Components of Emotional Experience and Reaction Time: A study of Normal Aging and Parkinson's Disease

by

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ABSTRACT

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We examined whether valence or arousal levels affect decision and movement times in Parkinson's disease (PD) and in healthy aging. For both decision and movement time, we were interested in differences in the speed and variability in responding. We also studied whether emotional experience is altered as a result of the aging process and PD pathology.

Participants included 16 young healthy adults, 15 older healthy adults, and 15 non-demented individuals with mild PD. The PD participants were tested on medication. Participants viewed pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001) differing in emotional content and performed self-report valence and arousal ratings during picture presentation. Components of reaction time (i.e., decision time [DT] and movement time [MT]) were assessed during a forced-choice reaction time task.

Results demonstrated that DT and MT were differentially affected by emotional stimuli. The PD group demonstrated significantly longer and more variable DTs than did the healthy controls for negative, positive, and neutral pictures; however, only the MTs for negative and neutral images were significantly different or more variable between groups. Although DTs

were longer for the older control group relative to the younger control group, MTs were equivalent between the two control groups.

Evidence of altered emotional experience in PD was found, as the PD participants rated negative pictures as less negative than did healthy older adults; however, this significant difference was reduced to a trend when individuals with more severe depressive symptomatology were excluded from the analysis. In addition, high arousal images were rated as more highly arousing among the PD group when depressed individuals were not included in the analyses. There was no evidence of impaired emotional experience as a function of aging, as valence and arousal ratings were not significantly different between younger and older adults.

Better understanding of emotional processing deficits, which have been associated with poorer quality of life, in healthy aging and PD may lead to a better understanding of the neural bases of emotional processing, as well as offer treatment approaches.

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INTRODUCTION

Parkinson's disease (PD) is the second most common neurodegenerative disorder, after Alzheimer's disease (AD; Schapira, 2009). It typically affects the elderly, with an average age of onset at 55. PD is characterized by tremor, rigidity, and bradykinesia. Although symptoms of PD were documented by several earlier researchers and clinicians, these symptoms were often considered to be part of separate and distinct diseases. James Parkinson may have been the first to recognize and describe these symptoms as part of a single disorder in his publication titled *Essay on the Shaking Palsy* (Parkinson, 1917). In his paper, James Parkinson described the cardinal PD symptoms as "involuntary tremulous motion, with lessoned muscular power, in parts not in action and even when supported; with the propensity to bend the trunk forwards, and to pass from a walking to a running pace." It is now known that PD is also characterized by a number of nonmotor symptoms, such as sleep disturbance, cognitive dysfunction, and emotional processing disorders (for review, see Zgaljardic, Borod, & Foldi, 2003).

Classification and Progression of Parkinson's Disease Symptoms

The Unified Parkinson's Disease Rating Scale (UPDRS; Fahn, Elton, & Committee, 1987) was developed in 1987 and is currently one of the most utilized methods of describing PD symptoms. The current version of the UPDRS has four components, which assesses both motor and nonmotor symptoms of PD. There are a total of 199 possible points, with higher scores reflecting more severe impairment. The first section of the UPDRS consists of questions pertaining to mentation, behavior, and mood. Items in this section include questions assessing the presence of intellectual impairment, thought disorder, and depression. The second component of the UPDRS examines the patient's ability to perform activities of daily living; patients are asked about their ability to perform these actions both on and off parkinsonian

medications. Included in this section are questions related to the patient's handwriting, swallowing, ability to use utensils, and sensory complaints. The third section assesses motor symptoms that are characteristic of PD, such as tremor, facial expressivity, and rigidity. In addition, a trained clinician assesses the patient while he or she performs several motor actions (e.g., finger taps, rapid alternating movements, and walking) and assigns a rating based on the degree of slowing or impairment observed. The fourth and final component of the UPDRS investigates whether any PD-related complications (e.g., dyskinesias, clinical fluctuations, and sleep disturbances) were present within the past week.

Results of the UPDRS are often reported in the context of other frequently utilized scales, such as the Hoehn and Yahr scale (Hoehn & Yahr, 1967). This scale describes five stages of the disease. During Stage I, signs and symptoms of PD are present unilaterally, typically presenting with tremor of one limb. These symptoms are mild and are not disabling. In this first stage, friends and family are able to notice changes in the patient's posture, movement, and facial expressions. During Stage II, symptoms have worsened. At this stage, PD symptoms are bilateral and cause minimal disability. At this point, the patient's posture and gait are affected. At Stage III of the illness, there is significant slowing of body movements, as well as early impairment of equilibrium on walking or standing. Symptoms cause moderate dysfunction for the patient. Stage IV is characterized by more severe symptoms. The patient is able to walk for limited duration, rigidity and bradykinesia are apparent. At this stage, the patient is no longer able to live alone. During Stage V, the patient is unable to stand or walk and requires constant nursing care.

The rate of disease progression varies among individuals. Marras, Rochon, and Lang (2002) reviewed studies that examined predictors of more rapid decline in PD. The authors

found that more severe impairment at baseline, early cognitive deficits, older age, and lack of tremor at onset were associated with rapidly increasing motor impairment. Although most patients live 10 to 15 years after the first symptoms are recognized, patients will experience severe motor impairment (e.g., loss of independent ambulation) approximately seven to nine years after disease onset [Poewe, 2006]).

Disease Pathology

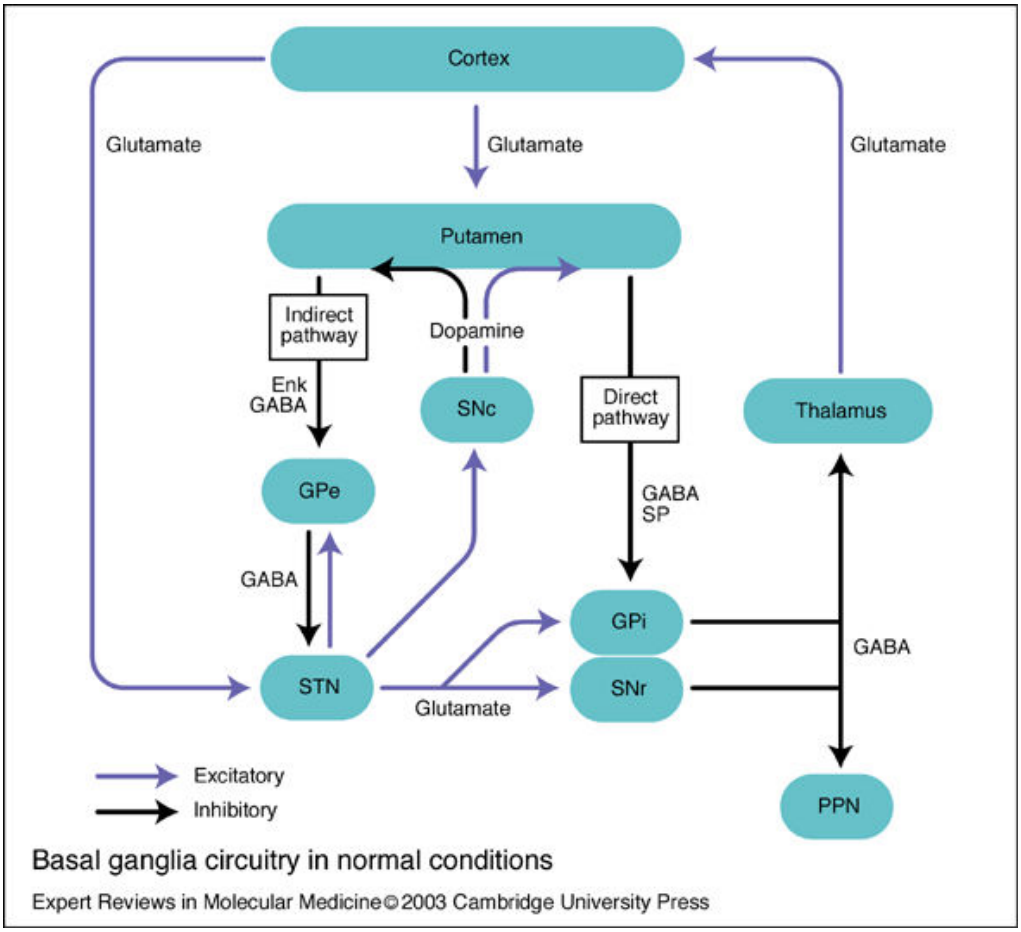
PD is the result of a loss of dopaminergic neurons in the substantia nigra, pars compacta. When dopamine levels drop below 30% of the level observed in healthy brains, motor and nonmotor symptoms of the disease appear. The remaining neurons in the substantia nigra contain cytoplasmic inclusions called Lewy Bodies (Blumenfeld, 2002). Although there are several hypotheses, the cause of the neuronal loss is unknown. Because of the widespread connections of the basal ganglia to other brain regions, as well as more recent findings of neuronal loss in areas of the brain outside the basal ganglia, PD affects cognitive abilities, motor functions, and emotion processing of affected persons. In order to better understand how PD can disrupt several brain systems, the anatomy of the basal ganglia will be described below. Subsequently, I will describe how PD affects this system. Summaries of these neural circuits were adapted from Blumenfeld (2002).

The basal ganglia are comprised of the caudate, putamen, nucleus accumbens (together, these three nuclei represent the striatum), globus pallidus, subthalamic nucleus, substantia nigra, and ventral pallidum. The afferents and efferents of the basal ganglia are a complex system with excitatory and inhibitory connections involving several different neurotransmitter systems (Blumenfeld, 2002). Generally, the striatum receives excitatory glutamatergic input from the cortex, which is then transmitted to various regions within the basal ganglia, and then to the

thalamus. Projections from the basal ganglia to the thalamus are inhibitory, utilizing GABA. Fluid, voluntary motor movements depend on the coordinated action of two neural pathways connecting the basal ganglia and the thalamus: the direct and indirect pathways.

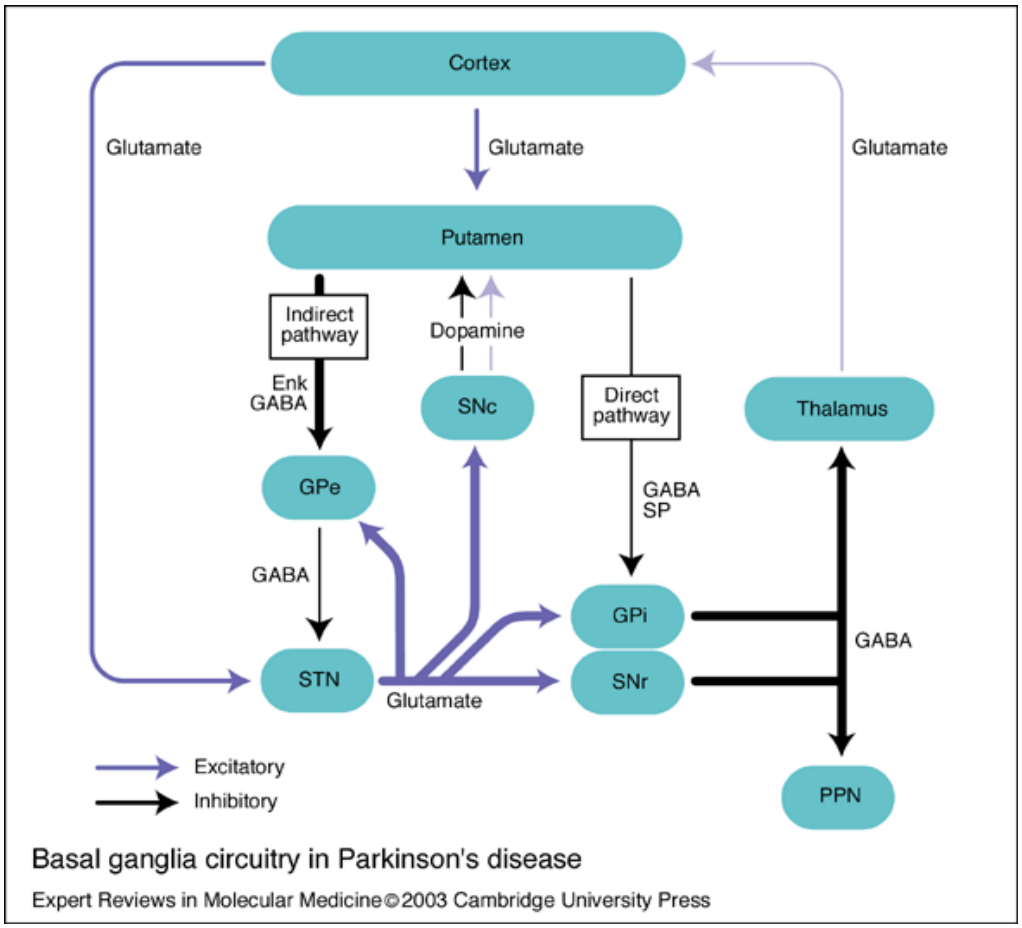
The direct pathway receives excitatory input from the cortex via the striatum. Excitation of the striatum releases inhibitory neurotransmitters on the internal segment of the globus pallidus, which has inhibitory connections to the thalamus. By inhibiting the communication between the internal segment of the globus pallidus and the thalamus, the thalamic neurons are able to relay information to the frontal lobes. The end result of the direct pathway is excitation of the thalamus, which facilitates movement.

