in the oldest old, there are minimal cognitive changes with age as individuals advance to their tenth decade of life (e.g., Hassing et al., 1998; Stewart, Zelinski, & Wallace, 2000). Other studies that have less stringent screening procedures often find that there are profound changes between octo- and nanogenerians in terms of discrete domains of cognitive functioning (e.g., memory [Backman, 1991; Cherry, Hawley, & Jackson, 2008; Rabbitt, Donlan, Watson, McInnes, & Bent, 1995; West, Crook, & Barron, 1992]). This discrepancy in the cognitive literature may indicate that cognitive and medical factors can confound results regarding cognitive functioning. Less research has focused on age-related declines in emotion perception in the oldest-old, and therefore, this phenomenon has not received much attention in the emotion literature. It is interesting to note, though, that there were significant emotion perception declines in the second to oldest group (i.e., participants in their 70s), but that the decline plateaued for octogenarians. This observation suggests that healthy, active octogenarians such as those who were able to complete this study are "selective survivors," and may not represent the majority of the older population. It may be useful to classify these individuals as comprising a subset of community-dwelling, active older adults and to consider generalizing the present findings to this subset of the older population.

Depression. It should also be noted that the rate of depression in older adults is generally higher than that for our sample (see Djernes, 2006, for a review of studies on the prevalence of depression in older adults). Considering that mood affects the way we interpret others' emotional affect (Borod et al., 1990; Gollan, Pane, McCloskey, & Coccaro, 2008), the absence of mood disorders in our sample might possibly cause our results to be a mild overestimate of emotion perception abilities in the oldest old.

Limitations and Directions for Future Research

Although we found significant results with our sample size, further research should attempt to recruit larger sample sizes in order to increase power and to have the data better approximate normal distributions. In terms of increasing power for the analyses of variance, it would be ideal to divide the groups into smaller age intervals, especially in the older groups, because age effects begin to become more profound with each year in older age. Additionally, we did not find significant findings for the correlational data when the age groups were divided by decade. Increasing the sample size would allow the sample to be divided into smaller subgroups and, consequently, allow the researcher to characterize age-related differences more precisely.

Also in terms of the sample, one limitation of the current study was that individuals in the older groups were less diverse in terms of gender and ethnicity than the younger groups. When compared to younger groups, there were larger proportions of women, as opposed to men, and more Caucasian, as opposed to non-Caucasian individuals, in the oldest group. Ideally, groups would be matched on all demographic variables, including education, socioeconomic status, gender, and ethnicity. The nature of the sample (i.e., inclusion of older participants) makes it more difficult to recruit men and non-Caucasian individuals because there are less surviving individuals with those characteristics in this country, relative to women and Caucasian individuals (U.S. Census Bureau Report, 2008). In Dr. Borod's research laboratory at Queens College, we are currently employing targeted recruiting strategies in order to obtain more non-Caucasian and male participants. For example, advertisements should explicitly state the demographic characteristics that are being targeted in order to draw attention to the study from specific ethnic groups. In order to obtain a more balanced sample in terms of gender, advertisements can also specifically target male participants.

The current study examined several neuropsychological models of aging that predict age-related changes in emotion perception in general (e.g., the "general decline" hypothesis), and changes that vary as a function of valence (e.g., the right hemi-aging hypothesis, the positivity bias, and the socioemotional selectivity theory). In accordance with our aim of testing these models, we looked at the data in terms of total scores and scores for the items grouped by valence. We did not look at discrete emotions (e.g., anger, sadness, etc.). Recent evidence suggests that emotion perception abilities in older adults may vary by discrete emotion. For example, some studies have shown that the perception of disgust remains intact in older adults, relative to that of other emotions (Montagne, Kessels, De Haan, & Perrett, 2007; Orgeta, 2010; Orgeta & Phillips, 2008). This finding concurs with evidence that the basal ganglia, which are not generally considered to be vulnerable to aging, mediate the perception of disgust. Moreover, examining the perception of discrete emotions in older adults may enlighten our understanding of aging processes in the brain. In Dr. Borod's lab, Kimberley R. Savage, M.A., is currently examining the perception of discrete emotions as a function of age from a neural perspective.

Conclusions

In conclusion, emotion perception abilities were compared among seven age groups of 116 participants ranging from 20 to 89 years old. This study was unique in that demographic and control variables were examined alongside analyses of age-related differences in order to distinguish age-related changes from those resulting from differences in ethnicity, gender, and educational level. Further, comprehensive cognitive, perceptual, and medical screens were implemented and nonemotional control tasks were administered in order to capture emotion-specific differences in emotion perception. Overall, the study supports the general decline hypothesis and a de-differentiation process with age. In addition, the age groups and experimental stimuli were balanced in terms of gender, and interestingly, no gender differences emerged for any of the age groups. This evidence argues against prevailing theories of gender differences that generally indicate a female advantage for emotion perception. Although the groups were matched, future research should include more subjects and focus on recruiting more diverse older groups. The cross-sectional nature of the design limits the generalizability of the findings such that they do not necessary indicate changes as individuals age, but rather differences among cohorts of various ages. A longitudinal design might help clarify the actual trajectory of age-related changes in emotional perception while limiting cohort effects.

Footnotes

1. Theories on aging that consider the plasticity of the brain have posited that experience can affect aging processes in the brain. Specifically, engagement in intellectual activities can promote “cognitive reserve,” or redundant connections in the brain protect it from age-related atrophy (Meguro et al., 2001). Years of education have been positively correlated with a marker of brain atrophy in a non-clinical sample (Coffey, Saxton, Ratcliffe, Bryan, & Lucke, 1999), supporting the view that cognitive reserve can protect cognition against these detrimental age-related brain changes.
2. For example, the right hemisphere is thought to be responsible for the perception of emotion in the upper part of the face, whereas the perception of the emotional expression of the lower part of the face is a function of the left hemisphere (Prodan et al., 2001). In older subjects, accurate processing of emotion in the upper part of the face has been shown to be impaired relative to the accuracy of younger participants (Prodan et al., 2007). It should be noted, however, that these findings have not been replicated to our knowledge.
3. The Brinley plot is a method of measuring speed-accuracy data. Brinley plots use ratios of standard deviations between groups to calculate the slope of a straight line that best fits scores of age groups across conditions. In other words, the mean reaction times for older groups in each condition are plotted against mean reaction times for younger groups (Ratcliff, Spieler, & McKoon, 2004).

4. Former arguments in this area focused on sensory loss as a factor to explain aging changes (Salthouse, 1992).
5. One example of a relevant cohort effect is attachment style, which might be subject to generational differences. Magai and Passman (1997) found facial expression decoding biases that were associated with distinct attachment styles. The attachment styles that were associated with these biases varied systematically by cohort among individuals aged 20-80.
6. Education was normally distributed for five out of the seven age groups. See Table 2 in the Appendix.
7. The Spearman rank-order correlation between Word Identification and Sentence Identification for all participants was .533 ($\underline{p} < .05$).

Table 1. Screening Measures: Cut-Off Values

Measure	Possible Range	Cutoff
		(Minimum score for inclusion in study)
BDAE[1] Commands subtest	0-15	3 of 6 points on items 1-3
BDAE Complex Ideational Material	0-12	4 of 6 points on items 1-6
BDAE Reading Sentences and Paragraphs	0-10	5 of 10 points
WMS – R[2] Logical Memory I	0-50	7 Age-Corrected Scaled Score (SS)
WMS – R Logical Memory II	0-50	7 (SS)
WAIS-R[3] Information	0-29	7 (SS)
WAIS-R Block Design	0-51	7 (SS)
Benton Visual Form Discrimination	0-32	26 points
Mattis Dementia Rating Scale - Attention	0-37	34 points
Mattis Dementia Rating Scale - Memory	0-25	22 points
Mattis Dementia Rating Scale - Total Score	0-144	
Highly-educated Caucasian subjects		129 points If 130-132, will complete CVLT – II[4]
Non-Caucasian subjects and subjects with <13 years of education		125 points; If 126-128, will complete CVLT – II
Mini-Mental State Exam	0-30	27 points
Benton Phoneme Discrimination	0-30	19 points
Pure Tone Threshold		
500 Hz	N/A	Mean of both ears is less than or
1000 Hz	N/A	equal to 40 dB for each frequency
2000 Hz	N/A	
		(Maximum score for inclusion in study)
Geriatric Depression Scale	0-30	9

[1] BDAE = Boston Diagnostic Aphasia Exam

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

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

[4] CVLT – II = California Verbal Learning Tests – 2nd Ed.

Table 2. Sample Demographic Characteristics

	N	Age	% Women	% Caucasian	Education	SES[a]	Handedness
Age Group		Mean			Mean	Mean	Mean
		(SD)			(SD)	(SD)	(SD)
20-29	19	25.1	52.6%	47.4%	15.4	6.8	11.9
		(3.0)			(1.7)	(1.9)	(0.5)
30-39	18	34.0	55.6%	47.4%	15.3	6.4	11.7
		(2.9)			(3.1)	(1.6)	(0.7)
40-49	18	45.4	61.1%	47.1%	13.8	6.4	12.0
		(3.0)			(1.5)	(2.1)	(0.0)
50-59	15	54.3	60.0%	66.7%	14.5	6.3	11.7
		(2.8)			(2.3)	(1.4)	(0.7)
60-69	15	62.5	40.0%	53.3%	14.7	6.6	11.7
		(2.5)			(2.9)	(1.4)	(0.6)
70-79	16	73.7	50.0%	50.0%	15.1	6.9	11.9
		(2.7)			(2.4)	(1.1)	(0.3)
80-89	15	82.9	73.0%	86.6%	14.5	6.0	11.7
		(2.3)			(3.1)	(1.2)	(1.2)

[a] Socioeconomic Status based on Hollingshead Scale (Hollingshead, 1977)

[b] Strength of Right Hand Dominance (Coren, Porac, & Duncan, 1979)

Table 3. One-Way ANOVAs on Age Group (7) for Subject Demographics

	df	F	p
Education	6, 108	0.686	0.661
SES[a]	6, 108	0.653	0.688
Handedness	6, 108	0.632	0.705

	df	χ^2	p
Gender[b]	6	3.99	.677
Ethnicity[c]	6	7.63	.266

[a] Socioeconomic Status based on Hollingshead Scale (Hollingshead, 1977). [b] Chi-square test run on Men vs. Women. [c] Chi-square test run on Caucasian vs. Non-Caucasian participants

Table 4. Sample Gender and Ethnicity Characteristics by Number of Subjects

	Ethnicity				Gender	
Age Group	Caucasian	African-American	Hispanic	Asian	Men	Women
20-29	9	4	3	3	9	10
30-39	9	5	3	2	8	10
40-49	9	5	4	0	7	11
50-59	10	4	0	1	6	9
60-69	8	5	0	2	9	6
70-79	10	3	2	1	8	8
80-89	13	0	0	2	4	11

Table 5. Means and Standard Deviations for Nonemotional Control Measures by Age Group

	Age Group						
	20-29	30-39	40-49	50-59	60-69	70-79	80-89
Task n	19	18	18	15	15	16	15
WDIS[a]	84.0±8.4	82.9±9.2	82.8±7.9	80.5±9.9	81.4±11.1	75.9±9.8	75.0±10.2
WID[b]	95.8±4.4	94.4±5.6	96.3±5.7	95.3±6.7	95.3±4.7	91.4±7.7	91.7±7.2
SID[c]	75.2±11.0	79.4±7.1	76.2±9.7	71.9±11.3	71.9±9.6	63.8±14.6	64.7±11.1
VM[d]	23.5±1.0	23.4±1.1	23.8±0.6	22.0±5.0	23.7±0.6	22.6±1.5	23.7±0.7
BFR[e]	49.0±2.4	47.0±3.6	47.0±4.1	46.9±4.6	47.9±4.3	44.8±6.4	48.5±3.2
ICP[f]	22.1±2.6	20.8±3.5	21.7±1.6	22.1±1.8	20.3±3.3	20.9±3.3	21.1±4.0
BPD[g]	28.7±1.1	28.2±1.8	28.1±1.3	27.5±2.2	27.9±1.7	26.4±1.7	26.3±3.3
BDI[h]	0.72±1.1	1.7±2.3	1.6±2.5	1.6±1.8	1.9±2.2	1.6±2.1	2.0±2.8

[a] Word Discrimination. [b] Word Identification. [c] Sentence Identification. [d] VM = Visual Matrices. [e] BFR = Benton Facial Recognition. [f] ICP = Intonation Contours Perception. [g] BPD = Benton Phoneme Discrimination. [h] BDI = Beck Depression Inventory.