Rather than directly projecting to the internal segment of the globus pallidus, the neuronal projections of the striatum in the indirect pathway first send inhibitory signals to the external segment of the globus pallidus, which have an inhibitory effect on the subthalamic nucleus. The subthalamic nucleus has excitatory projections onto the internal segment of the globus pallidus, which then inhibits the thalamus. Thus, excitation of the striatum inhibits the inhibitory effect of the globus pallidus on the subthalamic nucleus, resulting in activation of the internal segment of the globus pallidus. The indirect pathway results in inhibition of the thalamus, which inhibits movement. The following diagram provides a visual representation of the basal ganglia circuitry described above.



The striatum also receives dopaminergic projections from the substantia nigra, pars compacta, which then follow the direct and indirect circuitry outlined above. However, the projections of the substantia nigra, pars compacta to the striatum differentially affect the direct and indirect pathways. Dopamine has an excitatory effect on striatal neurons in the direct pathway and an inhibitory effect on striatal neurons in the indirect pathway. Since the direct pathway typically facilitates movement in the normal brain, reduced excitatory activation of its striatal neurons leads to reduced activation of the thalamus and cortex and a reduction in movements. As the indirect pathway typically inhibits movement in the normal brain, a loss of inhibitory dopaminergic neurons serves to facilitate the function of this inhibitory circuit.

Therefore, the loss of dopaminergic neurons of the substantia nigra, pars compacta in PD results in net inhibition of movement through both direct and indirect pathways. The following diagram provides a visual representation of the basal ganglia circuitry in PD.



The basal ganglia have extensive connections with the frontal lobes. Alexander, DeLong, and Strick (1986) proposed a model of basal ganglia-thalamocortical circuitry consisting of five "closed loops." Each circuit originates in functionally-related cortical areas and project to specific nuclei within the basal ganglia, which then terminate on one of the frontal regions where the circuit originated. These basal ganglia-thalamocortical circuits remain segregated throughout the basal ganglia and thalamus and also maintain topographical orientations. Two of the circuits

are involved in motor actions (i.e., the motor and oculomotor circuits), whereas the remaining three circuits (i.e., dorsolateral prefrontal, lateral orbitofrontal, and anterior cingulate) are hypothesized to be implicated in more complex cognitive actions, such as cognitive and behavioral functions (for review, see Zgaljardic, Borod, & Foldi, 2003). Thus, due to the depletion of dopaminergic neurons in the nigrostrial region, functions associated with the frontal system, such as working memory (Lewis, Dove, Robbins, Barker, & Owen, 2003), are often disrupted in PD.

Another pathological hallmark of PD is the presence of Lewy bodies. Studies examining the location of Lewy bodies in PD have found that Lewy bodies are not restricted to the basal ganglia. Lewy bodies have been found in the cortex, amygdala, locus coeruleus, vagal nucleus, and the peripheral autonomic nervous system (Samii, Nutt, & Ransom, 2004).

Is PD an Acceleration of Normal Aging or a Specific Disease Process?

There is some overlap in the clinical characteristics and pathophysiology of PD and healthy aging, raising the question as to whether PD is a specific disease process or an acceleration of normal aging. For example, parkinsonian signs are very common among older adults. Bennett et al. (1996) examined the prevalence of parkinsonism in the elderly and found that 159 of the 467 individuals examined demonstrated parkinsonian symptoms. Only 15 of the 159 individuals were diagnosed with PD. Among all individuals studied (age >65), rigidity and gait disturbance were the most commonly observed symptoms, present in approximately 31% of the sample. Tremor was present in about 25%, and bradykinesia was observed in about 23% of the participants. In addition, the prevalence of all signs, with the exception of resting tremor, increased with age.

The pathological hallmark of PD (i.e., neuronal death in the substantia nigra), is also observed in healthy adults. Specifically, there is a 5% neuronal loss per decade in the substantia nigra after the age of 40 (Gibb, 1997). In addition, Lewy bodies are found in the nervous system of healthy older adults without PD (Gibb, 1997); this finding is termed incidental Lewy body disease. Knopman et al. (2003) examined the presence of Lewy bodies in the substantia nigra, amygdala, and cingulate cortex in adults who were considered to be cognitively intact and did not have PD at the time of their death. Five of the 39 individuals had Lewy bodies in at least one of the examined brain regions. Markesbery, Jicha, Liu, and Schmitt (2009) found that the most common sites of Lewy body pathology in healthy older adults are the medulla, amygdala, pons, and midbrain. According to Gibbs (1997), the prevalence of incidental Lewy body disease is approximately 1% among individuals who die between the ages of 50 and 59. The prevalence rises to about 10% between the ages of 80 and 89.

Despite this overlap in symptoms and pathophysiology, Samii, Nutt, and Ransom (2004) argue that PD is not an acceleration of normal aging. They note that asymmetric motor signs and faster rate of progression can help distinguish PD from normal aging. In addition, unlike the motor signs of PD, the parkinsonian signs in normal aging do not substantially improve with levodopa. Kish, Shannak, Rajput, Deck, and Hornykiewicz (1992) examined the pattern of dopamine loss within the striatum among normal controls aged 14 to 92 to determine whether the pattern of cell loss in this region differs between individuals with and without PD. These authors hypothesized that if PD is the result of normal or accelerated aging, then the pattern of dopamine loss should be similar in normal controls and in PD. Results from this study indicated that dopamine levels in the caudate and putamen declined significantly with age. In this sample of participants, there was no difference in the magnitude of dopamine loss between the putamen

and caudate. This is in stark contrast to other studies demonstrating that in PD the rate of dopamine loss is much greater in the putamen than in the caudate (e.g., Kish, Shannak, & Hornykiewicz, 1988). Thus, the authors conclude that the pattern of dopamine loss in PD differs from that in normal aging, suggesting that PD is in fact a separate disease and not accelerated normal aging.

Emotion: Components and Neural Substrates

Components of Emotion

There are several ways to conceptualize emotion. For instance, one can approach emotion from a cognitive, physiological, biological, or neuropsychological perspective (Borod, Tabert, Santschi, & Strauss, 2000). The componential theoretical approach is a hierarchical model of emotion proposed by Borod (1993) that states emotion is comprised of "processing modes that utilize different brain systems." The basic processing modes are perception, expression, experience, and physiological arousal (Plutchik, 1984), which make up the top level of Borod's model. These processing modes are considered to be separate and distinct, based upon findings from brain-damaged patients with deficits in some components while other components were spared. The next level, the communication channel, reflects the different modalities in which emotion can be processed. Facial, prosodic (intonational), lexical (speech content), gesture, and posture represent the distinct channels of communication. At the third level are the dimensions of emotion, such as pleasant-unpleasant and approach-avoidance. The final, and perhaps most basic, level encompasses those discrete emotions that have a biological basis.

Neural Substrates of Emotion Processing

There are multiple brain areas that have a role in emotion processing. These areas span several regions and include cortical, as well as subcortical, structures (Rolls, 1999) and generally include, but are not limited to, the amygdala, the orbitofrontal cortex, and the basal forebrain.

The amygdala is probably one of the structures most frequently associated with emotion. This subcortical structure has consistently been associated with fear recognition (LeDoux, 2000) and in forming emotional memories (Carlson, 2004). Increased activity in the amygdala has been observed during several tasks, including recalling emotionally arousing films and reading threatening words (Carlson, 2004). There is also evidence that the amygdala has a role in emotion recognition. Amygdala lesions have been associated with impaired recognition of emotional facial expressions (Carlson, 2004).

The basal ganglia are another structure important for emotion processing. Individuals with damage to this region have more impaired comprehension of emotional facial expression (Cancelliere & Kertesz, 1990). Damage to the basal ganglia may result in a disproportionate impairment in recognizing disgust. Patients with Huntington's disease, a disorder affecting the basal ganglia, have been shown to have deficits in recognizing facial expressions, in particular, ones displaying disgust (Sprengelmeyer et al., 1996).

A large body of evidence from healthy controls, as well as brain-damaged patients, demonstrates that the right hemisphere mediates the perception and expression of emotion (Borod, Zgaljardic, et al., 2001; Borod, Bloom, et al., 2002). For example, tachistoscopic studies of healthy participants have revealed emotional faces are perceived better when presented to the left visual field (for review, see Borod, Zgaljardic, Tabert, & Koff, 2001). This is because each cerebral hemisphere receives and processes information predominantly from the contralateral

side of the environment (Carlson, 2004). Furthermore, right-hemisphere damaged patients perform worse than left-hemisphere damaged patients at recognizing facial affect (Borod et al., 1998; Borod, Bloom, et al., 2002)). Additional evidence that the right-hemisphere mediates emotional processing comes from studies utilizing chimeric faces. When an image of a face is cut in half and mirror images are made, whole facial images formed from the left side of the face are considered to be more expressive than those made from the right side (Carlson, 2004).

Most language functions are mediated by the left hemisphere, with the exception of emotional prosody. As described in Carlson (2004), George and colleagues (1996) measured cerebral blood flow using PET. In this study, participants listened to sentences and identified the emotional content of these sentences. Increased blood flow in the right prefrontal cortex was associated with comprehension of emotional tone. Right-sided brain damage results in aprosodic speech. On the contrary, patients with left-sided damage resulting in Wernicke's aphasia modulate their voice, though their speech output is often incomprehensible (Carlson, 2004).

Age-related Changes in Emotion Processing

Several studies have demonstrated that older adults activate different cortical networks during emotion processing tasks. For example, Gunning-Dixon et al. (2003) found that during an emotion discrimination task, compared to younger adults, older participants demonstrate less activation of the limbic areas relative to other brain regions, such as the anterior cingulate, prefrontal, and parietal regions. As post-mortem studies have found age-associated neuronal loss and atrophy in temporo-limbic regions (e.g., amygdala, hippocampus entorhinal cortex), it is possible that there is an age-related reorganization of networks involved in emotional processing (Gunning-Dixon et al., 2003). Such reorganization has been demonstrated for cognitive

functions (e.g., Cabeza, 2002) and, more recently, for emotional perception (Finley & Borod, 2008).

Despite evidence of cortical and peripheral changes in emotional processing with age, the majority of studies examining emotional experience and aging do not find age-related declines. Carstensen, Pasupathi, Mayr, and Nesselroade (2000) assessed the frequency and intensity of emotional experience in a group of African American and European American adults ranging from age 18 to 94. Participants rated the degree to which they experienced various emotions five times a day over the course of one week. Results indicated that older adults experience positive emotions as frequent as younger adults; however, the frequency of negative emotions decreases with age. Additionally, there were no significant group differences with respect to the subjective intensity of either positive or negative emotions. Other studies have demonstrated that older adults' valence and arousal ratings for pictures have been shown to be similar to that of younger adults (Charles, Mather, & Carstensen, 2003; Denburg, Buchanen, Tranel, & Adolohs, 2003; Weiser, Muhlberger, Kenntner-Malbiala, & Paul, 2006b). However, Smith, Hillman, and Duley (2005) found increased valence and arousal ratings among older adults in response to emotional pictures, whereas Mather and colleagues (2004) found reduced arousal ratings for unpleasant pictures among older adults relative to younger adults.

In fact, studies that have simultaneously examined changes in cortical and/or peripheral responses to emotional stimuli and subjective affective experience have failed to find age-related changes in emotional experience. Utilizing self-report and psychophysiological measures, Smith, Hillman, and Duley (2005) examined age-related effects on emotional reactivity in response to pictures. Results indicated that the physiological reactivity to emotional pictures was attenuated for several measures among the older adults (i.e., EMG, heart rate, and blink);

however, self-report and startle blink responses were enhanced among the older adults. These findings suggest that there are age-related changes in emotional reactivity, but that these changes are not unitary and do not affect all systems the same.

Other studies have utilized the rapid serial visual presentation (RSVP) paradigm, in which images are presented very quickly (i.e., three to five frames per second) without any perceivable interval between the images to study emotion processing. EEG activity is often recorded while viewing the stimuli. Results from previous studies of younger adults demonstrated that event-related potentials (ERPs) to highly arousing stimuli exhibit an enhanced negativity at approximately 106ms after picture onset (Junghoefer et al., 2001). This enhanced negativity is termed the early posterior negativity (EPN) and is assumed to be an early indicator of selective emotional processing in the brain. Weiser and colleagues (2006b) examined whether older adults demonstrated this phenomenon. They found similar valence and arousal ratings between older and younger participants, despite findings that older adults' delayed and decreased EPN for all visual content.

Many studies have suggested a specific age-related shift towards more meaningful goals and a bias toward emotional information. There may also be a bias in the type of emotional material recalled by older adults, such that there is increased attention to and better recall of positive events as a function of age. This has been conceptualized as socioemotional selectivity theory (SST; Mather & Carstensen, 2003). For example, older adults' recollections of stories (Carstensen & Turk-Charles, 1994) and advertisements (Fung & Carstensen, 2003) contain more emotional material than those of younger adults.

Emotion Processing Deficits in PD

There are several reasons one might expect to find emotion processing deficits in PD. As documented above, studies examining patients with basal ganglia strokes, as well as other degenerative disorders affecting the basal ganglia, have documented emotion processing deficits. Imaging studies of healthy participants also point to a role for the basal ganglia in emotion processing. For instance, using functional MRI, Kotz and colleagues (2003), found striatal activation during a task where participants distinguished positive from negative speech intonation.

It is evident that PD patients demonstrate impairments in emotional behaviors. For example, PD patients often demonstrate blunted facial expressions and aprosodic speech. Research over the past few decades indicates that the emotional deficits observed in PD are more extensive, and may include deficits in the expression, perception, and experience of emotion.

Relative to the cognitive and motor symptoms of PD, much less is known about emotional deficits in PD. Depression is probably one of the most heavily researched and most common emotional disorders associated with PD. It has been reported that slightly less than 50% of Parkinson's patients have symptoms of depression (Mayeux, Stern, Rosen, & Leventhal, 1981). There have also been reports of higher incidence of depression in individuals who are later diagnosed with PD (Leentjens, Van den Akker, Metsemakers, Lousberg, & Verhey, 2003).

As previously noted, a growing body of literature is revealing that emotional deficits in PD extend beyond depression, and that the person's ability to express and perceive emotions may be affected by disease related pathology. It appears that the ability to recognize emotional facial expression is impaired early in the disease course (Dujardin et al., 2004; Sprengelmeyer et al., 2003), while deficits in the recognition of emotional prosody may not be affected until later

in the disease course (Breitenstein, Van Lancker, Daum, & Waters 2001). Some have even found that deficits in facial expressivity are apparent before the onset of motor symptoms (Kawamura & Koyama, 2007).

Results from these studies are far from conclusive and results are conflicting. For example, a review by Zgaljardic, Borod, Foldi, and Mattis (2003) reported that approximately half of the published studies examining emotional perception in PD have found deficits in facial and prosodic perception, but the remaining did not find this to be the case. By contrast, this review indicated that all studies of emotional expression, regardless of modality (i.e., facial expression, prosody), found impairments in PD patients relative to healthy controls.

Much less work has examined how PD affects the experience of emotion. One way to examine emotional experience is through subjective ratings of affective stimuli. Typically, these rating scales are Likert scales. Stimuli are often rated on two dimensions: valence and arousal. Valence refers to the positive-negative (pleasant-unpleasant) quality of the stimulus (Dara, Monetta, & Pell, 2008), thus the Likert scale has unpleasant on one end of the continuum and pleasant at the other, with neutral in the middle. Arousal refers to the intensity of the stimulus (Dara, Monetta, & Pell, 2008) and ratings range from high to low. Often, these ratings are made simultaneously during stimuli presentation.

Based on a large body of literature indicating decreased emotional expressivity in PD (for review, see Zgaljardic et al., 2003), some researchers hypothesized that patients with PD will also have reduced emotional experience. However, results from several studies suggest individuals with Parkinson's disease do not have decreased emotional experience relative to other patient populations or healthy controls. For example, PD patients have been found to make similar ratings as depressed patients (Katsikitis & Pilowsky, 1988), participants with ischemic

heart disease (Pitcairn, Clemie, Gray, & Pentland, 1990), and healthy controls (Borod, Rogers, Spielman, Halfacre, McCabe, et al., 2008). Smith, Smith, and Ellgring (1996) found that PD participants' ratings of emotional videos were as high as, and in some cases higher than, healthy controls; however, this may have been accounted for by depression, as greater depressive symptomatology was associated with higher intensity ratings.

Weiser and colleagues (2006a) demonstrated differences in emotional ratings in a sample of PD participants while viewing emotional pictures. In this study, participants (PD and demographically-matched controls) were presented with all 702 images from the International Affective Picture System (IAPS), using the RSVP paradigm while EEG activity was recorded. Afterwards, participants made valence and arousal ratings for a subset of 54 stimuli. Results demonstrated that PD participants rated highly arousing images as less arousing than healthy controls. There were no group differences in ratings for low arousing pictures or in valence ratings. Results from the EEG recordings indicated that the early posterior negativity (EPN) of PD participants did not differ from older controls, leading the authors to conclude that there are no differences in the early visual processing of emotional pictures between the groups.

Hillier, Beversdorf, Raymer, Williamson, and Heilman (2007) investigated the possibility that PD patients have a degradation of the emotional-semantic network. In this study, participants rated the valence and arousal of emotional words, as well as the cost of items that can be purchased (e.g., crayon and pearl; termed "expense-related words"). PD patients demonstrated an overall blunting of ratings for emotional words, such that positive words were rated as less positive and negative words as less negative. In addition, low arousal words were rated as more arousing compared to healthy controls. However, this tendency to rate words toward the middle of the scale among PD participants was not observed for expense-related

words; PD participants rated high- and mid-expense words as more expensive than the healthy control group. The authors conclude that these findings suggest that PD patients have impaired emotional conceptual-semantic networks; however, they also note that one cannot rule out the possibility of a more general semantic processing deficit.

Changes in Reaction Time in Older Adults

Generally, reaction time decreases from infancy into early adulthood and then increases as an individual ages (Birren & Fisher, 1995). There is also greater variability among older than younger adults (Hultsch, MacDonald, & Dixon, 2002). Age-related slowing has been documented on many different tasks (for review, see Salthouse, 2000). However, some studies have failed to produce significant differences between younger and older adults on simple reaction time tasks (e.g., De Jong, Kok, & Van Rooy, 1989; Yordanova, Kolev, Hohnsbein, & Falkenstein, 2004). Differential results regarding age-related motor slowing have been attributed to task complexity, such that behavioral slowing increases with more difficult tasks (Kok, 2000).

Components of Reaction Time

Several reasons have been proposed for age-related slowing, such as health status (Earles & Salthouse 1995) and decreased working memory (Briggs, Raz, & Marks, 1999). Overall response time can be divided into the components of movement time and decision time. In order to better understand changes in overall reaction time, one might choose to examine these components. Falkenstein, Yordanova, and Kotev (2006) compared separate stages of the central sensorimotor processing system between young and older participants in an attempt to evaluate their specific roles in age-related slowing. These authors compared stimulus processing, response selection, and motor response generation using ERPs during a four-choice reaction task. Though slowed stimulus processing of visual stimuli was evident, this perceptual slowing in the

visual modality could not account for the overall slowing in response to visual information. The authors concluded that there is a delayed response in the motor cortex of the older participants to initiate a motor response, evidenced by enhanced and prolonged motor response potential at the motor cortex contralateral to the moving hand of the older participants. Krampe (2002) also demonstrated that age-related motor slowing can, at least in part, be accounted for by slowing of components of the central nervous system (i.e., cognitive processing speed).

Reaction Time and Parkinson's Disease

Slowed motor movements are one of the characteristic features of PD. According to Evarts, Teravaine, and Calne (1981), in 1925 Wilson quantified the slow reaction time in PD patients, reporting values of "… 0.24 seconds for normal individuals and 0.36 seconds for subjects with paralysis agitans."

There are two basic types of reaction time paradigms: simple and choice. In tests of simple reaction time, participants make the same response across all trials, whereas in choice reaction time tasks, participants' responses are selected from two or more alternatives (Gauntlett-Gilbert & Brown, 1998). Studies have consistently demonstrated that patients with PD, relative to controls, are impaired on simple reaction time tasks; however, results from choice reaction time studies are more variable (Wang, Thomas, & Stelmach, 1998).

Variations on reaction time tasks include the use of a cue, which orients the participant toward the response. . Generally, participants respond faster when cues are provided, which is assumed to reflect a benefit of being able to prepare the movement in advance (Gauntlett-Gilbert & Brown, 1998). However, studies have demonstrated that PD participants do not benefit from such cues. For example, Evarts, Teräväinen, and Calne (1981) examined a variety of reaction time tasks (e.g., simple and choice, with or without a cue) in PD, healthy older adults, and young

adults. Expectedly, they found that the PD had the slowest reaction times, followed by older adults; young adults responded the fastest. The PD group was impaired on both the cued and uncued choice reaction time tasks; however, the difference between the cued and uncued was less than what is typically observed in controls in other studies (for this study, control groups did not participate in the uncued condition). It has been concluded that this pattern of deficits observed in PD is the result of patients' inability to preprogram their response (Jahanshahi, Brown, & Marsden, 1993).

Bloxham, Mindel, and Frith (1984) found that PD patients, relative to age-matched controls, were significantly slower on tasks when given a cue, but not on tasks without a cue. However, in this study, PD participants were not impaired on a tracking task, which consisted of both predictable and unpredictable tracks. Thus, the authors concluded that PD patients are able to make use of predictable movements to produce a preprogrammed response, but have difficulty in selecting an appropriate movement or in initiating that movement. Gauntlett-Gilbert and Brown's (1998) review of the literature also lead them to conclude that PD patients do not have a motor preprogramming deficit.

Relative to demographically-matched controls, PD patients demonstrate more variability on tests of reaction time. Evarts, Teräväinen, and Calne (1981) found enormous variability within and between patients with PD. For example, patients may be significantly slower with the left arm than the right arm when performing the same task. Patients also demonstrated impaired initiation with relative sparing of movement speed for one arm, and vice versa for the opposite arm.