Table 6. Shapiro-Wilk Tests of Normality for Identification Tasks: Seven Groups

Task	Age Group	Statistic	df	p
Facial Identification	1	0.922	19	0.125
	2	0.904	18	0.067
	3	0.949	18	0.416
	4	0.952	15	0.555
	5	0.871	15	0.035*
	6	0.945	16	0.410
	7	0.944	15	0.436
Word Identification	1	0.668	19	<.001**
	2	0.837	18	0.005**
	3	0.907	18	0.076
	4	0.825	15	0.008**
	5	0.787	15	0.002**
	6	0.952	16	0.527
	7	0.895	15	0.079
Sentence Identification	1	0.907	19	0.065
	2	0.900	18	0.058
	3	0.935	18	0.242
	4	0.904	15	0.111
	5	0.908	15	0.128
	6	0.979	16	0.953
	7	0.892	15	0.072
Prosodic Identification	1	0.950	19	0.394
	2	0.914	18	0.101
	3	0.961	18	0.627
	4	0.950	15	0.517
	5	0.920	15	0.191
	6	0.950	16	0.493
	7	0.928	15	0.256

Note. Group 1=20-29; Group 2=30-39; Group 3=40-49; Group 4=50-59; Group 5=60-69; Group 6=70-79; Group 7=80-89. $^{**}p < .01$ $^{*}p < .05$.

Table 7. Shapiro-Wilk Tests of Normality for Discrimination Tasks: Seven Groups

Task	Age Group	Statistic	df	p
Facial Discrimination	1	0.936	19	0.219
	2	0.943	18	0.324
	3	0.917	18	0.114
	4	0.887	15	0.060
	5	0.939	15	0.365
	6	0.964	16	0.743
	7	0.945	15	0.445
Word Discrimination	1	0.909	19	0.071
	2	0.938	18	0.264
	3	0.966	18	0.725
	4	0.945	15	0.455
	5	0.957	15	0.641
	6	0.941	16	0.358
	7	0.888	15	0.062
Prosodic Discrimination	1	0.814	19	0.002**
	2	0.866	18	0.016**
	3	0.866	18	0.016**
	4	0.821	15	0.007**
	5	0.889	15	0.066
	6	0.816	16	0.004**
	7	0.905	15	0.112

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

[a]Group 1=20-29; Group 2=30-39; Group 3=40-49; Group 4=50-59; Group 5=60-69;Group 6=70-79; Group 7=80-89

Table 8. Shapiro-Wilk Tests of Normality for Identification and Discrimination Tasks: Three Groups

		Age Group[a]	W	df	p-value
Identification	Task				
	Facial	Young	0.931	37.000	0.023*
		Middle	0.963	33.000	0.305
		Older	0.960	46.000	0.114
	Word	Young	0.758	37.000	<.001**
		Middle	0.826	33.000	<.001**
		Older	0.894	46.000	0.001**
	Sentence	Young	0.945	37.000	0.067
		Middle	0.948	33.000	0.114
		Older	0.920	46.000	0.004**
	Prosodic	Young	0.964	37.000	0.266
		Middle	0.947	33.000	0.111
		Older	0.954	46.000	0.069
Discrimination		Age Group[a]	Statistic	df	p-value
	Task				
	Facial	Young	0.933	37.000	0.028*
		Middle	0.827	33.000	<.001**
		Older	0.943	46.000	0.025*
	Word	Young	0.943	37.000	0.058
		Middle	0.957	33.000	0.215
		Older	0.925	46.000	0.005**
	Prosodic	Young	0.844	37.000	<.001**
		Middle	0.844	33.000	<.001**
		Older	0.882	46.000	<.001**

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

[a] Young=20-39; Middle=40=59; Older=60-89

Table 9. Multiple Regression (Six Variables Entered Blockwise): FID

	F	p (F)	ß	t	p (t)
Model 1	10.59	<0.001			
Benton Facial Recognition			0.394	4.496	<0.001*
Visual Matrices			0.096	1.091	0.278
Model 2	7.02	<0.001			
Benton Facial Recognition			0.397	4.476	<0.001*
Visual Matrices			0.097	1.102	0.273
Gender			-0.022	-0.245	0.807
Model 3	5.22	0.001			
Benton Facial Recognition			0.397	4.458	<0.001*
Visual Matrices			0.097	1.098	0.275
Gender			-0.021	-0.24	0.811
Ethnicity			0.012	0.134	0.894
Model 4	4.89	<0.001			
Benton Facial Recognition			0.385	4.358	<0.001*
Visual Matrices			0.07	0.784	0.435
Gender			0.001	0.014	0.989
Ethnicity			0.029	0.325	0.746
Education			0.161	1.78	0.078
Model 5	13.79	<0.001			
Benton Facial Recognition			0.335	4.52	<0.001*
Visual Matrices			0.038	0.51	0.611
Gender			0.012	0.163	0.871
Ethnicity			-0.073	-0.975	0.332
Education			0.111	1.469	0.145
Age			-0.518	-6.893	<0.001*

*p < .05

Table 10. Multiple Regression (Five Variables Entered Blockwise): WID

	F	p (F)	ß	t	p (t)
Model 1					
Nonemotional Word ID	24.79	<0.001			
			0.426	4.980	<0.001*
Model 2	12.33	<0.001			
Nonemotional Word ID			0.425	4.954	<0.001*
Gender			0.023	0.266	0.791
Model 3	10.84	<0.001			
Nonemotional Word ID			0.374	4.341	<0.001*
Gender			0.056	0.658	0.512
Education			0.224	2.573	0.011*
Model 4	8.12	<0.001			
Nonemotional Word ID			0.38	4.344	<0.001*
Gender			0.057	0.672	0.503
Education			0.227	2.590	0.011*
Ethnicity			0.038	0.443	0.659
Model 5	10.22	<0.001			
Nonemotional Word ID			0.293	3.429	0.001*
Gender			0.061	0.756	0.451
Education			0.211	2.557	0.012*
Ethnicity			-0.038	-0.456	0.649
Age			-0.321	-3.819	<0.001*

*p < .05

Table 11. Multiple Regression (Five Variables Entered Blockwise): SID

	F	p (F)	ß	t	p (t)
Model 1	9.13	0.003			
Nonemotional Sentence ID			0.275	3.022	0.003*
Model 2	4.60	0.012			
Nonemotional Sentence ID			0.270	2.930	0.004*
Gender			0.034	0.371	0.711
Model 3	10.93	<0.001			
Nonemotional Sentence ID			0.298	3.522	0.001*
Gender			0.087	1.022	0.309
Education			0.396	4.675	<0.001*
Model 4	8.12	<0.001			
Nonemotional Sentence ID			0.298	3.496	0.001*
Gender			0.087	1.018	0.311
Education			0.397	4.629	<0.001*
Ethnicity			0.002	0.028	0.978
Model 5	9.13	<0.001			
Nonemotional Sentence ID			0.168	1.839	0.069
Gender			0.104	1.264	0.209
Education			0.357	4.287	<0.001*
Ethnicity			-0.047	-0.572	0.568
Age			-0.297	-3.219	0.002*

*p < .05

Table 12. Multiple Regression (Six Variables Entered Blockwise): PID

	F	p (F)	ß	t	p (t)
Model 1	14.34	<.001			
Benton Phoneme Discrimination			0.289	3.096	0.002*
Intonation Contours Perception			0.252	2.699	0.008*
Model 2	9.87	<.001			
Benton Phoneme Discrimination			0.281	2.996	0.003*
Intonation Contours Perception			0.259	2.771	0.007*
Gender			0.083	0.975	0.332
Model 3	7.40	<.001			
Benton Phoneme Discrimination			0.288	3.014	0.003*
Intonation Contours Perception			0.247	2.53	0.013*
Gender			0.081	0.947	0.346
Ethnicity			-0.039	-0.435	0.664
Model 4	5.87	<.001			
Benton Phoneme Discrimination			0.285	2.914	0.004*
Intonation Contours Perception			0.244	2.418	0.017*
Gender			0.083	0.957	0.341
Ethnicity			-0.038	-0.418	0.677
Education			0.015	0.162	0.871
Model 5	15.38	<.001			
Benton Phoneme Discrimination			0.059	0.681	0.497
Intonation Contours Perception			0.228	2.72	0.008*
Gender			0.102	1.412	0.161
Ethnicity			-0.12	-1.593	0.114
Education			0.038	0.491	0.625
Age			-0.558	-7.042	<.001*

*$p < .05$

Table 13. Multiple Regression (Six Variables Entered Blockwise): FDIS

	F	p (F)	ß	t	p (t)
Model 1	5.43	0.006			
Benton Facial Recognition			0.194	2.127	0.036*
Visual Matrices			0.235	2.567	0.012*
Model 2	3.65	0.015			
Benton Facial Recognition			0.199	2.154	0.033*
Visual Matrices			0.238	2.583	0.011*
Gender			-0.040	-0.430	0.668
Model 3	2.88	0.026			
Benton Facial Recognition			0.202	2.179	0.031*
Visual Matrices			0.238	2.580	0.011*
Gender			-0.038	-0.408	0.684
Ethnicity			0.073	0.789	0.432
Model 4	3.65	0.004			
Benton Facial Recognition			0.185	2.041	0.044*
Visual Matrices			0.199	2.173	0.032*
Gender			-0.005	-0.058	0.954
Ethnicity			0.097	1.068	0.288
Education			0.229	2.480	0.015*
Model 5	6.78	<0.001			
Benton Facial Recognition			0.148	1.765	0.080
Visual Matrices			0.176	2.075	0.040*
Gender			0.003	0.030	0.976
Ethnicity			0.023	0.269	0.788
Education			0.193	2.255	0.026*
Age			-0.375	-4.393	<0.001*

*p < .05

Table 14. Multiple Regression (Five Variables Entered Blockwise): WDIS

	F	p (F)	ß	t	p (t)
Model 1	25.94	<0.001			
Nonemotional Word DR			0.434	5.094	<0.001*
Model 2	12.86	<0.001			
Nonemotional Word DR			0.433	5.041	<0.001*
Gender			-0.007	-0.085	0.932
Model 3	9.28	<0.001			
Nonemotional Word DR			0.382	4.096	<0.001*
Gender			0.006	0.075	0.940
Education			0.129	1.38	0.170
Model 4	7.90	<0.001			
Nonemotional Word DR			0.359	3.857	<0.001*
Gender			-0.001	-0.015	0.988
Education			0.121	1.3	0.196
Ethnicity			-0.153	-1.789	0.076
Model 5	6.54	<0.001			
Nonemotional Word DR			0.321	3.197	0.002*
Gender			-0.003	-0.034	0.973
Education			0.125	1.348	0.180
Ethnicity			-0.177	-1.996	0.048*
Age			-0.096	-1.032	0.304

*p < .05

Table 15. Multiple Regression (Six Variables Entered Blockwise): PDIS

	F	p (F)	ß	t	p (t)
Model 1	7.64	0.001			
Benton Phoneme Discrimination			0.238	2.426	0.017*
Intonation Contours Perception			0.176	1.789	0.076
Model 2	5.96	0.001			
Benton Phoneme Discrimination			0.224	2.293	0.024*
Intonation Contours Perception			0.188	1.924	0.057
Gender			0.139	1.553	0.123
Model 3	4.45	0.002			
Benton Phoneme Discrimination			0.22	2.197	0.030*
Intonation Contours Perception			0.195	1.907	0.059
Gender			0.14	1.556	0.123
Ethnicity			0.022	0.24	0.811
Model 4	3.54	0.005			
Benton Phoneme Discrimination			0.224	2.192	0.031*
Intonation Contours Perception			0.201	1.902	0.060
Gender			0.137	1.498	0.137
Ethnicity			0.02	0.218	0.828
Education			-0.023	-0.233	0.816
Model 5	3.91	0.001			
Benton Phoneme Discrimination			0.135	1.249	0.214
Intonation Contours Perception			0.194	1.875	0.064
Gender			0.144	1.608	0.111
Ethnicity			-0.012	-0.131	0.896
Education			-0.014	-0.143	0.886
Age			-0.221	-2.252	0.026*

*$p < .05$

Table 16. Control and Demographic Variables Entered in Analyses of Covariance and Pearson Partial Correlation Analyses

		Variable Type	
Task Type	Channel	Control Task(s)	Demographic
Identification	Facial	Benton Facial Recognition	-
	Word	Nonemotional Word ID	Education
	Sentence	-	Education
	Prosodic	Intonation Contours Perception	-
Discrimination	Facial	Visual Matrices	Education
	Word	Nonemotional Word DIS	Ethnicity
	Prosodic	-	-

Note. Nonemotional control and demographic variables entered in correlational analyses determined by blockwise multiple regression analyses.