A large body of literature suggests that variability in responding is associated with neurological dysfunction. Researchers have demonstrated greater variability in responding

among patients with PD (Camicioli, Wieler, de Frias, & Martin, 2008), AD (Gorus, De Raedt, Lambert, Lemper, & Mets, 2008), traumatic brain injury (Hetherington, Stuss, & Finlayson, 1996), and epilepsy (Bruhn & Parsons, 1977). Results from Burton and colleagues study (2006) examining the performance of participants with AD, PD, and healthy older adults on cognitive and reaction time tasks found significantly greater variability among the patient groups relative to healthy controls. In addition, there was evidence that variability in responding was associated with more severe cognitive impairment, as the AD group, who had greater cognitive impairment, was more variable than the PD group. However, statistically controlling for cognitive decline did not eliminate group differences, thus suggesting that intraindividual variability is not completely explained by cognitive dysfunction.

Components of Reaction Time

As previously noted, overall reaction time is comprised of cognitive and motor components. One might expect to find slowed cognitive processing speed in PD, given findings that the striatum is involved in information processing speed (Rao, Mayes, & Harrington, 2001). According to Zimmerman, Sprengelmeyer, Fimm, and Wallesch (1992), Naville was the first to investigate cognitive speed in PD and found cognitive slowing on more complex tasks. Naville coined the term bradyphrenia to describe mental slowing.

One method that has been used to estimate the cognitive component of a response is to compare a participant's performance across tasks with increasingly difficult cognitive demand while holding the motor action for the response constant. Using this technique, several studies have found that as the cognitive load increases, patients with PD demonstrated prolonged reaction times (Jordan, Sagar, & Cooper, 1992; Zimmerman, Sprengelmeyer, Fimm, & Wallesch, 1992). Given that the motor movement to perform the task is identical, researchers

conclude that the exaggerated reaction time is the result of slowed cognitive processing. However, as stated above, several studies have not found disproportionate impairment on tasks of choice reaction time, although simple reaction time seems to be impaired (Evarts, Teräväinen, & Calne, 1981).

Some researchers have investigated cognitive speed using tasks that require minimal movement by the participant. Ransmayr and colleagues (1990) measured the response latency of PD and age-matched controls on a memory scanning task. On this task, participants viewed a series of two, three, or four digits on a screen. Following the presentation of each set, a target digit was presented. As quickly as possible, participants indicated whether the target number was one of the digits presented in the series by pressing a key. To minimize movement, the "yes" key was held in the participant's right hand and the "no" key was held in the participant's left hand. For this study, the slope of the linear regression between the response latencies and the set-size (i.e., two, three, four digits) was considered to be the "mental component." Results indicated that patients with advanced PD were slower at performing this task relative to normal controls and patients in the early stages of the disease.

There is consistent evidence that PD patients demonstrate both cognitive and motor slowing. However, it is not clear if motor slowing is the result of central processing impairments or if motor deficits cause poorer performance on cognitive tasks. Hsien, Chen, Wang, and Lai (2008) found that PD participants were significantly slower on all three tasks of the Stroop task (i.e., word naming, color naming, and color-word naming). The authors used a subtraction method to estimate the time to determine ink color (i.e., the difference between color naming and word reading was the decision time for ink color). Results indicated that this decision time was not significantly different between the PD group and age-matched controls. Thus, the authors

concluded that the slowed performance by the PD group was due to motor response impairments rather than central processing deficits. However, other studies have found evidence of slowed central processing during cognitive tasks that are independent of motor functioning (Grossman, Carvell, & Peltzer, 1994). Using a lexical list-priming paradigm, Grossman and colleagues (2002) found that a subgroup of PD participants demonstrated prolonged priming of lexical information.

The Effect of Emotion on Reaction Time

The emotional valence of a stimulus may affect reaction time. For example, White (1996) found longer reaction times for negatively than positively valenced words on a Stroop-paradigm task (in Dahl, 2001). Similarly, Stenberg, Wiking, and Dahl (1998), when superimposing affective words on faces, found that participants had longer response latencies for negatively valenced words (in Dahl, 2001). It has been hypothesized that negative information is more complex (Labouvie-Vief, Lumley, Jain, &Heinze, 2003) and requires more cognitive resources to evaluate (Dahl, 2001).

Healthy Older Adults

Relatively few studies have examined age effects on reaction time for emotional stimuli. One study found no significant differences in response rates as a function of age between positive faces and negative faces in a forced-choice recognition task (Mather & Carstensen, 2003). Another study (Wurm, Labouvie-Vief, Aycock, Rebucal, & Koch, 2004) also found no difference in response time as a function of valence between younger and older participants on an emotional stroop task.

In contrast, Gunning-Dixon and colleagues (2003) examined emotional and age discrimination among older and younger adults. The younger adults were significantly faster at

both the age and emotion discrimination tasks. Thus, suggesting that age does not differentially affect speed of emotion processing.

Parkinson's Disease

Even fewer studies have examined the effect of PD-related pathology on reaction time for emotional stimuli. Indirect evidence suggests that emotional arousal may improve motor functions in PD. For example, music therapy has been shown to improve motor function in PD. It has been hypothesized, that this effect is mediated by emotional arousing effects of musical stimuli (Pacchetti, Aglieri, Mancini, Martignoni, & Nappi, 1998). However, empirical evidence for this hypothesis is lacking.

Of the available data, studies examining both valence and arousal effects on response time in the same population are not available, to our knowledge. For example, Bowers and colleagues (2006) found similar eye-blink response latencies between older adults and PD patients in response to pleasant and unpleasant images from the IAPS. A follow-up study also found similar response latencies between groups for pleasant, neutral, fearful, and disgust images (Miller, Okun, Marsiske, Fennell, & Bowers, 2009). Unfortunately, eye-blink response latencies for high and low arousing pictures were not reported for either study. Tessitore and colleagues (2002) had participants (PD and controls) select the affective facial expression that matched a target expression. For this task, there were no group differences in reaction time.

Aims and Hypothesis of the Current Study

The current study aimed to address the methodological gaps in the literature (e.g., using paradigms requiring a motor response to assess cognitive processing speed in PD) pertaining to reaction time in healthy aging and PD. We examined whether emotional stimuli affect components of reaction time (i.e., movement time [MT] and decision time [DT]) in mild PD.

Examination of the components of reaction time would allow researchers and clinicians to better understand where differences in reaction time exist (i.e., cognitive processing or movement speed). The literature has consistently shown that PD participants, in general, respond more slowly than healthy controls on measures of simple reaction time; several studies have demonstrated slower responding by individuals with PD on tasks of choice reaction time, although results are not consistent (Wang, Thomas, & Stelmach, 1998). PD participants have also demonstrated longer reaction times on tasks of cognitive processing, even when the motor output required to complete the task has been minimized (Ransmayr et al., 1990). Fewer studies have examined how emotional stimuli affect the reaction time of PD participants. Furthermore, the effects of both valence and arousal on reaction time have not been previously examined. We were not only interested in whether emotional stimuli affect reaction time in PD patients, but also in which component of reaction time (i.e., MT or DT) the effect is observed. This latter issue has not been addressed in a PD population. We hypothesized that PD participants would demonstrate slower MT and DT relative to age-matched controls. In light of emotional processing deficits that have been reported in PD (e.g., Zgaljardic, Borod, Foldi, & Mattis, 2003), we expected that group differences in MT and DT would be greater in response to emotional than nonemotional stimuli, relative to demographically similar healthy controls.

We also examined whether emotional experience was disrupted in a cognitively intact PD sample. Emotional processing deficits are associated with diminished quality of life; better understanding of these deficits may lead to treatment and improved functioning. Relative to studies of emotional expression and perception, fewer studies have examined emotional experience in PD (Zgaljardic, Borod, Foldi, & Mattis, 2006). The IAPS is one paradigm that has been used to study emotional experience. Studies that have used the IAPS in PD have found that

PD participants make similar valence ratings as healthy controls (e.g., Smith, Smith, & Ellgring, 1996), whereas some studies have found that PD participants rate highly arousing pictures as less arousing in comparison to healthy controls (Wieser et al., 2006; cf. Kaszniak, 2001). We predicted that valence ratings would be similar between groups; however, PD patients would rate high arousing pictures as less arousing relative to demographically-matched older adults.

We examined the variability in responding among PD patients. Several patient populations, including PD, have been shown to respond with greater variability on tests of reaction time. For example, comparison of participants with AD, PD, and healthy older adults indicated greater variability on tasks of cognition and reaction time among the patient groups relative to healthy controls (Burton et al., 2006). However, to our knowledge, variability has not been assessed on an emotion processing task. We hypothesized that PD patients would demonstrate greater variability in DT and MT relative to age-matched healthy adults for affective (i.e., pleasant and unpleasant) and nonaffective images. Given evidence of emotional processing deficits among PD patients (e.g., Zgaljardic et al., 2003), greater variability in responding was expected for emotional pictures.

Finally, we were interested in whether emotional stimuli would affect MT or DT in the healthy aging process, an area that has received little attention in the literature thus far. There is some evidence to suggest that older adults exhibit slower response times than do younger adults; however, less is known regarding the effect of emotional stimuli on MT and DT in healthy aging. We predicted that older adults would demonstrate slower DTs and MTs in response to the images.

METHODS

Participants

Participants included 16 (8 male, 8 female) younger adults (*M* age = 27.06, *SD* = 3.91*),* 15 (8 male, 7 female) older adults (*M* age = 57.73, *SD* = 9.63), and 15 (9 male, 6 female) cognitively intact individuals with mild PD (*M* age = *61.7, SD = 11.1)*. PD patients were recruited from the Movement Disorders Clinic at the Mount Sinai Medical Center (MSMC). For the younger and older adults, students and employees of the MSMC in New York City were recruited via an IRB-approved posted flyer. In addition, spouses and/or caregivers of patients at the Movement Disorders Clinic at the MSMC were recruited for the study.

PD was diagnosed based on UK Brain Bank criteria (Hughes, Daniel, Kilford, & Lees, 1992), and patients were required to be on stable doses of dopaminergic therapy for at least 2 months; all PD participants were prescribed dopamine receptor agonists. The mean disease duration was 6.0 years (*SD* = 5.5), and the mean UPDRS motor score was 15.2. All participants were tested on medication.

Participants were required to meet the following inclusion criteria: over 18 years of age; healthy from a medical, neurological, and psychiatric perspective; and possessing the ability to understand and give informed consent. Participants were excluded based on the following criteria: presence of neurological (with the exception of PD) or psychiatric history as determined by responses to health questionnaires and self-report, cognitive deficits that might prevent giving informed consent or cooperation to the study as determined by a score less than 25 on the MMSE, and pharmacological treatment modulating beta-adrenergic and/or glucocorticoid system. The latter was included in the exclusion criteria because there is some evidence to suggest that pharmacological blockade of the beta-adrenergic and/or glucocorticoid system

results in memory impairments for emotional stimuli (Cahill, Prins, Weber, & McGaugh, 1994). To cover the cost of travel, participants were reimbursed $25 following the completion of each experimental session. IRB approval for this project was obtained from the Mount Sinai School of Medicine (MSSM).

Measures Administered

Cognitive Functioning

The Mini-Mental Status Exam (Cockrell & Folstein, 1988) was administered to all participants as a brief assessment of global cognitive functioning. This instrument examines several domains of cognitive functioning (i.e., orientation, attention, memory, executive functions, language, visuo-spatial ability, and construction) and was used to screen participants for cognitive dysfunction. We used a cutoff score of 25 (out of 30 points) to exclude participants with cognitive dysfunction.

Mood Symptoms

The Brief Patient Health Questionnaire (PHQ; Spitzer, Kroenke, Williams, & Group, 1999) is 15-item, self-administered, questionnaire that was used to determine the presence and frequency of depressive and anxiety symptoms over the past two weeks.

Disease Severity

Parts II, III, and IV of the UPDRS (Fahn et al., 1987) were administered to participants with PD by a trained neurologist. The overall purpose of the second component of the UPDRS was to assess whether complications related to PD interfered with the participant's daily functioning. The UPDRS-II consists of 17 items covering speech, swallowing, handwriting, dressing, and gait. The UPDRS-III is a 14-item motoric rating scale based on the clinical examination of motor symptoms such as tremor, rigidity, fine motor movements, gait, or postural

stability by the neurologist. The UPDRS-IV consists of eight items covering motor complications such as dyskinesias or motor fluctuations, which usually occur in later stages of disease progression.

Emotional Stimuli

Selected pictures from the International Affective Picture System (IAPS) were presented to each participant to elicit emotions. Picture selection was based on published self-ratings of valence and arousal for each picture (Lang, Bradley, & Cuthbert, 1998). Two series of 54 pictures (18 negative, 18 positive, and 18 neutral in each of the two sets) were chosen for the present experiment (see Appendix A). One series of pictures serves as encoding stimuli for each subject and are considered "old" pictures during the recognition phase. The other set of pictures serves as "new" pictures in the recognition phase.

Procedures

Overview

The study was comprised of two parts. During Part 1 of the study, participants viewed a series of emotional and neutral pictures taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert 2001) and made valence and arousal ratings of each picture. This was done for validity purposes to ensure participants were experiencing the pictures as intended (i.e., as positive, negative, and neutral). After a 10-minute delay (i.e., the "Retention Interval"), Part 2 of the study began. During this break, surface electrodes were attached to the participant's arm that was used to measure the time of first muscle contraction following the onset of the stimulus, which was termed decision time (DT). Again, during Part 2, participants viewed a series of emotional and neutral pictures from the IAPS, with half of the pictures comprised of the pictures for which they made valence and arousal ratings during Part 1 (termed "old") and half of

the pictures being pictures they had not been exposed to yet (termed "new"). Participants were instructed to press a button on the keyboard to indicate if each picture was a "new" or "old" picture. In addition to decision time, overall reaction time (RT) and movement time (MT) were measured. RT represented the time from picture onset to button press and was recorded automatically by the computer. MT represented the time from first muscle contraction to button press; this was calculated by subtracting DT from RT.

Part 1

Participants were greeted in the main lobby of the Mount Sinai Medical Center (1468 Madison Ave, New York, NY, 10029) and were taken to the examination room by the experimenter. Participants read and then signed a Mount Sinai School of Medicine Institutional Review Board approved informed consent document and an approved HIPAA form. Each participant enrolled in the study was given a copy of the signed and dated consent documents. As part of informed consent procedures, participants were given the opportunity to ask questions. Following informed consent, the participant's demographic information (i.e., name, age, sex, ethnicity, marital status, and education) and medical history (i.e., self-reported presence of medical, psychiatric, or neurological disorders and any medications) were obtained. The screening measures were then administered, and the UPDRS was administered to PD participants.

Participants were told that they would view a series of slides differing in emotional content. They were asked to attend to the slide for the entire exposure time (6s), to perform valence and arousal ratings after each trial and to relax during the inter-slide interval (10s). Valence (pleasant/unpleasant) and arousal (high/low) ratings for each picture were obtained separately by using a paper–and-pencil version of the Self-Assessment Manikin (SAM) rating system (Bradley & Lang, 1994). The valence dimension depicted a figure that ranged from

happy to *unhappy*. The corresponding SAM figures ranged from *smiling with raised eyebrows* to *frowning with knitted eyebrows*. The arousal dimension ranged from *excited* to *calm*. The corresponding SAM figures ranged from *having an active body and eyes wide open* to *having an inactive body and closed eyes.* Ratings were made by placing an *X* on or between any of the figures marked for valence and arousal level, producing a scale that ranged from 1 to 9. As previously stated, experiential ratings were obtained for validity purposes. No mention of a memory test was given at this time.

Picture onset was indicated by a fixation cue (asterisk) appearing in the middle of the screen for 4s. Digitized versions of the IAPS pictures were displayed on a PC screen (19-in./48.3 cm.), situated approximately 0.5 m from the participant. Presentation of stimuli was controlled by a Digital Equipment Corporation model 11/23 and an IBM computer. The timing of the picture presentation duration was preprogrammed using Visual Basic software. Five practice trials were administered to familiarize the participant with the rating procedure, which took approximately four minutes. Participants were then given the opportunity to ask questions and if necessary, a second series of 5 practice trials was administered to make certain the participants understood the directions. During the test trials, a series of 54 pictures (18 pleasant, 18 unpleasant, and 18 neutral) was presented to each participant in one of two varied orders (i.e., versions A and B); 50% of participants in each group viewed version A, and 50% viewed version B. The order in which pictures were presented was randomized for each participant. The experimenter was seated next to the participant with his or her back to the computer screen, thus the experimenter was unable to view the pictures presented to the participant. This seating arrangement was to ensure that the participant's rating was not influenced by the presence of the examiner. Following the rating made by the participant for each picture, the experimenter

removed the experiential rating sheet and numbered it. These testing trials took approximately 18 minutes.

Retention Interval

Participants were given a 10-minute break. During this time, the surface EMG electrodes were attached to the forearm extensors with a pair of disposable surface electrodes (Ag/AgCl) placed 2 cm apart on the dorsal aspect of the forearm. The proximal electrode was placed one-quarter the distance between the elbow and the wrist, more proximal to the elbow. The distal electrode was placed 2 cm below the first along the same line. A ground electrode was placed on the upper arm. The signal was amplified (Differential Amplifier MDA/2, BAK Electronics, Inc., Germantown, MD) with a 1K gain, filtered (bandpass 10 Hz to 10 kHz), digitized at 2.5 kHz (Micro 1401, Cambridge Electronic Design, Cambridge, UK), and stored in a laboratory computer for offline analysis.

Part 2

The participants, again, were seated in front of the computer monitor with their dominant hand resting comfortably on a predetermined spot on the table. This spot was clearly marked to ensure that the participant returned to the same spot following each trial. Again, the experimenter was seated next to the participant without being able to observe the picture presentation. Two response buttons were fixed on the keyboard. One button was labeled "O" and the other "N". The participant was instructed that another series of slides would be viewed and that he or she had to decide whether he or she had seen the picture earlier during the first part of the experiment by pushing one of two possible response buttons. If the picture had been seen before (old or repeated slide), he or she was told to press the button labeled "O" for "old." If he or she had not seen the slide previously (new slide), the participant was told to press the button

labeled “N” for “new.” Participants were instructed to briskly lift their arm in response to the stimulus and to press the button indicating their response choice. Participants were asked to keep the arm rested as much as possible between each picture presentation. Both speed and accuracy were emphasized in the instructions. Five practice trials were administered to familiarize the participant with the test trials. Participants were given the opportunity to ask questions regarding the procedure following the practice trials.

Picture onset was indicated by a fixation cue (asterisk) appearing in the middle of the screen for 4s. Each picture was presented for 6s followed by the fixation cue. Pictures during Part 2 were comprised of the same 54 pictures from Part 1 in addition to 54 new slides (18 negative, 18 neutral, and 18 positive), giving a total of 108 pictures. The pictures were, again, presented in a randomized order. After making the recognition decision, there was an inter-trial interval of 3 seconds, where the screen remained blank before the next slide was shown. The overall duration of the Part 2 was 4 minutes for the training trials and 18 minutes for the testing trials.

RESULTS

Data Preparation

Only accurate trials were included in the analyses; all three groups were highly accurate in distinguishing old pictures from new pictures (YC $M = 98\%$; OC $M = 95\%$; PD $M = 92\%$) Previous research suggests that extremely slow and fast reaction times may indicate erroneous responding, thus these outliers were excluded from our statistical analyses. Based on previous research, RTs less than 100 ms were eliminated (Whelan, 2008). We then computed *z*-scores for each participant, based on his or her mean RT, and eliminated all RTs with *z*-scores equal to or greater than +/-3.00.

Normality Testing

The Shapiro-Wilk test (Field, 2005) was conducted on the mean and standard deviations of DTs and MTs for each participant group (i.e., PD, OC, and YC) to examine the distributions of our data. Results demonstrated that for the YC group, the standard deviation of MT was not normally distributed ($p = 0.023$). See Table 1. For the PD group, the mean MT ($p < 0.001$) and the standard deviation of MT ($p < 0.001$) were not normally distributed. In addition, we examined the distribution of the response measures (i.e., DT and MT) for each valence and arousal category. This examination of the data yielded more significant results (see Table 1). Thus, we transformed the raw scores to their logs (log base 10) and, again, conducted the Shapiro-Wilk test on the log-transformed data. As seen in Table 2, the mean DT and mean MT, as well as the standard deviation of MT and DT, were normally distributed among the YC group. However, for the OC group the standard deviation of DT was significant ($p = 0.004$). In addition, the mean DT ($p = 0.004$), standard deviation of DT ($p = 0.000$), and standard deviation

of MT (p = 0.000) for the PD group were significant. Again, when the each response measure was analyzed by valence and arousal levels, there were even more significant results (Table 2).

As the log10 transformation failed to normalize the data, the raw scores were computed into their natural log (ln) and square roots, and retested for normality. Results of the Shapiro-Wilk remained significant for several variables (See Table 2). Thus, as a number of our variables deviated from the normal curve, nonparametric tests (i.e., Kruskal-Wallis; Kruskal & Wallis, 1952) were conducted to ascertain whether there were group differences in the DT and MT in response to emotionally laden images. The Kruskal-Wallis test was also conducted to examine the variability in responding among groups in response to the IAPS.

Demographic Variables

We wanted to ensure that the PD and OC groups did not significantly differ with respect to age as this variable has been shown to affect response time (Salthouse, 2000) and emotion processing (Mather et al., 2004; Smith, Hillman, & Duley, 2005). Furthermore, as an aspect of this study examines the effect of age on emotion processing, we wanted to ensure that the OC group was significantly older than the YC group. Depression and anxiety might affect emotion (Etkin, in press) and cognitive processing, as well as movement speed. In order to determine whether there were group differences with respect to age, level of education, and on screening measures of depression and anxiety, we performed one-way ANOVAs on each demographic variable.

Results are presented in Table 3. As expected, the YC group was significantly younger than both the OC and PD groups; however, the OC and PD groups did not differ significantly with respect to age (see Table 4). There were no significant group differences with respect to the MMSE score, symptoms of anxiety endorsed on the PhQ (PhQ-A), or MDQ scores (Table 3).

However, as can be seen in Table 4, the PD group endorsed significantly more symptoms of depression than both the YC and OC groups on the PhQ (PhQ-D).

Inspection of the PhQ-D items indicated that the PD group (M = 5.87, SD = 6.13) had symptoms of mild depression (Kroenke & Spitzer, 2002) and their scores were not indicative of clinical depression. The means for the YC (M = 1.25, SD 1.61) and OC groups (M = 1.93, SD = 2.05) were in the range of minimal depression. Inspection of individual participants' responses on the PhQ-D revealed that one YC and two OCs scored in the mild range. In the PD group, four scored in the mild range, one in the moderate range, and one in the severely depressed range.

Given that one of the characteristics of depression is slowed cognitive processing, as well as the fact that numerous studies have demonstrated that depression can affect one's processing of emotional stimuli (e.g., Ritchey, Dolcos, Eddington, Strauman, & Cabeza, 2011), we repeated the analyses outlined above excluding individuals with scores on the PhQ-D of 10 or greater. We chose this cut-off score for two reasons: 1) individuals with scores lower than 10 are characterized as having minimal to mild depressive symptoms (Kroenke & Spitzer, 2002), 2) research suggests that individuals with symptoms of only mild depression do not exhibit significantly slowed cognitive processing speed (Albert, Bear-Lehman, & Burkhardt, 2012). Using this cut-off score, three individuals, whose scores were 10, 17, and 21, were eliminated from the PD group; there were no participants in the OC group with a score on the PhQ-D of 10 or greater. When scores on the PhQ-D were compared, there were no significant differences between the OC group (M = 1.93, SD = 2.05*)* and the PD group (M = 3.33, SD = 2.67) when the three individuals with greater depressive symptomatology were eliminated, t (25) = -1.54, p = *0.136*.