Table 17. Age Group (7) x Valence (2 or 3) Analyses of Covariance

Task	Covariate(s)	Source	df	F	p
Facial Identification					
	Benton Facial Recognition	Age Group	6,107	7.673	.007**
		Valence	1,107	0.154	.695
		Age Group x Valence	6,107	1.106	.364
Word Identification					
	Education	Age Group	6,107	9.669	.002**
	Nonemotional Word ID	Valence	1,107	0.195	.660
		Age Group x Valence	6,107	0.297	.937
Sentence Identification					
	Education	Age Group	6,106	7.544	.007**
		Valence	1,106	7.316	.008**
		Age Group x Valence	6,106	1.265	.280
Prosodic Identification					
	Intonation Contours Perception	Age Group	6,107	3.173	.007**
		Valence	1,107	0.038	.846
		Age Group x Valence	6,107	2.340	.037*
Facial Discrimination					
	Visual Matrices	Age Group	6, 107	4.004	.001**
	Education	Valence	2,107	3.071	.083
		Age Group x Valence	6,107	0.116	.994
Prosodic Discrimination					
	-	Age Group	6,107	2.144**	.054
		Valence	2,109	5.041**	.008**
		Age Group x Valence	6,109	2.663**	.002**

Note. ID = Identification. DIS = Discrimination. **p < .01. *p < .05.

Table 18. Means and Standard Deviations for Identification and Discrimination Tasks

Age Group		Identification Tasks Task			
	n	Facial	Word	Sentence	Prosodic
1	19	82.07 ± 7.57	94.52 ± 7.86	86.40 ± 11.01	69.52 ± 11.29
2	18	75.18 ± 9.31	90.27 ± 9.69	79.86 ± 10.62	62.96 ± 10.29
3	18	74.65 ± 9.64	92.36 ± 6.27	82.18 ± 11.85	64.35 ± 11.89
4	15	73.34 ± 10.22	88.33 ± 12.52	78.06 ± 11.62	56.39 ± 18.02
5	16	70.63 ± 10.68	92.22 ± 6.84	81.66 ± 11.55	55.83 ± 13.71
6	15	61.92 ± 9.00	77.86 ± 13.50	67.45 ± 15.31	38.28 ± 18.14
7	15	64.37 ± 13.25	82.22 ± 14.73	68.61 ± 25.00	41.11 ± 19.85
		Discrimination Tasks Task			
	n	Facial	Word	Prosodic	
1	19	87.78 ± 4.95	87.22 ± 10.12	96.81 ± 2.63	
2	18	88.10 ± 4.42	82.34 ± 10.21	96.23 ± 3.11	
3	18	87.90 ± 4.92	83.33 ± 9.49	96.23 ± 3.12	
4	15	82.62 ± 11.44	82.86 ± 10.47	95.95 ± 3.79	
5	16	81.67 ± 8.84	83.57 ± 7.37	92.86 ± 7.01	
6	15	80.80 ± 6.88	77.45 ± 12.49	93.08 ± 5.13	
7	15	80.47 ± 7.13	82.38 ± 9.78	94.29 ± 3.77	

Note. Age Group 1=20-29; Group 2=30-39; Group 3=40-49; Group 4=50-59; Group 5=60-69; Group 6=70-79; Group 7=80-89.

Table 19. Post-hoc Comparisons among Seven Age Groups: Facial Identification

Age Group			Age Group			
	1	2	3	4	5	6	7
1	-	.357	.271	.156	.020*	<.001**	<.001**
2	-	-	1.00	.998	.848	.003**	.038*
3	-	-	-	1.00	.909	.006**	.058
4	-	-	-	-	.989	.030*	.183
5	-	-	-	-	-	.195	.605
6	-	-	-	-	-	-	.993
7	-	-	-	-	-	-	-

Note. Post-hoc comparisons are based on Tukey HSD tests and p values are represented.

Table 20. Post-hoc Comparisons among Seven Age Groups: Word Identification

Age Group			Age Group				
	1	2	3	4	5	6	7
1	-	.882	.996	.613	.996	<.001**	.016*
2	-	-	.997	.998	.998	.014*	.306
3	-	-	-	.927	1.00	.002**	.093
4	-	-	-	-	.950	.090	.686
5	-	-	-	-	-	.004**	.133
6	-	-	-	-	-	-	.909
7	-	-	-	-	-	-	-

Note. Post-hoc comparisons are based on Tukey HSD tests and p values are represented.

Table 21. Post-hoc Comparisons among Seven Age Groups: Sentence Identification

Age Group			Age Group				
	1	2	3	4	5	6	7
1	-	.809	.973	.630	.962	.003**	.009**
2	-	-	.999	1.00	1.00	.165	.284
3	-	-	-	.982	1.00	.053	.108
4	-	-	-	-	.993	.387	.551
5	-	-	-	-	-	.095	.174
6	-	-	-	-	-	-	1.00
7	-	-	-	-	-	-	-

Note. Post-hoc comparisons are based on Tukey HSD tests and p values are represented.

Table 22. Post-hoc Comparisons among Seven Age Groups: Prosodic Identification

Age Group			Age Group				
	1	2	3	4	5	6	7
1	-	.832	.939	.151	.118	<.001	<.001**
2	-	-	1.00	.867	.816	<.001	.001**
3	-	-	-	.726	.658	<.001	<.001**
4	-	-	-	-	1.00	.017*	.082
5	-	-	-	-	-	.023*	.998
6	-	-	-	-	-	-	.998
7	-	-	-	-	-	-	-

Note. Post-hoc comparisons are based on Tukey HSD tests and p values are represented.

Table 23. Post-hoc Comparisons among Seven Age Groups: Facial Discrimination

Age Group			Age Group				
	1	2	3	4	5	6	7
1	-	1.00	1.00	.361	.175	.068	.055
2	-	-	1.00	.305	.142	.054	.043*
3	-	-	-	.349	.169	.066	.053
4	-	-	-	-	1.00	.992	.982
5	-	-	-	-	-	1.00	.999
6	-	-	-	-	-	-	1.00
7	-	-	-	-	-	-	-

Note. Post-hoc comparisons are based on Tukey HSD tests and p values are represented.

Table 24. Follow-Up Univariate Analyses for Age Group x Valence Interactions

Task Type	Valence				
		n	df	F	p
Prosodic Identification	Negative	116	6, 109	1.721	.123
	Positive	116	6, 109	3.387	.003**
Prosodic Discrimination	Negative	116	6, 109	6.418	<.001**
	Positive	116	6, 109	1.680	.133
	Mixed	116	6, 109	1.242	.291

*p < .05. ** p < .01. ***p < .001.

Table 25. Kruskal-Wallis Tests for Non-Normally Distributed Tasks

Task	n	df	W	p
Prosodic Discrimination	116	6	22.89	0.001**
	Significant Pairwise Comparisons			
	6 vs. 3			0.033*
	6 vs. 1			0.001**
Word Identification	116	6	12.88	0.045*

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

Table 26. Kruskal-Wallis Tests for Non-Normally Distributed Tasks by Valence

Task Type	Task	Valence				
Discrimination			n	df	W	p
	Prosodic					
		Negative	116	6	16.00	0.014*
		Positive	116	6	8.42	0.209
		Mixed	116	6	6.98	0.322

Identification	Task	Valence	Education				
				n	df	W	p
	Word						
		Negative	<16 Years	67	6	13.37	0.037*
			≥16 Years	48	6	18.72	0.005**
		Positive	<16 Years	67	6	8.45	0.207
			≥ 16 Years	48	6	15.61	0.016*

Note. DIS = Discrimination. ID = Identification.
* $p < .05$. ** $p < .01$.

Table 27. Pearson Partial Correlations between Emotional Identification Tasks: Seven Age Groups

	Age Group						
	1	2	3	4	5	6	7
n	19	18	18	15	15	16	15
Comparison							
FID vs WID	0.324	0.498	0.381	0.569	0.636*	0.708**	0.651*
FID vs WID	0.343	0.049	0.196	0.079	0.614*	0.762**	0.228
FID vs PID	0.157	0.234	0.240	0.134	0.724**	0.623*	0.677*
WID vs PID	0.335	0.619**	0.306	0.457	0.622*	0.520	0.772**
SID vs PID	0.426	0.202	0.326	0.201	0.449	0.576*	0.437
Medians							
Partial r	**0.335**	**0.234**	**0.306**	**0.201**	**0.622**	**0.623**	**0.651**
Spearman r[a] (not partialled)	**0.197**	**0.279**	**0.359**	**0.367**	**0.636**	**0.571**	**0.648**
WID vs SID	0.597*	0.705**	0.167	0.318	0.792**	0.520	0.634*

[a] Comparison is made to Spearman rho median values because some variables are not normally distributed.

Table 28. Pearson Partial Correlations between Discrimination Tasks: Seven Age Groups

	Age Group						
	1	2	3	4	5	6	7
n	19	18	18	15	15	16	15
Comparison							
FDR vs WDIS	0.447	0.305	-0.053	0.365	0.409	0.030	0.560
FDR vs PDIS	0.568*	0.096	0.368	-0.406	0.303	0.134	0.303
WDR vs PDIS	0.068	-0.264	0.302	0.081	0.311	0.227	0.311
Medians							
Partial r	**0.447**	**0.096**	**0.302**	**0.081**	**0.311**	**0.134**	**0.311**
Spearman r[a] (not partialled)	**0.420**	**-0.336**	**0.234**	**0.268**	**0.250**	**0.392**	**0.198**

[a] Comparison is made to Spearman rho median values because some variables are not normally distributed.

Table 29. Fisher's Z-tests Comparing Intercorrelations among Emotion Tasks: Seven Age Groups

		Age Group						
Task		1	2	3	4	5	6	7
Type	n	19	18	18	15	15	16	15
	Identification							
	1	-	-0.31	0.09	0.38	-0.99	-1.02	-1.12
	2	-	-	-0.21	0.09	-1.26	-1.3	-1.39
	3	-	-	-	0.29	-1.06	-1.09	-1.19
	4	-	-	-	-	-1.28	-1.31	-1.40
	5	-	-	-	-	-	0.00	0.12
	6	-	-	-	-	-	-	0.12
	7	-	-	-	-	-	-	-
		1	2	3	4	5	6	7
		Discrimination						
	1	-	1.07	0.47	1.05	0.42	0.93	0.42
	2	-	-	-0.59	0.04	-0.58	-0.10	-0.58
	3	-	-	-	0.60	-0.03	0.47	-0.03
	4	-	-	-	-	-0.59	-0.13	-0.59
	5	-	-	-	-	-	0.47	0.00
	6	-	-	-	-	-	-	-0.46
	7	-	-	-	-	-	-	-

Note. Statistics reported are Fisher's z values derived from Fisher's r-to-z transformation.

* $p < .05$

Table 30. Pearson Partial Correlations Between ID Tasks: Three Age Groups

	Age Group		
	1	2	3
n	37	33	46
Comparison			
FID vs WID	0.312	0.373*	0.730**
FID vs SID	0.243	0.364*	0.652**
FID vs PID	0.246	0.204	0.634**
WID vs PID	0.441**	0.602**	0.738**
SID vs PID	0.326*	0.471**	0.701
Medians			
Partial r	**0.312**	**0.373**	**0.701**
Spearman r[a]	**0.301**	**0.416**	**0.709**
(not partialled)			
WID vs SID	0.602	0.524	0.815

[a] Comparisons are made to Spearman rho median values because some variables are not normally distributed.

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

Table 31. Pearson Partial Correlations between DIS Tasks: Three Age Groups

	Age Group		
	1	2	3
n	37	33	46
Comparison			
FDIS vs WDIS	0.421*	0.164	0.219
FDIS vs PDIS	0.237	-0.111	0.191
WDIS vs PDIS	-0.079	0.192	0.154
Medians			
Partial r	**0.237**	**0.164**	**0.191**
Spearman r[a]			
(not partialled)	**0.211**	**0.130**	**0.241**

[a] Comparisons are made to Spearman rho median values because some variables are not normally distributed

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

Table 32. Fisher's z-tests Comparing Intercorrelations: Three Age Groups

Task Type	n	Age Group: Young	Middle	Older
		37	33	46
Identification				
Young		-	-0.28	-2.38**
Middle		-	-	-2.01*
Older		-	-	-
		1	2	3
Discrimination				
Young		-	0.30	0.21
Middle		-	-	-0.12
Older		-	-	-

Note. Statistics reported are Fisher's z values derived from Fisher's r-to-z transformations.

*$p < .05$. ** $p < .01$

Figure Captions

Figure 1. Age Group x Task Comparison: Unadjusted Means for Identification Tasks

Figure 2. Age Group x Task Comparison: Unadjusted Means for Discrimination Tasks

Figure 3. Age Group x Valence Comparison Collapsed over 4 Identification Tasks (Facial, Word, Sentence, and Prosodic)

Figure 1. Age Group x Task Comparison: Unadjusted Means for Identification Tasks

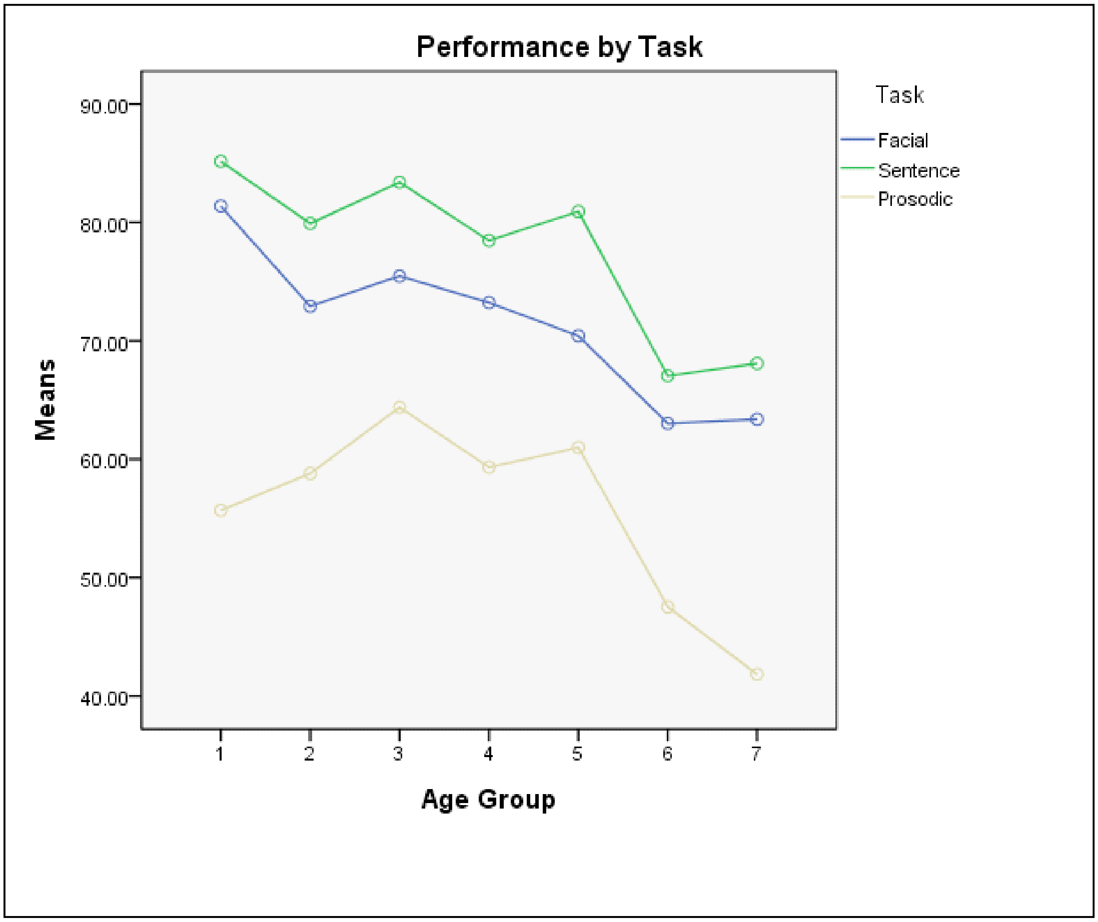


Figure 2. Age Group x Task Comparison: Unadjusted Means for Discrimination Tasks

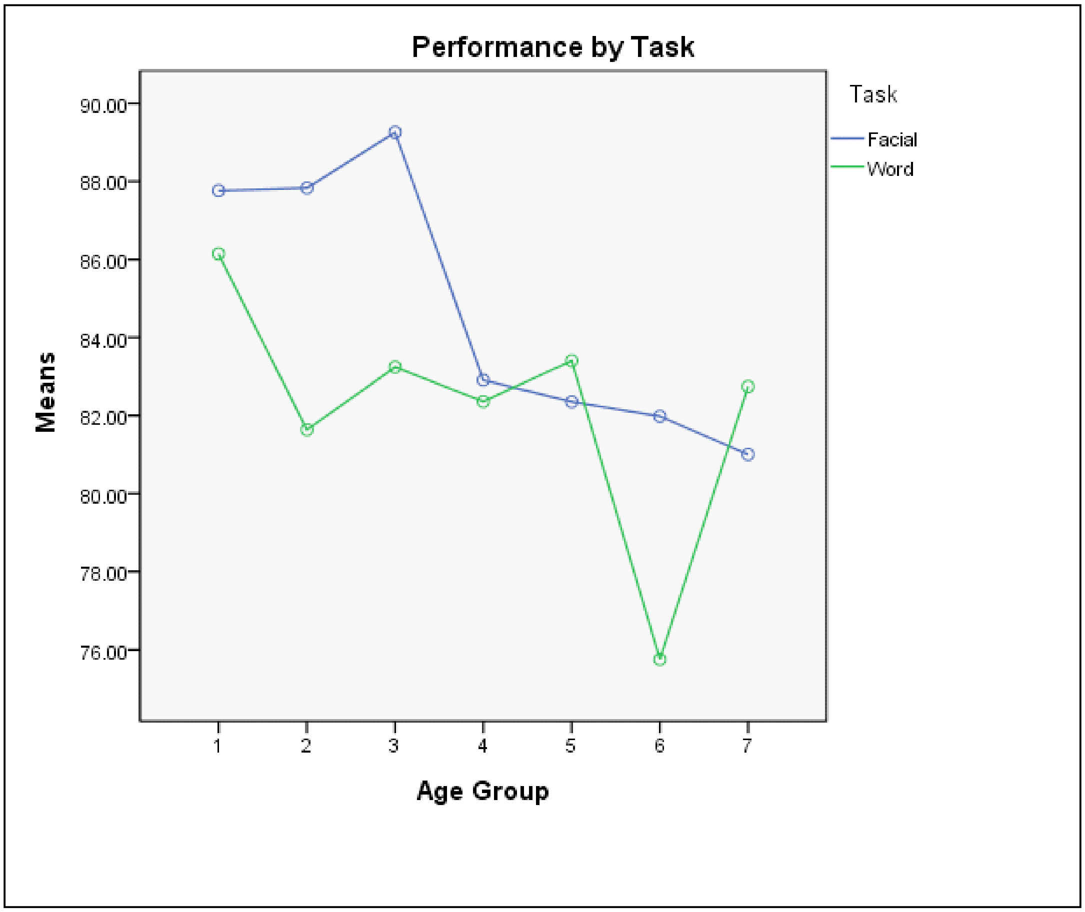
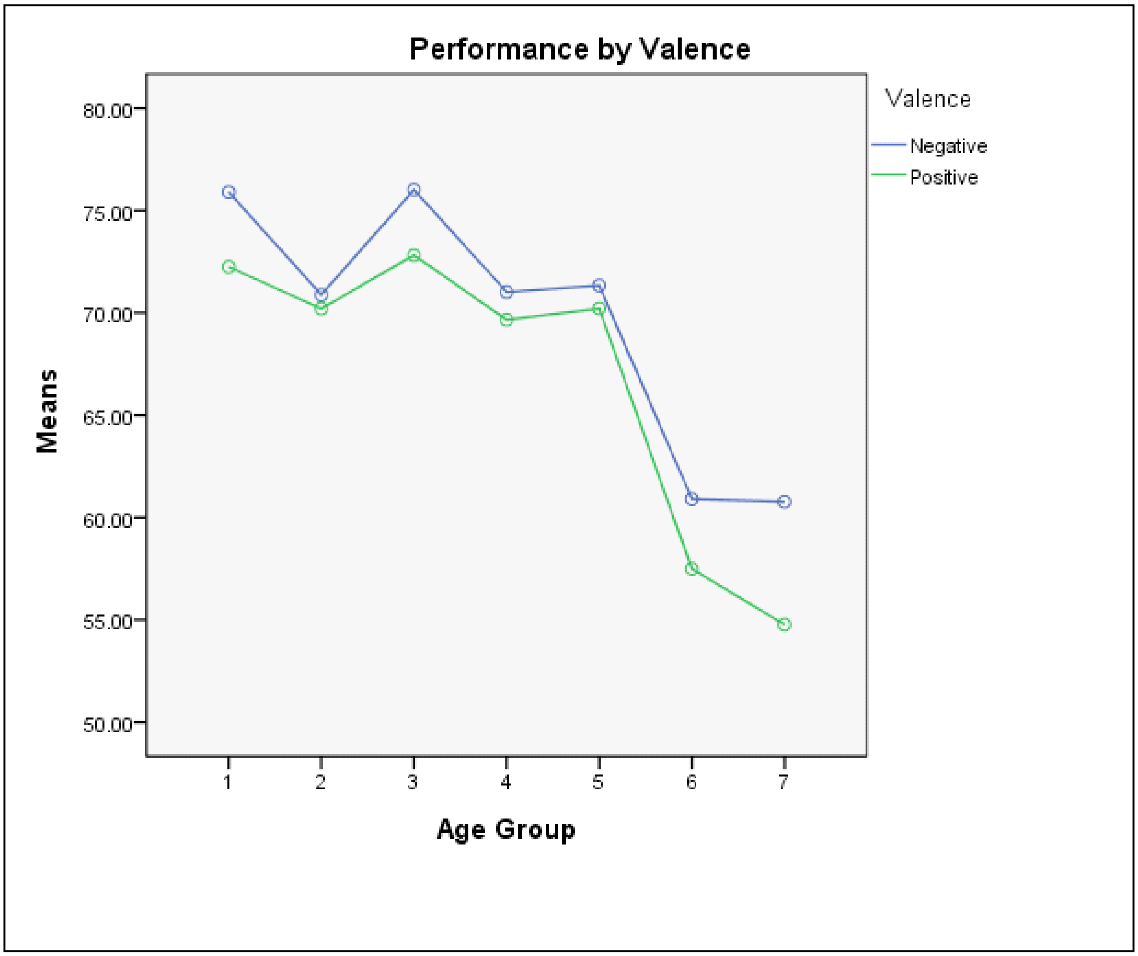
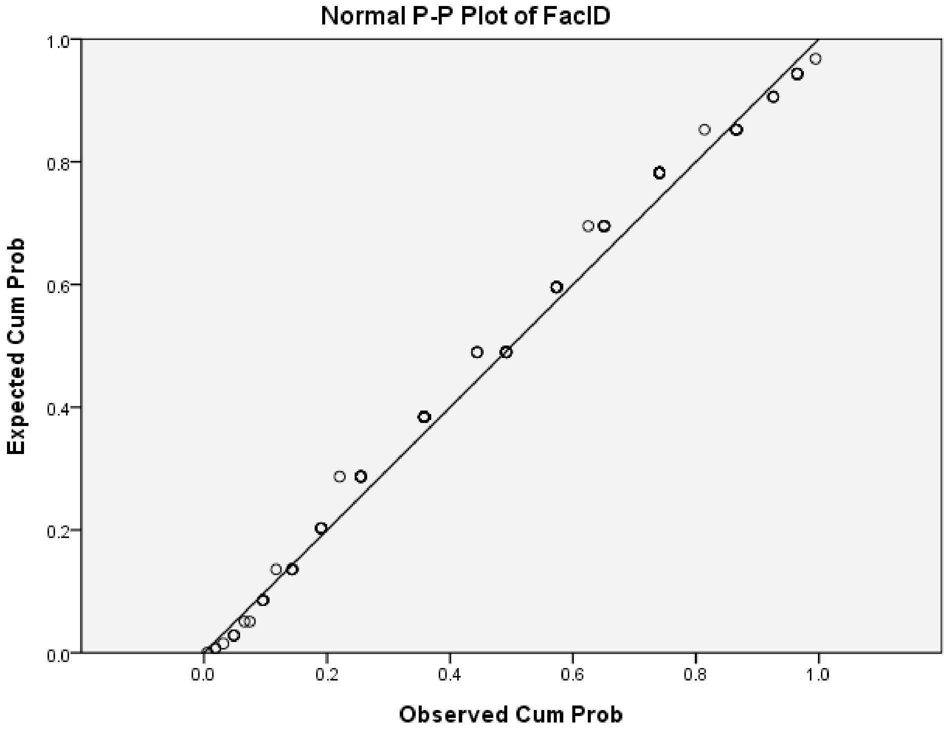