The Effect of Emotion on the DT and MT in Parkinson's Disease

This series of analyses were performed in order to examine how emotional stimuli affect the rate and variability of response time (i.e., DT and MT) in PD. Separate Kruskal-Wallis ANOVAs were conducted using DT and MT means and standard deviations of each response time as the dependent variables. For each analysis, Group (OC and PD) was a between-subjects factor and Stimulus Type (positive, negative, and neutral) was a with-in subjects factor.

Decision Time (DT)

All participants. This first set of analyses examines group differences in DT with every participant, regardless of depressive symptomatology. A total of eight one-way Kruskal-Wallis ANOVAs were conducted. First, we conducted a series of ANOVAs using the mean DT; we examined differences in overall DT (i.e., all pictures combined), as well as differences in mean DT for negative, neutral, and positive images. The same four analyses were run using the standard deviation of DT. Please refer to Table 5 for a summary of these findings.

There was a significant main effect of group for mean DT ($p = 0.003$), such that PD ($M = 1.3809$) participants had slower DTs than the OC participants ($M = 1.0337$). The PD group had significantly longer mean DTs for negative ($p = 0.005$), neutral ($p = 0.001$), and positive ($p = 0.005$) images than their demographically matched control group.

When examining the variability of DT on emotional images, a similar pattern of results emerged. The PD group demonstrated significantly greater variability in responding compared to the healthy OC group when examining the overall DT ($p = 0.014$). In addition, the DT of the PD group is more variable on negative ($p = 0.033$), neutral ($p = 0.007$), and positive ($p = 0.021$) pictures.

Excluding individuals with PhQ-D scores of ≥10. Overall, the findings of these one-way Kruskal-Wallis ANOVAs mirror the results of the analyses conducted including all of the participants with slower and more variable DTs among the PD group relative to the OC group. A summary of these results can be found in Table 6.

In sum, the PD group demonstrated significantly slower DTs, regardless of the valence of the image. Separate analyses were conducted to eliminate the possible confound of depression on DT; although formal analyses were not conducted to compare the PD group with and without the depressed participants, examination of the data provides some information about the influence of depression on DT in this sample. Of note, the mean DT was slightly faster when depressed individuals were excluded from the PD group; however, the participants with PD remained significantly slower than the OC group. In addition, the PD group demonstrated significantly more variability in DT than the OC group, even when depressed individuals were excluded.

Movement Time (MT)

All participants. This set of analyses investigated group differences in MT; analyses were conducted with every participant, regardless of depressive symptomology. Again, a total of eight one-way Kruskal-Wallis ANOVAs were conducted. First, we ran four one-way Kruskal-Wallis ANOVAs using the mean MT; we examined group differences in overall MT (i.e., all pictures combined), as well as differences in MT for negative, neutral, and positive pictures. The same four analyses were conducted using the standard deviation of MT. Please refer to Table 7 for a summary of these findings.

In contrast to results comparing PD and OC groups on DT, the mean MT for the PD group was not significantly different than the mean MT for the comparison group ($p = 0.130$).

Analyses of mean MT by valence category revealed a significant group difference for neutral images ($p = 0.021$), such that the PD group had a longer MT than did the OC group; however, there were no group differences in mean MT for negative ($p = 0.237$) or positive ($p = 0.110$) pictures.

Analysis of the standard deviation of MT revealed similar findings; however, there was a trend toward significance for the overall standard deviation of MT ($p = 0.085$), with the PD group exhibiting more variability than the demographically-matched controls. Analysis of the standard deviation of MT for neutral images was significant ($p = 0.026$), with greater variability among the PD group than the among OC group. The group differences in variability on negative ($p = 0.206$) and positive ($p = 0.254$) pictures were not significant.

Excluding individuals with PhQ-D scores of ≥10. As depression can also slow one's movements (Sachdev & Aniss, 1994), we conducted a separate set of analyses excluding individuals with PhQ-D scores of 10 or greater, as detailed above. A summary of these findings can be found in Table 8.

Interestingly, by excluding individuals with considerable depressive symptomatology, group differences on mean MT emerged. For mean MT, the PD group demonstrated significantly longer mean MT than demographically-matched controls ($p = 0.032$). The difference in mean MT between the PD and OC groups for neutral ($p = 0.002$) and positive ($p = 0.032$) images was also significant, with the PD group exhibiting longer mean MT than the OC group.

Examination of the standard deviation of MT revealed a trend toward significance ($p = 0.071$) for overall MT, as PD participants demonstrated more variable MTs. There was a significant group difference on neutral pictures ($p = 0.015$), again as the PD group demonstrated

greater variability in responding. The group difference in variability on negative ($p = 0.223$) and positive ($p = 0.118$) pictures was not significant between the PD and OC groups.

In general, the PD group did not demonstrate slower or more variable MTs in response to emotionally laden stimuli than the OC group. Thus, there were fewer significant findings when examining MT than DT. Another interesting finding is that when participants with moderate to severe depressive symptoms were excluded, the differences in MT between the PD group and demographically matched controls was exaggerated and yielded more significant results.

Emotional Experience in Parkinson's Disease

To investigate whether there are differences in the experience of emotion between individuals with PD and healthy older adults, we compared the mean valence and arousal ratings for the pictures. For valence ratings, we compared the mean valence rating for positive, negative, and neutral pictures between the PD and OC groups. For arousal ratings, we compared the mean arousal ratings for high and low arousal pictures. We were also interested in whether the PD group's valence and arousal ratings were more variable than the OC group. Thus, we compared the standard deviation for the valence and arousal ratings. A total of eight one-way Kruskal-Wallis ANOVAs were conducted to examine the valence and arousal ratings. For each analysis, Group (OC and PD) was a between-subjects factor and Valence (positive, negative, and neutral) or Arousal (low, high) was a within-subjects factor; valence categories and arousal levels were examined with separate analyses.

To ensure that any potential group differences in valence and arousal ratings could not be attributed to depression, the analyses were initially conducted with all participants and then again without individuals who scored in the moderate to severe range of depression (i.e., $\geq$10) on the PhQ-D.

Valence Ratings

All participants. Results revealed that although the PD group (M = 6.8400) tended to rate the positive pictures as slightly less positive than the OC group (M = 7.1926), the difference was not significant (p = 0.618). For the neutral images, the mean valence ratings were very similar between the PD (M = 5.44) and OC (M = 5.33) groups and were not significant (p = 0.560). However, there was a significant difference with respect to the valence rating for negative images (p = 0.040), such that the PD group rated the negative pictures as being less negative than the OC group (M = 3.4791, M = 2.6889, respectively).

Regarding the variability of the valence ratings for the emotional stimuli, the group differences were not significant for the negative (p = 0.213), neutral (p = 0.678), or positive (p = 0.901) pictures.

Excluding individuals with PhQ-D scores of ≥10. Inspection of the valence ratings when individuals with PhQ-D scores of 10 or greater were excluded revealed that the mean valence rating for negative images was slightly more negative than when all participants were included in the analysis. Thus, the significant difference in valence ratings between the PD and OC groups for negative images was reduced to a trend (p = 0.079) when the depressed PD participants were excluded from the analysis. The mean valence rating for positive images when the depressed individuals were excluded was also slightly more positive and thus, more similar to the valence rating of the OC group. Therefore, there was no significant difference in the valence rating of positive images between the PD and OC groups (p = 0.942) when the depressed individuals were excluded. The mean valence rating for neutral images was also not significant between groups (p = 0.541).

With respect to the variability of the valence ratings for the emotional stimuli, the group differences were not significant for the negative (p = 0.107), neutral (p = 0.903), or positive (p = 0.575) pictures when the depressed individuals were excluded.

In sum, when depressed individuals were excluded from the analyses, the PD group rated the negative, neutral, and positive images more similarly to the OC group. In addition, as a group, the PD participants were not more variable in their valence ratings of the emotional stimuli. A summary of these results can be found in Table 9.

Arousal Ratings

All participants. The mean arousal rating for low arousal pictures in the PD group (M = 3.5723) was slightly higher than the OC group (M = 2.9312); however, the difference was not significant (p = 0.229). For high arousal images, the mean arousal rating in the PD group (M = 4.7966) was also slightly higher than the OC group (M = 4.1931); again, this difference was not significant (p = 0.102).

Regarding the variability in arousal ratings for the low arousal pictures, the PD and OC groups were not significantly different (p = 0.585). Neither were group differences apparent on high arousal images (p = 0.965).

Thus, PD participants' subjective level of arousal was comparable for both low and high arousal images when compared to age-matched controls. In addition, their ratings were not more variable than the OC group.

Excluding individuals with PhQ-D scores of ≥10. When the analyses were conducted excluding individuals with more severe depressive symptoms (i.e., PhQ-D ≤ 10), the mean arousal ratings of the PD group for the low arousal pictures was slightly higher than when all participants were included in the analyses. However, the difference in arousal ratings for the PD

group without the depressed individuals was not significantly different than the arousal rating of the OC group ($p = 0.226$). In contrast, the difference in arousal ratings between the PD and OC groups for high arousal pictures was significant ($p = 0.051$), as the PD group rated the high arousal pictures as more highly arousing than the OC group.

Group differences in the variability of arousal ratings for low and high arousal images were not significant ($p = 0.269$, $p = 0.837$, respectively) when the individuals with more severe depressive symptoms were omitted from the analyses.

Overall, the differences in valence and arousal ratings were similar between the PD and OC groups. However, the PD group rated the negative images as being less negative than the OC group. When the depressed participants were eliminated from the analyses, the PD group rated the high arousal images as more arousing than did the OC group. The variability in valence and arousal ratings was not significantly different between the PD group and the OC group. Results are summarized in Table 10.

Age Differences In Emotion Processing

We conducted separate analyses comparing the performance of younger adults and older adults to examine potential age differences in the effect of emotional stimuli on decision time and movement time. Thus, Kruskal-Wallis ANOVAs were conducted using the mean, as well as the standard deviation of each response measure. For each Kruskal-Wallis ANOVA, Group (YC and OC) was a between-subjects factor and Stimulus Type (positive, negative, and neutral) was a with-in subjects factor; separate analyses were conducted for each valence category. Mean DT, mean MT, the standard deviation of DT, and the standard deviation of MT was analyzed separately; this permitted us to not only investigate age differences in the time of response, but also whether one group exhibited more variability in responding. Given that none of the

participants in the YC group or the OC group had a PhQ-D score of 10 or greater, all participants were included in all analyses.

Decision Time (DT)

Eight one-way Kruskal-Wallis ANOVAs were conducted (see Table 11). Four of these ANOVAs used the mean DT when comparing overall DT (i.e., all pictures combined), as well as differences in mean DT for negative, neutral, and positive pictures. These same four analyses were repeated using the standard deviation of DT.

Results revealed a significant main effect of group for mean DT ($p = 0.033$), such that the OC participants had longer DTs than the YC participants. Significant findings were also evident when examining the DT for each valence category. For negative ($p = 0.053$), neutral ($p = 0.036$), and positive ($p = 0.044$) images, the older adults had significantly slower DTs than the YC group. Examination of the variability of DT in response to the IAPS did not yield any significant results.

In sum, the older adults demonstrated significantly longer DTs in response to the stimuli for all valence groups. The variability in responding to the images was similar between groups.

Movement Time (MT)

This set of analyses investigated group differences in MT in response to the emotional stimuli. Again, eight one-way Kruskal-Wallis ANOVAs were conducted with four ANOVAs using the mean MT and four ANOVAs using the standard deviation of MT. For all analyses, we examined differences in overall MT (i.e., all pictures combined), as well as differences in MT for negative, neutral, and positive pictures. These findings are summarized in Table 12.