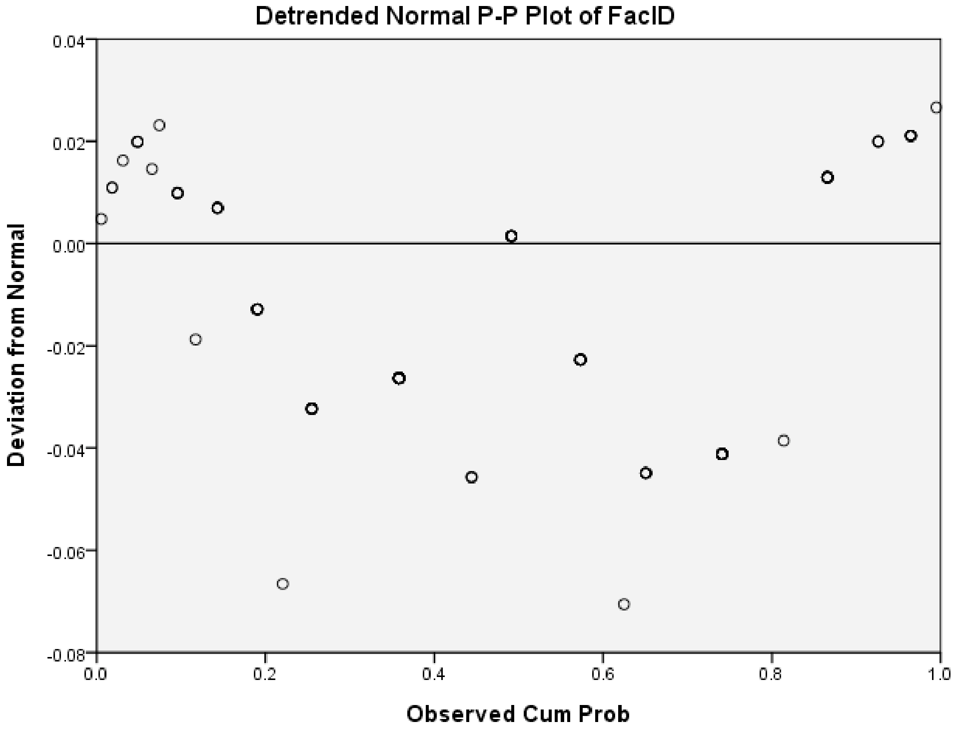
Figure 3. Age x Valence Comparison Collapsed over 4 Identification Tasks (Facial, Word, Sentence, and Prosodic)



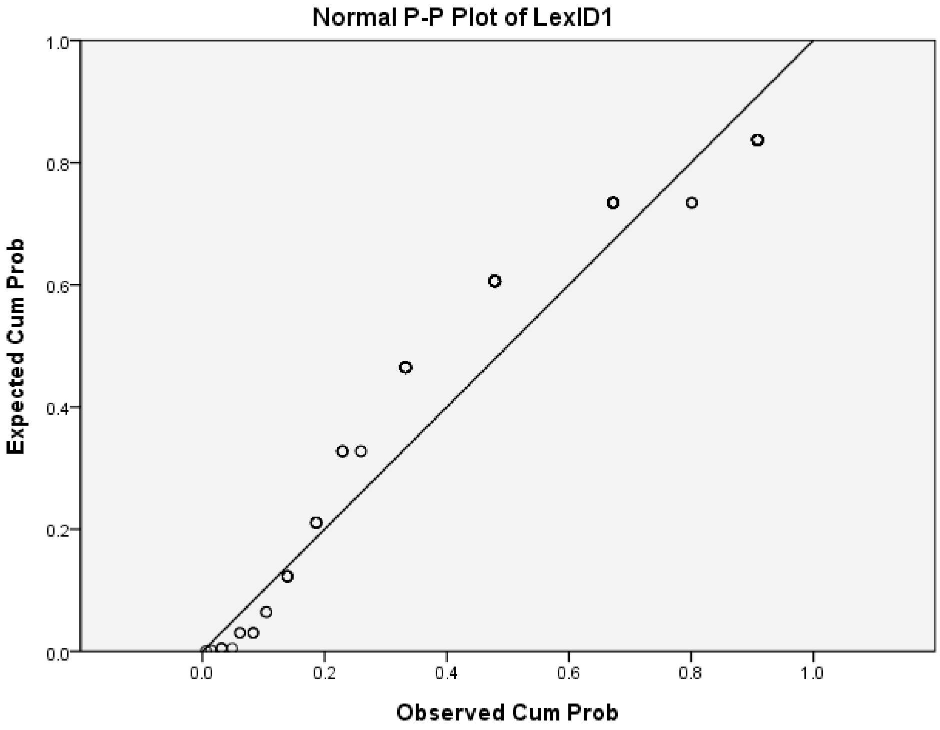
Appendix

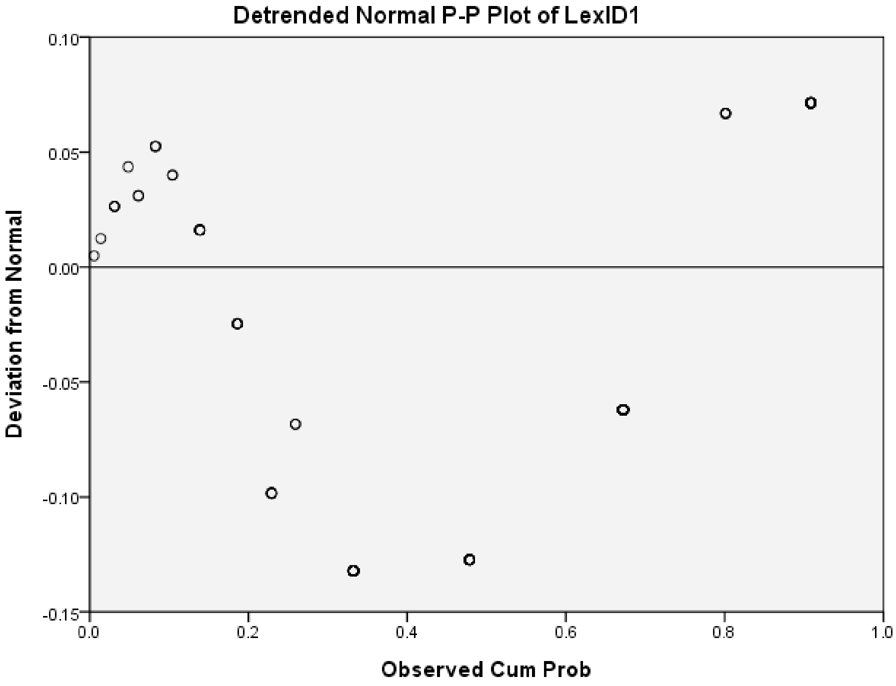
P-P Plot 1. Task: Facial Identification



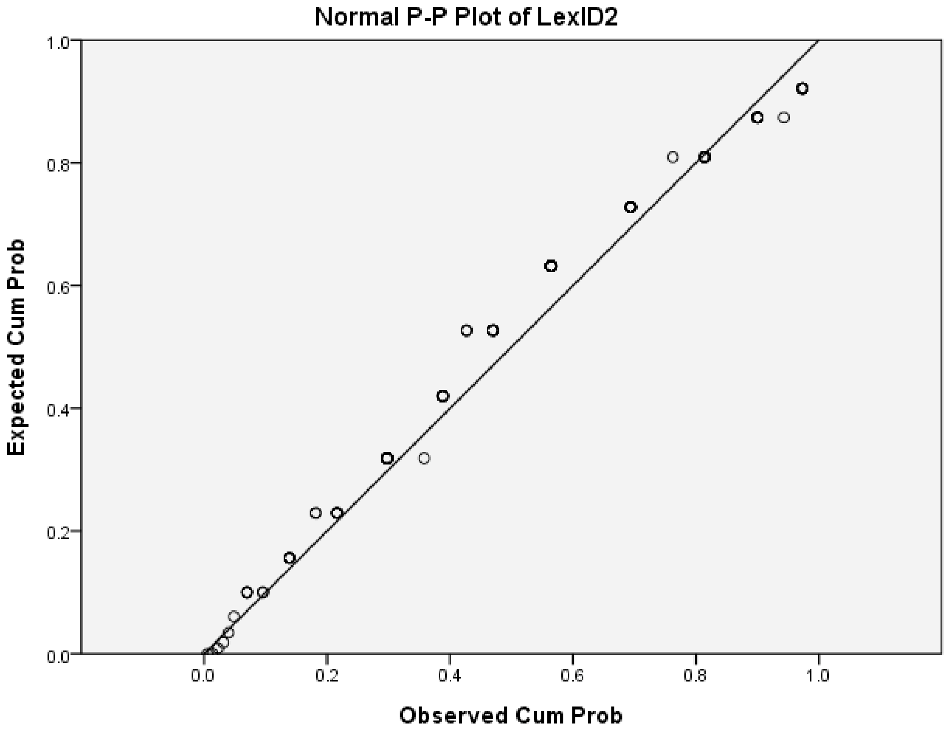


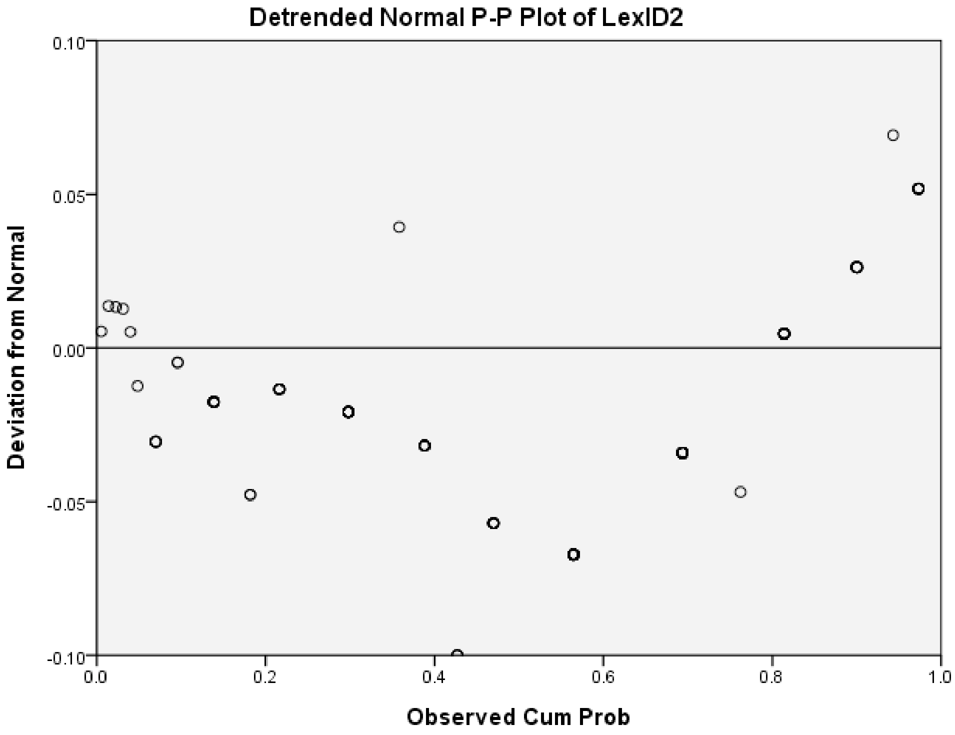
P-P Plot 2. Task: Word Identification



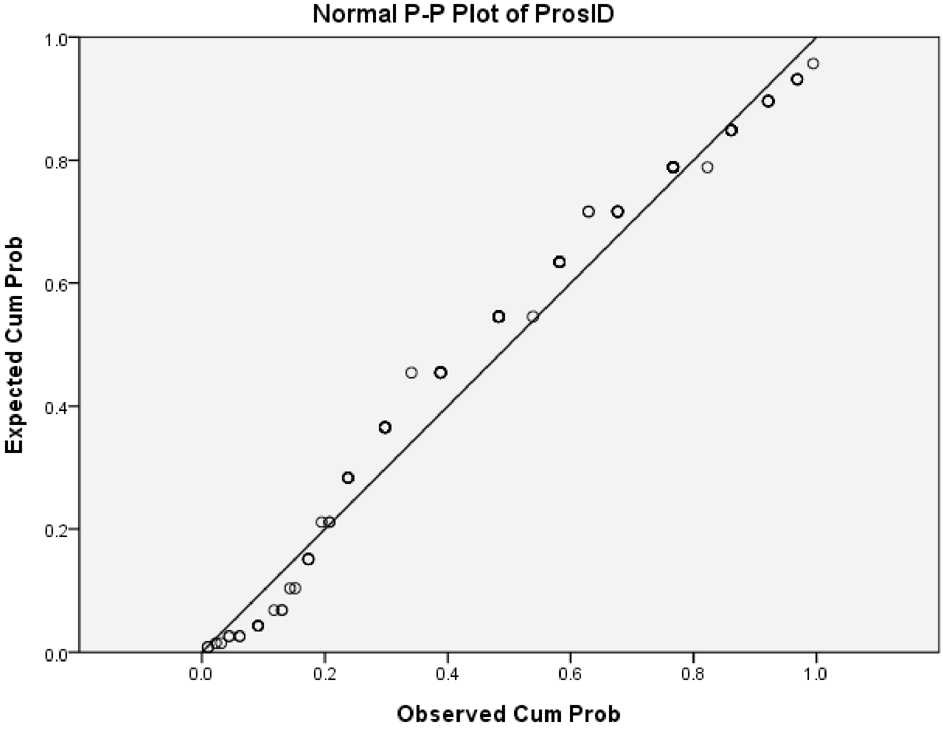


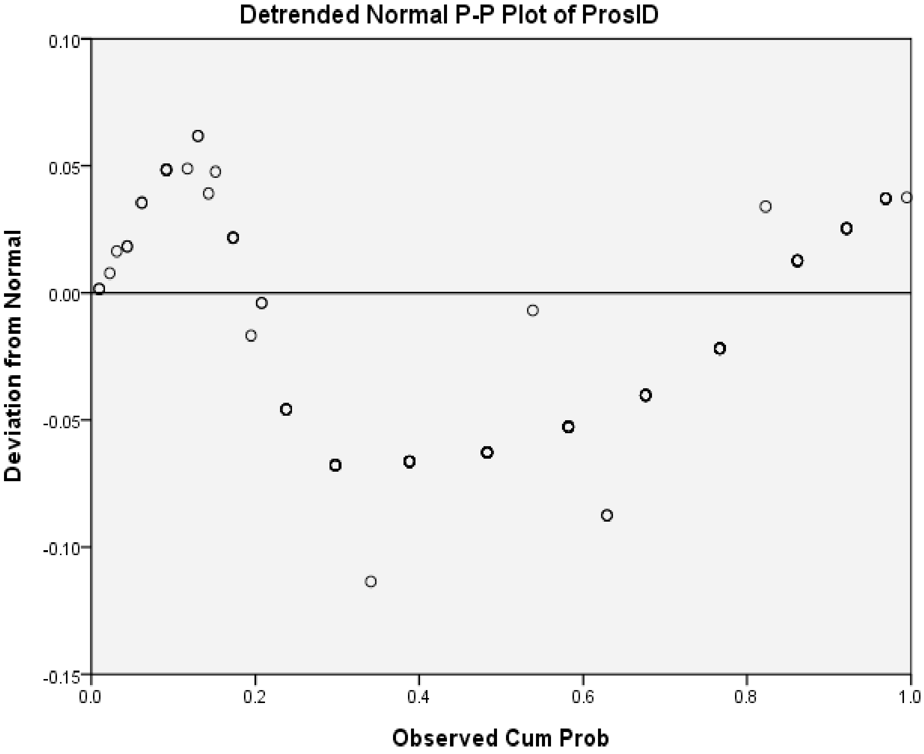
P-P Plot 3. Task: Sentence Identification



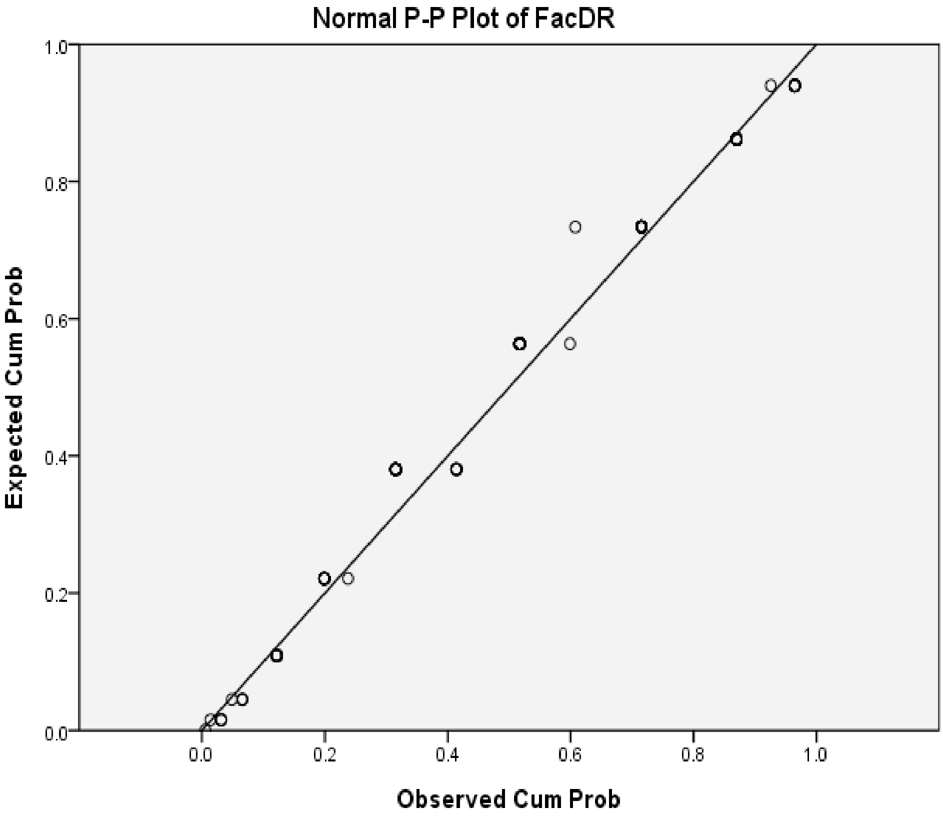


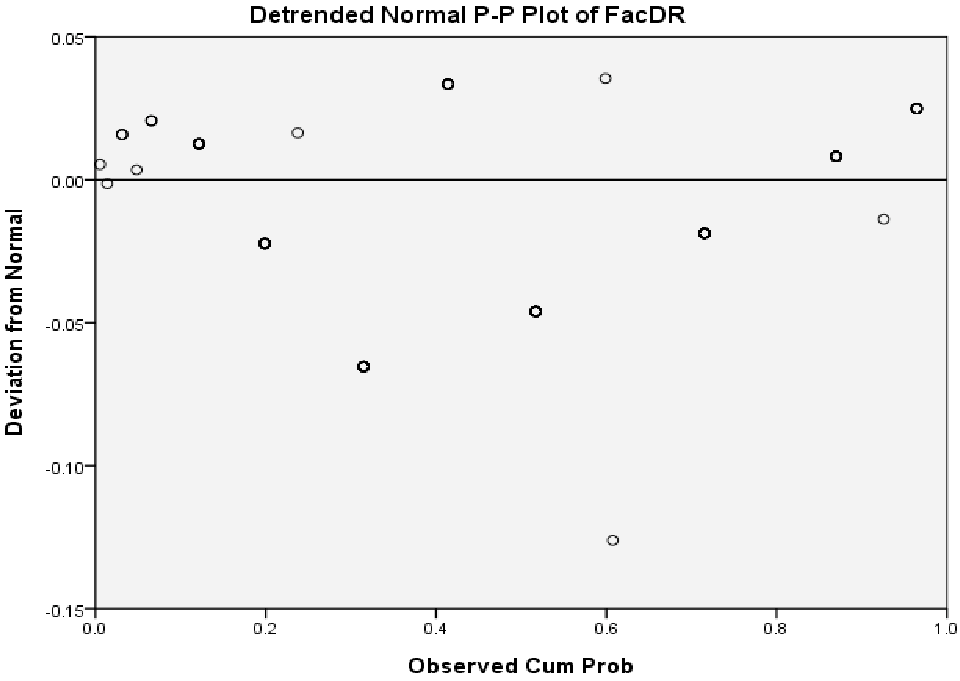
P-P Plot 4. Task: Prosodic Identification