Unlike the results for mean DT, the mean MT for the OC group was not significantly slower than the mean MT for the YC group ($p = 0.323$). The mean MT for negative ($p = 0.155$),

neutral (p = 0.453), and positive pictures (p = 0.385) was not significantly different between groups.

Similar findings were evident when examining the variability in MT. The standard deviation for MT for the OC and YC groups was not significantly different (p = 0.693). In addition, group differences were not evident with respect to the standard deviation of MT for negative (p = 0.192), neutral (p = 0.813), or positive (p = 0.363) stimuli.

Thus, although the OC group demonstrated significantly longer DTs when compared to the YC, these group differences were not evident in MT. In addition, the OC group did not demonstrate more variable response times for DT or MT relative to the YC group.

Age Effects in Emotional Experience

To determine whether emotional experience is disrupted in healthy aging, we compared the mean valence and arousal ratings of younger and older adults for the pictures, as well as the standard deviation for the valence and arousal ratings. A total of eight one-way Kruskal-Wallis ANOVAs were conducted to examine the valence and arousal ratings. For each analysis, Group (OC and YC) was a between-subjects factor and Valence (positive, negative, and neutral) or Arousal (low, high) was a within-subjects factor; valence and arousal ratings were examined separately. Separate analyses were conducted for each valence and arousal category.

Valence Ratings

Table 13 summarizes the findings. Results revealed that although the OC group tended to rate the negative pictures as slightly more negative than the YC group (M = 2.6889, M = 3.0313, respectively), the difference was not significant (p = 0.178). In addition, the OC group (M = 7.1926) tended to rate the positive images as more positive than the YC group (M =

6.8924), but again, this difference was not significant (0.243). For the neutral images, the mean valence ratings were very similar between both groups and thus was not significant ($p = 0.781$).

Regarding the variability of the valence ratings for the emotional stimuli, the group differences were not significant for the negative ($p = 0.692$), neutral ($p = 0.144$), or positive ($p = 0.722$) pictures.

Arousal Ratings

The mean arousal ratings for low arousal pictures in the OC and YC groups were very similar and therefore the difference between groups was not significant ($p = 0.441$). Similarly, the ratings for high arousal pictures were not significantly different between the OC and YC groups ($p = 0.771$). In addition, the variability in arousal ratings for low arousal and high arousal images were not significant between groups. A summary of these findings is provided in Table 14.

Overall, the older adults and the younger adults do not demonstrate differences in emotional experience in response to the affective stimuli.

DISCUSSION

Summary

The current study examined whether emotional stimuli affected cognitive (i.e., decision time) and/or the motor aspects (i.e., movement time) of reaction time in healthy aging and in mild PD. Examining this effect on the components of reaction time has received little attention in the literature. For both decision time and movement time, we were interested in differences in the speed and variability in responding. Of note, the PD group reported more depressive symptomatology than the OC group, with three out of 15 individuals endorsing symptoms in the moderate and severe ranges on the PhQ-D. As depression can affect emotion and the speed of cognitive processing, analyses were repeated excluding individuals with scores in the moderate or severe range of depressive symptomatology. In our study, some differences were evident when these individuals with more severe symptoms of depression were excluded from the analyses; these differences are discussed below. None of the participants in the OC group or YC group had depression scores in the moderate or severe ranges.

We predicted that PD participants would have significantly slower and more variable MTs and DTs relative to age-matched controls, especially for affective stimuli. Examination of decision and movement times revealed that the PD group exhibited significantly longer and more variable DTs than older controls for all valence categories; however, only the MTs for negative and neutral images were significantly different or more variable between groups. We hypothesized that valence ratings would be similar between the PD and OC groups, but that the PD patients would rate high arousing pictures as less arousing relative to demographically-matched older adults. However, in this study individuals with PD rated negative pictures as less negative than did healthy older adults; this significant difference was reduced to a trend when the

depressed individuals were excluded from the analysis. In addition, high arousal images were rated as more highly arousing among the PD group when depressed individuals were not included in the analyses.

Our data also revealed that the DTs were longer for the OC group relative to the YC group, whereas group differences were not evident in MTs. In addition, our findings suggest that emotional experience is not disrupted by the normal aging process, as self-reported valence and arousal ratings were not significantly different between younger and older adults.

Emotion Processing in Parkinson's Disease

Studies of patients with neurological disorders of the basal ganglia (Sprengelmeyer et al., 1996) and healthy controls (Kotz et al., 2003) suggest a role for the basal ganglia in emotion processing. Thus, one would expect emotion processing deficits in PD. In fact, studies have demonstrated that PD patients are less expressive (for review, see Zgaljardic, Borod, Foldi, & Mattis, 2003), have trouble recognizing facial expressions (Borod, Welkowitz, et al., 1990; Dujardin et al., 2004) and emotional prosody (Breitenstein, Van Lancker, Daum, & Waters 2001), and often have symptoms of depression (Mayeux, Stern, Rosen, & Leventhal, 1981; Raskin, Borod, & Tweedy, 1990). Although a number of studies have not demonstrated disruptions in the experience of emotion in the PD population, this area has not been evaluated as extensively as the topics of emotional expression and perception (for review, see Zgaljardic, Borod, Foldi, & Mattis, 2003).

Results of the Effect of Emotion on the Components of Reaction Time

Decision time. Regardless of depressive symptomatology, the PD group consistently demonstrated significantly slower DTs than did the OC group, consistent with our hypothesis. Significant group differences were evident for overall DT, as well as the DTs for negative,

neutral, and positive pictures, with the PD group having slower DTs than did the OC group. These findings are consistent with results of other studies demonstrating slowed cognitive processing in PD (e.g., Jordan, Sagar, & Cooper, 1992). As predicted, compared to the demographically-matched older adults, the PD group also demonstrated significantly more variable DTs in response to the images. Greater variability in responding was evident for negative, neutral, and positive images; these differences were present even when those with greater depressive symptomatology were excluded from the analyses. As the analyses excluding the individuals with high depressive symptomatology yielded similar results as when all participants were included in the analyses, the slowed cognitive processing evident in the PD group cannot be attributed to depression alone. In addition, as group differences were present in response to neutral and emotional stimuli, our findings do not suggest that affective stimuli differentially impact DT in our PD sample.

Using structural MRI to examine differences in cortical and subcortical volume between PD participants and demographically-matched controls, Tinaz, Courtney, and Stern (2011) found evidence of significant cortical thinning in several structures within the ventral prefrontal and parietal cortices and the putamen among early-stage Parkinson's patients relative to healthy controls. The putamen is a structure that has been shown to have a role in processing speed (Ystad, et al., 2011). This suggests that Tinaz and colleagues' evidence of cognitive processing deficits present early in the disease course, along with similar findings of a decision time deficit in our sample, may be attributable to cortical and subcortical atrophy in PD.

Movement time. We predicted that the PD group would demonstrate significantly slower MTs compared to the OC group. However, contrary to our hypothesis on this reaction time task, the PD group did not exhibit significantly slower MTs in response to the negative or positive

stimuli when all participants were included in the analyses. On the contrary, the PD group's MT for only neutral images was significantly slower than the OC group. Similarly, a group difference in variability of MT for neutral images was present, with the PD group displaying more variable MTs than the OC group. The PD and OC groups demonstrated similar variability in response to the negative and positive images.

There is some evidence suggesting that emotion may improve motor functioning in PD. For example, music therapy has been shown to improve motor functioning in PD (Pacchetti et al., 1998). The influence of affective stimuli on motor functions may be related to the activation of the dopaminergic system, which has been shown to be involved in emotion processing. A study examining how music affects the dopaminergic pathway revealed that music leads to increased calcium-dependent DA synthesis in the brain (Sutoo & Akiyama, 2004).

When the analyses were repeated excluding the depressed individuals in the PD sample, group differences for MT for positive pictures emerged, such that PD participants had longer MTs than the control group. The group effect for neutral images remained.

Results of Emotional Experience in PD

Our participants rated the valence and arousal level of each image. In order to ascertain whether PD affects the experience of emotion, we compared the ratings of the PD and OC groups using Kruskal-Wallis ANOVAs. Separate ANOVAs were conducted for each valence and arousal category.

Valence ratings. With respect to valence ratings, the PD group tended to rate the negative images as less negative and the positive pictures as less positive than did the OC group; however, group differences in ratings were significant for only the negative images. The valence ratings for neutral images were nearly identical between the PD group and the OC sample.

When the depressed participants were excluded from the analyses, the significant group difference for negative pictures was reduced to a trend. This suggests that the PD group tends to experience the negative images as less negative than does the OC group and that depression exaggerates this finding. Regardless of symptoms of depression, there were no group differences in the variability of valence ratings.

We did not expect to find any group differences in the valence ratings of the emotional stimuli given several previous studies indicating intact emotional experience in PD (e.g., Smith, Smith, & Ellgring, 1996). In our study, the valence ratings in the PD group were more toward the middle of the scale as the negative images were viewed as less negative; as previously stated, the rating for the positive images was less positive, though not significant. Our results are in line with findings from the study by Hillier, Beversdorf, Raymer, Williamson, and Heilman (2007) who found that PD participants tended to rate emotional words toward the middle of the Likert scale (i.e., further away from the positive and negative extremes of the scale), suggestive of emotional blunting in the PD group.

There is some evidence suggesting that positive and negative emotions are processed by different regions in the striatum. Badgaiyan (2010) demonstrated release of dopamine in the dorsal, but not ventral, striatum when healthy adults viewed negative words; this finding is consistent with those from other studies illustrating dorsal striatum activation in response to negative emotions, such as sadness (George, Ketter, Parekh, Horwitz, Herscovitch, & Post, 1995).

The dorsal striatum receives dopaminergic input from the substantia nigra (SN), while the ventral striatum receives input from the ventral tegmental area (VTA). In PD, cellular loss in the SN is greater than cell loss in VTA; therefore, dopamine-deficiency is significantly greater in

dorsal compared to ventral striatum, possibly resulting in a decreased ability to experience negative emotion.

Arousal ratings. When all participants were included in the analyses, the PD group and the OC group did not differ with respect to arousal ratings for high or low arousal images. However, when the depressed individuals were excluded from the analyses, the PD group rated the high arousal pictures as more arousing than did the OC group. Regardless of depressive symptomatology, there was no difference with respect to the variability of the arousal ratings between the groups.

The finding that PD participants rated the high arousal images as more highly arousing than the OC participants is the opposite of what we predicted, as we expected the PD participants to rate the high arousal images as less arousing than did the OC group. Although not significantly different, the mean arousal rating for low arousal pictures for the PD group was greater than that for the OC group. Thus, our sample of individuals with PD found these images to be more arousing than did the control group.

Smith, Smith, and Ellgring (1996) found that participants with mild and moderate PD rated pictures from the IAPS as more intense than did healthy age-matched controls, although this may be partially attributed to depression. As the finding of increased arousal levels for high arousal images did not emerge until the depressed individuals were excluded from the analyses, our results cannot be attributed to depression. Rather, it seems that depression may dampen arousal levels in our PD sample.

The Pathology of PD and How It Relates To Reaction Time

Although Naville described cognitive slowing among Parkinson's patients in 1922 (Zimmerman, Sprengelmeyer, Fimm, & Wallesch, 1992), cognitive slowing exhibited in patients

with PD has been somewhat controversial, as studies examining cognitive processing often involve procedures that require a motor response. As PD is characterized by bradykinesia, it is difficult to ascertain whether impaired performance on cognitive processing tasks requiring a motor response is due to slowed cognitive processing or to slowed movement. Our study is unique in that although a motor response is required, the participant's decision time is measured from picture onset to first muscle contraction. Thus, we are able to capture a response time *before* the motor response.