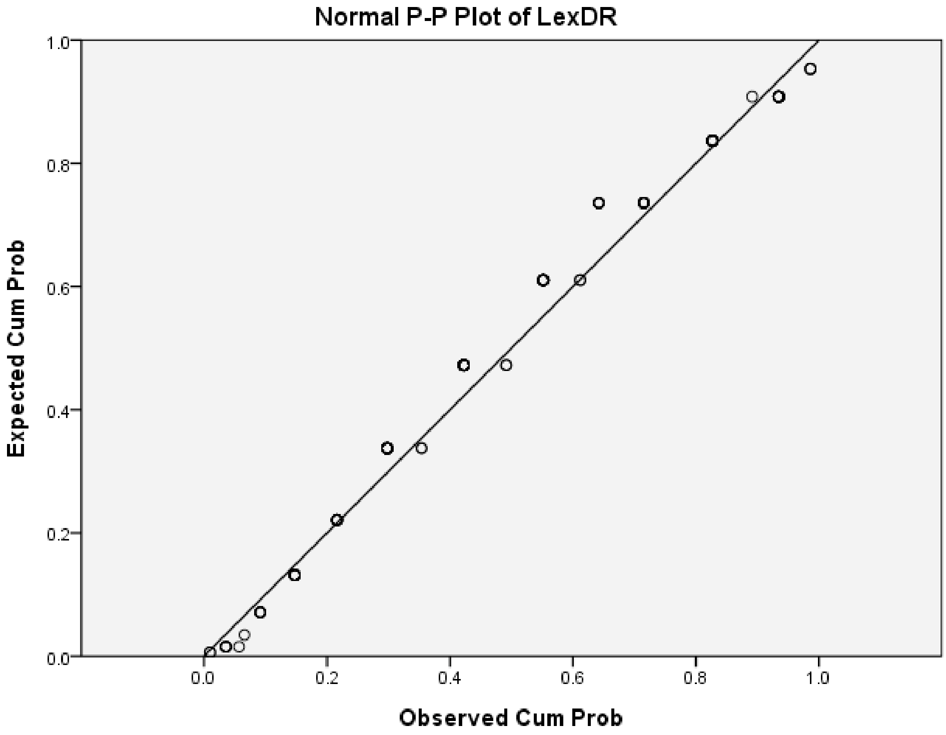


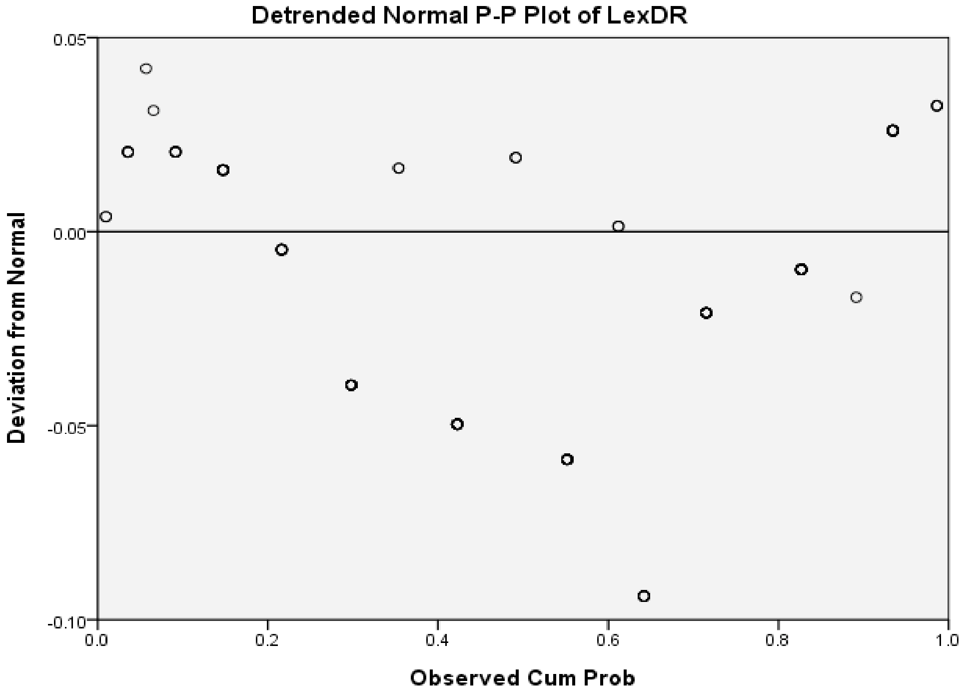
P-P Plot 5. Task: Facial Discrimination



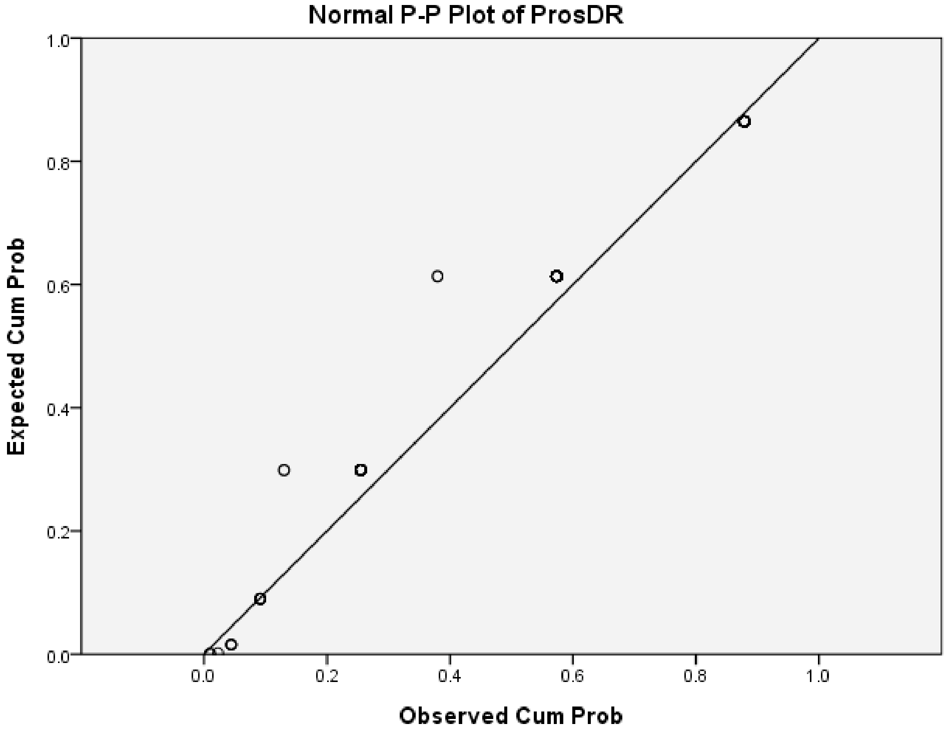


P-P Plot 6. Task: Word Discrimination





P-P Plot 7. Task: Prosodic Discrimination



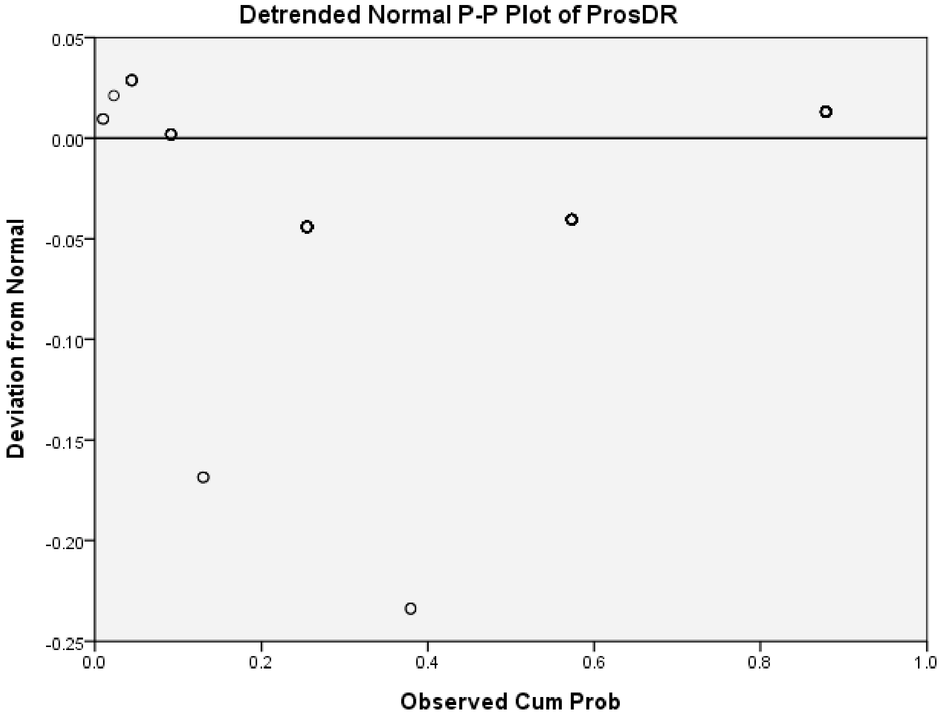


Figure 1.

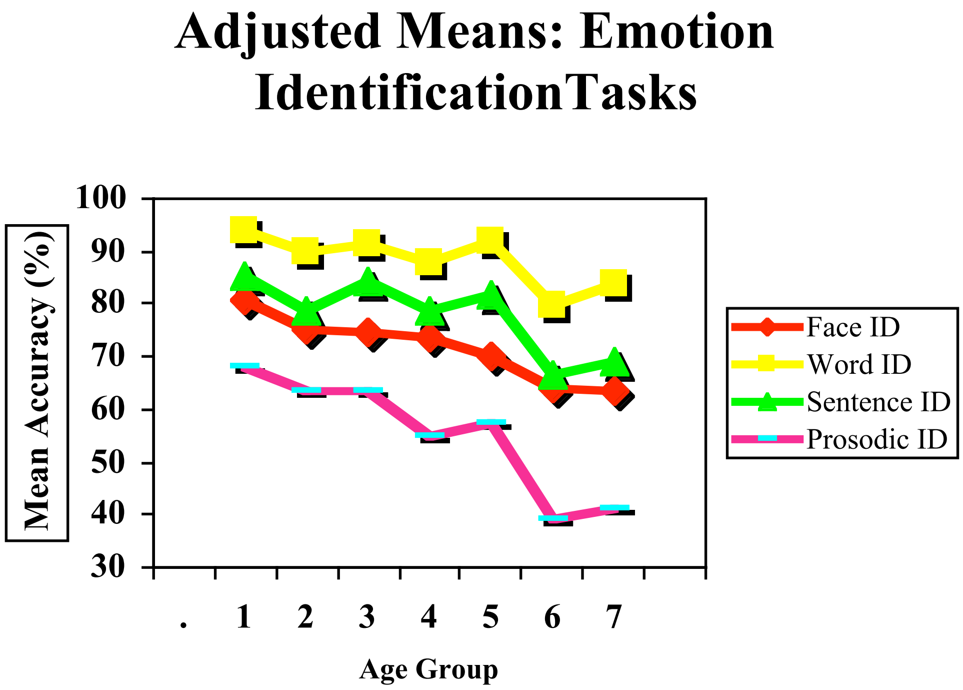


Figure 2.

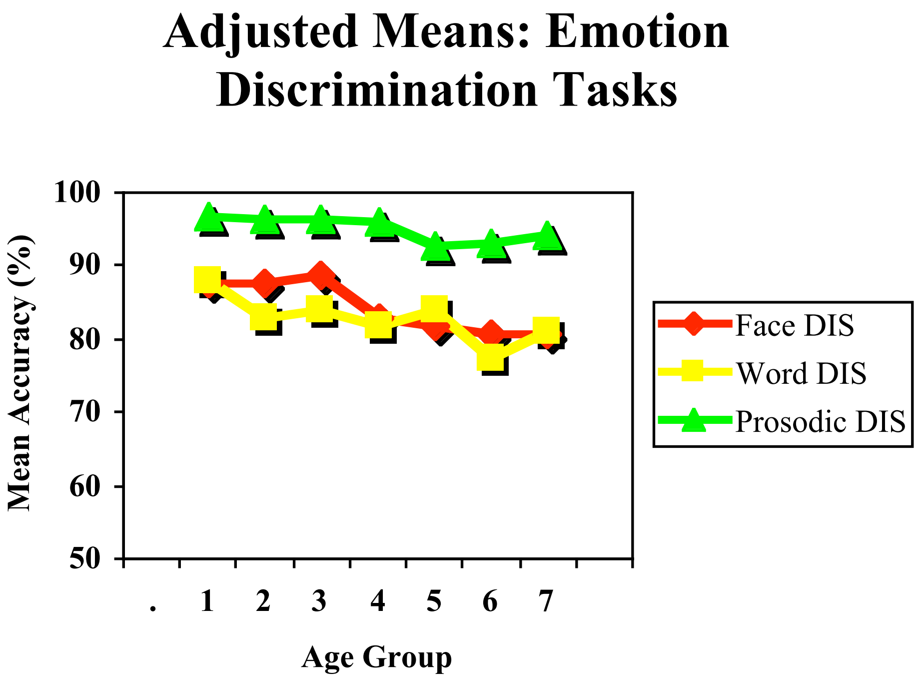


Table 1. Shapiro-Wilk Tests of Normality for Non-Emotional Control Tasks: Seven Groups

Task	Age Group[a]	W	df	p-value
Benton Facial Recognition	1	0.946	18	0.359
	2	0.896	19	0.041*
	3	0.828	17	<.001**
	4	0.936	14	0.368
	5	0.896	14	0.098
	6	0.902	16	0.086
	7	0.877	14	0.052
Visual Matrices	1	0.557	18	<.001**
	2	0.588	19	<.001**
	3	0.490	17	<.001**
	4	0.457	14	<.001**
	5	0.627	14	<.001**
	6	0.824	16	0.006**
	7	0.837	14	0.015*
Intonation Contours Perception	1	0.689	18	<.001**
	2	0.840	19	<.001**
	3	0.938	17	0.294
	4	0.824	14	0.010*
	5	0.906	14	0.139
	6	0.843	16	0.011*
	7	0.753	14	<.001**
Phoneme Discrimination	1	0.729	18	<.001**
	2	0.839	19	<.001**
	3	0.893	17	0.052
	4	0.857	14	0.027*
	5	0.922	14	0.235
	6	0.930	16	0.245
	7	0.892	14	0.087
Nonemotional Word Identification	1	0.817	18	<.001**
	2	0.830	19	<.001**
	3	0.694	17	<.001**
	4	0.747	14	<.001**
	5	0.843	14	0.018*
	6	0.865	16	0.023*
	7	0.834	14	0.014*
Nonemotional Sentence Identification	1	0.916	18	0.110
	2	0.959	19	0.549

	3	0.958	17	0.597
	4	0.913	14	0.176
	5	0.942	14	0.443
	6	0.925	16	0.203
	7	0.935	14	0.363
Nonemotional Word Discrimination	1	0.907	18	0.075
	2	0.882	19	0.023*
	3	0.966	17	0.743
	4	0.925	14	0.260
	5	0.852	14	0.024*
	6	0.964	16	0.739
	7	0.904	14	0.129

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

[a]Group 1=20-29; Group 2=30-39; Group 3=40-49; Group 4=50-59; Group 5=60-69; Group 6=70-79; Group 7=80-89

Table 2. Shapiro-Wilk Tests of Normality for Years of Education: 7 Groups

Task	Age Group[a]	W	df	p-value
Education	1	0.926	18	0.165
	2	0.958	19	0.539
	3	0.855	17	0.013*
	4	0.922	14	0.235
	5	0.778	14	<.001**
	6	0.927	16	0.218
	7	0.940	14	0.424

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

[a]Group 1=20-29; Group 2=30-39; Group 3=40-49; Group 4=50-59; Group 5=60-69; Group 6=70-79; Group 7=80-89

Table 3. One-Way ANOVAs for the Normally Distributed Tasks

Task	N	F Statistic	df	p-value
Benton Facial Recognition	115	1.680	6, 108	0.133
Sentence Identification	116	4.830	6, 109	>.001**
Word Discrimination	116	2.288	6, 109	0.041*

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

Table 4. Fishers LSD Post-Hoc Pairwise Comparisons: 7 Age Groups by Task

Task	Significant Group Differences	p
Sentence ID	Group 7 vs. Group 2	.007**
	Group 6 vs. Group 2	.016*
Word DIS	Group 7 vs. Group 1	.034*
*p < .05; **p < .01		

Table 5. Kruskal-Wallis Tests for Non-Normality Distributed Tasks: 7 Groups

Task	H Statistic	df	p-value
Visual Matrices	12.933	6	0.044*
Intonation Contours	4.609	6	0.595
Word ID	9.691	6	0.138
Benton Phoneme Discrimination	16.501	6	0.011*

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

Table 6. Kruskal-Wallis Post-Hoc Pairwise Comparisons: 7 Age Groups by Task

Task	Significant Group Differences	p
Visual Matrices	Group 6 vs. Group 3	.036*
Benton Phoneme Discrimination	Group 6 vs. Group 1	.008**
*p < .05; **p < .01		

Table 7. Performance of Seven Age Groups on Screening Measures

		Age Group						
		20-29	30-39	40-49	50-59	60-69	70-79	80-89
Task	n	19	18	18	15	15	16	15
(Possible Range)		M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
BDAE Commands		14.78 (0.73)	15.00 (0.00)	15.00 (0.00)	14.87 (0.35)	14.87 (0.35)	14.88 (0.34)	14.80 (0.41)
(0-15)	Range	12-15	15-15	15-15	14-15	14-15	14-15	14-15
BDAE CIM		10.83 (1.29)	11.11 (1.24)	11.41 (0.87)	11.07 (1.03)	11.20 (0.94)	10.94 (1.00)	10.73 (1.67)
(0-12)	Range	8-12	7-12	10-12	9-12	9-12	9-12	6-12
BDAE S & P		9.50 (0.86)	9.53 (0.51)	9.47 (1.01)	9.73 (0.59)	9.67 (0.82)	9.75 (0.58)	9.73 (0.59)
(0-10)	Range	7-10	9-10	6-10	8-10	7-10	8-10	8-10
WMS-R LM I		28.17 (6.53)	25.47 (7.00)	24.53 (5.84)	26.60 (8.27)	25.07 (5.18)	21.19 (4.49)	22.27 (5.74)
(0-50)	Range	18-42	11-37	13-36	9-41	18-35	13-32	13-34
WMS-R LM II		24.61 (6.48)	22.47 (6.30)	20.88 (6.26)	23.13 (7.19)	21.20 (5.31)	15.56 (6.17)	17.27 (5.11)
(0-50)	Range	17-41	11-31	10-34	8-41	14-33	5-23	10-27
WAIS-R Information		20.83 (6.09)	19.83 (5.44)	22.88 (4.51)	22.80 (4.48)	22.53 (4.75)	22.25 (4.84)	21.79 (6.03)
(0-29)	Range	7-28	9-28	9-29	15-28	13-29	12-29	7-28
WAIS-R Block Des		36.17 (8.77)	29.84 (12.01)	30.65 (8.75)	25.80 (9.92)	22.93 (7.38)	17.94 (9.57)	18.20 (7.80)
(0-51)	Range	20-51	13-47	13-44	114-51	11-36	7-42	10-34
Benton VFD		29.50 (2.43)	30.79 (1.18)	29.76 (3.19)	29.20 (3.51)	30.13 (2.95)	29.00 (2.61)	27.40 (5.14)
(0-32)	Range	24-32	29-32	20-32	18-32	22-32	23-32	16-32
MDRS Attention		36.39 (0.61)	36.16 (1.12)	36.76 (0.44)	36.07 (1.22)	36.00 (1.13)	36.06 (0.85)	36.13 (0.92)

(0-37)	Range	35-37	34-37	36-37	33-37	34-37	34-37	34-37
MDRS Memory		24.33 (0.91)	24.58 (0.77)	24.12 (1.11)	24.47 (0.92)	24.60 (0.74)	24.19 (1.05)	24.20 (1.70)
(0-25)	Range	22-25	22-25	21-25	22-25	23-25	22-25	19-25
Benton PhonDisc	0-30	28.72 (1.13)	28.16 (1.80)	28.12 (1.32)	27.53 (2.20)	27.93 (1.67)	26.38 (1.71)	26.33 (3.27)
(0-30)	Range	26-30	24-30	26-30	24-30	24-30	24-30	22-30
Pure Tone Threshold	500 Hz	16.37 (10.93)	16.67 (7.55)	17.37 (5.73)	21.00 (8.32)	20.43 (5.72)	25.19 (8.70)	33.64 (5.42)
	Range	3-38	-3-28	8-28	10-35	10-30	13-40	25-45
	1 kHz	10.44 (12.47)	7.44 (6.16)	13.94 (5.54)	15.87 (8.14)	14.86 (7.76)	22.88 (12.85)	30.46 (6.22)
	Range	0-49	-2-20	8-25	5-49	3-30	8-60	20-45
	2 kHz	8.06 (13.38)	4.61 (6.66)	8.88 (5.51)	17.00 (12.04)	14.29 (9.90)	23.06 (13.87)	34.39 (7.75)
	Range	-5-50	-5-18	0-20	0-50	0-30	10-63	15-47
MMSE[a]		N/A	N/A	N/A	N/A	N/A	N/A	28.85 (1.14)
(0-30)							Range	27-30
MDRS[a] Total		N/A	N/A	N/A	N/A	N/A	N/A	138.23 (4.75)
(0-144)							Range	131-144

Note. BDAE = Boston Diagnostic Aphasia Examination; CIM = Complex Ideational Material; S & P = Reading Sentences and Paragraphs; WMS-R = Wechsler Memory Scales – Revised; LM = Logical Memory; WAIS-R = Wechsler Adult Intelligence Scale – Revised; Block Des = Block Design; VFD = Visual Form Discrimination; MDRS = Mattis Dementia Rating Scale; PhonDisc = Phonemic Discrimination; MMSE = Mini-Mental State Examination. N/A = Not Administered.

[a] N = 13. Data for these measures are available only for 13 of the 15 participants who are in the 80-89 year-old group.

Table 8. Adjusted Means and Standard Errors for Identification and Discrimination Tasks

Age Group		Identification Tasks Task			
	n	Facial	Word	Sentence	Prosodic
1	19	80.71 ± 2.15	93.67 ± 2.28	85.10 ± 3.12	68.01 ± 3.25
2	18	75.34 ± 2.19	89.99 ± 2.33	78.58 ± 3.12	63.69 ± 3.32
3	18	74.82 ± 2.19	91.38 ± 2.34	84.25 ± 3.14	63.61 ± 3.32
4	15	73.72 ± 2.40	87.82 ± 2.55	78.57 ± 3.41	55.04 ± 3.64
5	16	69.83 ± 2.48	91.71 ± 2.55	81.86 ± 3.41	57.55 ± 3.65
6	15	64.28 ± 2.38	79.69 ± 2.52	66.54 ± 3.30	39.04 ± 3.52
7	15	63.26 ± 2.41	83.89 ± 2.59	69.13 ± 3.41	41.26 ± 3.76

		Discrimination Tasks Task		
	n	Facial	Word	Prosodic
1	19	87.54 ± 1.62	87.79 ± 2.26	96.81 ± 0.97
2	18	87.64 ± 1.62	82.78 ± 2.32	96.23 ± 0.99
3	18	88.63 ± 1.64	83.77 ± 2.32	96.23 ± 0.99
4	15	82.80± 1.77	81.82 ± 2.62	95.95 ± 1.09
5	16	81.74 ± 1.77	83.83 ± 2.53	92.86 ± 1.09
6	15	80.48 ± 1.72	77.23 ± 2.45	93.08 ± 1.05
7	15	80.66 ± 1.77	80.88 ± 2.59	94.29 ± 1.09

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