As stated above, all of the DTs for the PD group were significantly longer than those for the OC group in response to the IAPS. In contrast, the MTs for neutral and positive stimuli were significantly different between groups, especially when depressed individuals were omitted from the analyses. Our findings suggest that although some studies have found that motor and cognitive slowing may be correlated (Sawamoto, Honda, Hanakawa, Fukuyama, & Shibasaki, 2002), these deficits may represent distinct phenomena in this population and are differentially affected by emotion.

Several hypotheses have been offered to explain the motor slowing that is characteristic of PD, such as muscle weakness, tremor, and rigidity (Barardelli, Rothwell, Thompson, & Hallett, 2001). Some studies suggest that the motor slowing is due to changes in the central nervous system that are responsible for initiating the instruction to move, rather than changes in the peripheral nervous system that performs the motor action. For instance, Pascual-Leone and colleagues (1994) demonstrated that the excitability in the motor cortex prior to the onset of movement is slower among individuals with PD and that the administration of transcranial magnetic stimulation to this region resulted in similar reaction times as those seen in the control group.

Significance of Variability

Intraindividual variability has been shown to be related to poorer cognitive performance (e.g., Hultsch, MacDonald, & Dixon, 2002) and poorer physical performance (e.g., Li, Aggen, Nesselroade, & Baltes, 2001). Increased variability in responding has been shown to be associated with neurological dysfunction among several patient populations, including PD, Alzheimer's disease, and brain injury (Camicioli, Wieler, de Frias, & Martin, 2008; Gorus, De Raedt, Lambert, Lemper, & Mets, 2008) and may be indicative of poor prognosis (Bielak, Hultsch, Strauss, MacDonald, & Hunter, 2010). In our study, we found that the sample of patients with PD demonstrated more variable DTs relative to age-matched controls; only the MT for neutral pictures was more variable among the PD group. Of note, more variable response times were only evident when the PD group exhibited a significantly slower response time (i.e., if the SD of the response time was significant then so was the mean response time). Thus, providing further evidence that variability in responding is reflective of performance decline.

Emotion Processing in Healthy Aging

The healthy aging process also results in neurological changes leading one to expect changes in emotion processing; these changes include neuronal loss and atrophy in temporo-limbic regions (e.g., amygdala, hippocampus, and entorhinal cortex). Some studies have suggested that a positivity bias emerges with increasing age, such that there is increased attention to and better recall of positive events with age (Mather & Carstensen, 2003).

Results of the Effect of Emotion on the Components of Reaction Time in Healthy Aging

Decision time. As expected, the OC group demonstrated significantly slower DTs for negative, neutral, and positive images; however, their responses were not more variable than the YC group. These findings are consistent with other studies demonstrating longer processing

times for older adults. A common finding in the literature is that the difference in RT between the young and the old increases as cognitive processing demands are increased, suggesting that the slower response speed of elderly persons is mediated primarily by changes in the rate of mental processing (Bashore, Osman, & Heffley, 1989). Given that our study found slower DTs before a motor output was required, our findings provide further evidence for slowed mental processing that cannot be explained by slowed motor movements.

Although it has long been known that older adults are considerably slower than younger adults, there is no general agreement regarding the age that cognitive slowing begins (Salthouse, 2009). The mean age of our OC group was 57 years, thus suggesting that changes in cognitive processing speed are evident by the mid-50s.

Movement time. In our study, the OC group did not have significantly longer or more variable MTs than the YC group. While this finding appears to be in contrast to a large body of research demonstrating age-related motor slowing, some studies have failed to produce significant differences between younger and older adults on simple reaction time tasks (e.g., De Jong, Kok, & Van Rooy, 1989; Yordanove, Kolev, Hohnsbein, & Falkenstein, 2004). Our study indicates that significant motor differences are not detectable on simple and short-distanced movements among healthy individuals in their mid-50s.

Results of Emotional Experience in Healthy Aging

Although the OC group rated the negative pictures as slightly more negative and the positive pictures as more positive than did the YC group, the differences in valence ratings between groups were not significant. Group differences were not apparent for arousal ratings. Thus, our study does not provide evidence for age-related changes in emotional experience, as we predicted. These findings are consistent with other studies that have failed to find age-related

differences in valence and arousal ratings for pictures (Charles, Mather, & Carstensen, 2003; Denburg, Buchanen, Tranel, & Adolohs, 2003; Weiser, Muhlberger, Kenntner-Malbiala, & Paul, 2006b).

Central slowing -- a reason for motor slowing?

Differential results regarding age-related motor slowing have been attributed to task complexity, such that behavioral slowing increases with more difficult tasks (Kok, 2000). Recent literature also suggests that age-related motor slowing can, at least in part, be accounted for by slowing of components of the central nervous system (i.e., cognitive processing speed [Krampe, 2002]). Falkenstein, Yordanova, and Kotev (2006) demonstrated that on a four-choice reaction task older adults demonstrated a delayed response in the motor cortex resulting in slowed perceptual processing. Results from our study are consistent with this theory of central processing deficits, as evidenced by group differences on DT, but not MT.

Cortical Reorganization and Healthy Aging

Studies have demonstrated that older adults activate different cortical networks during tests of cognition (Cabeza, 2002) and emotional perception (Finely & Borod, 2008). For instance, older adults have been shown to demonstrate less activation in limbic areas than younger adults during an emotion discrimination task (Gunning-Dixon, 2003). Other studies have demonstrated that for a variety of cognitive abilities (e.g., executive function, autobiographical memory, and motor control), older adults exhibit overactivation of the brain regions involved in the cognitive function when compared to younger adults (Reuter-Lorenz & Lustig, 2005).

It is possible that this cortical reorganization is a compensatory mechanism for the neuronal loss resultant of the aging process. Reuter-Lorenz and Lustig (2005) reported that older

adults demonstrate bilateral activation of brain regions for tasks that show minimal decline due to age. These authors also indicate that overactivation of certain brain regions was evident among older adults who performed better on certain tasks.

Thus, although post-mortem studies have found age-associated neuronal loss and atrophy in brain regions involved in emotion processing leading one to conclude that older adults would demonstrate emotion processing impairments, the recruitment of additional brain regions may result in no obvious changes in emotion processing.

Implications

This study examined emotional processing in healthy aging and mild PD. By examining emotional processing in healthy aging, we are better able to differentiate between healthy and pathological aging. Given that emotional processing deficits are associated with diminished quality of life, improved understanding of these deficits may lead to alternative treatment approaches.

Our findings support previous research that emotional arousal may benefit motor functioning in PD, as evidenced by similar movement times to emotional stimuli. This finding in conjunction with other studies that have suggested that music may benefit the motor functioning of individuals with PD may lead clinicians to recommend and/or develop alternative treatments for individuals with PD, such as dance therapy.

In our study, the PD group was often significantly more variable than the older adults. However, the older adults were never more variable than the younger adults. Previous research has also documented that variability is associated with neurological dysfunction. Perhaps variability may even be a predictor of neurological disorders.

Limitations

The materials and methods utilized in this study were based upon the methodology of other studies (Bradley & Lang, 1994), and with our sample size we found significant results. However, future studies should include a larger sample size in order to increase power. In addition, our data failed to normalize. A larger sample size may allow the data to better fit the assumptions about normality. Due to the non-normal distribution of our data, we employed nonparametric analyses, which only permitted us to compare one within-subject variable at a time.

Our PD group demonstrated significantly more depressive symptomatology than the OC group, resulting in the exclusion of additional subjects and further reduction in sample size and statistical power for some analyses. Although, results with and without the individuals with high depressive symptomatology were not significantly different for most of our analyses, in the future, control groups should be carefully matched in terms of baseline depression scores. Also, future studies may wish to investigate differential patterns between PD patients with and without depression.

Valence can affect how quickly one responds to a stimulus. Studies have demonstrated that negative stimuli have longer reaction times than do positive stimuli (Halbig et al., 2011; Stenberg, Wiking, & Dahl, 1998). Although we demonstrated that the PD group demonstrated longer and more variable DTs than did the OC group, unfortunately, the use of the Kruskal-Wallis ANOVA procedure does not permit us to include three within-subjects variables. Thus, we are unable to contribute to the literature regarding the differential effect of positive versus negative stimuli on response times.

To extend our findings future researchers may wish to examine whether discrete emotions, such as happiness, disgust, or fear, are differentially affected by PD.

Table 1. Summary of Normality Testing

	YC N = 16	**OC N = 15**	**PD N = 15**
Mean DT	0.8709	1.0404	1.3809
p-value	.242	.408	.773
Mean MT	.7466	.7952	1.0173
p-value	.966	.090	.000*
Standard Deviation DT	.2352	.2989	.5191
p-value	.165	.326	.490
Standard Deviation MT	.2086	.2348	.3569
p-value	.023*	.165	.000*
N**egative Valence**			
Mean DT	.9296	1.1077	1.4587
p-value	.138	.258	.340
Mean MT	.7538	.8344	1.0345
p-value	.688	.006	.000*
Standard Deviation DT	.2475	.3131	.5055
p-value	.039*	.369	.456
Standard Deviation MT	.1797	.2612	.3450
p-value	.029*	.010*	.000*
Neutral Valence			
Mean DT	.8251	.9873	1.3519
p-value	.289	.818	.743
Mean MT	.7455	.7492	.9794
p-value	.370	.225	.001*
Standard Deviation DT	.2001	.2588	.5222
p-value	.139	.014*	.224
Standard Deviation MT	.2203	.1767	.3181
p-value	.000*	.367	.000*
Positive Valence			
Mean DT	.8550	1.0254	1.3356
p-value	.084	.175	.293
Mean MT	.7404	.8046	1.0413
p-value	.603	.037*	.000*
Standard Deviation DT	.2177	.2901	.4972
p-value	.022*	.666	.134
Standard Deviation MT	.1691	.2301	.3758
p-value	.690	.082	.001*

Table 1. Summary of Normality Testing, continued (cont'd.)

Low Arousal	**YC N = 16**	**OC N = 15**	**PD N = 15**
Mean DT	.8564	1.0084	1.3208
p-value	.199	.250	.637
Mean MT	.7351	.7733	.9987
p-value	.844	.017*	.000*
Standard Deviation DT	.2318	.2805	.4617
p-value	.096	.574	.288
Standard Deviation MT	.2318	.2805	.4617
p-value	.008*	.230	.001*
High Arousal			
Mean DT	.8850	1.0737	1.4327
p-value	.267	.771	.720
Mean MT	.8850	1.0737	1.4327
p-value	.822	.035*	.000*
Standard Deviation DT	.2321	.3091	.5345
p-value	.173	.094	.177
Standard Deviation MT	.1999	.2500	.3824
p-value	.002*	.039*	.000*

*significant at the 0.05 level

Table 2. Summary of Normality Testing on Transformed Data

Log 10 Transformed Data			
	YC N = 16	**OC N = 15**	**PD N = 15**
Mean DT	-.0860	-.0061	.0678
p-value	.660	.648	.004*
Mean MT	-.1507	-.1201	-.0480
p-value	.730	.268	.156
Standard Deviation DT	.1017	.1185	.2065
p-value	.368	.004*	.000*
Standard Deviation MT	.0941	.1089	.1382
p-value	.246	.396	.000*
Negative Valence			
Mean DT	-.0611	.0212	.0932
p-value	.522	.516	.024*
Mean MT	-.1446	-.1027	-.0423
p-value	.727	.132	.220
Standard Deviation DT	.1039	.1090	.1882
p-value	.636	.741	.000*
Standard Deviation MT	.0898	.1145	.1369
p-value	.402	.464	.000*
Neutral Valence			
Mean DT	-.1037	-.0276	.0594
p-value	.372	.779	.009*
Mean MT	-.1572	-.1419	-.0570
p-value	.964	.776	.339
Standard Deviation DT	.0907	.1174	.1962
p-value	.636	.000*	.000*
Standard Deviation MT	.0945	.0953	.1277
p-value	.005*	.035*	.000*
Positive Valence			
Mean DT	-.0941	-.0122	.0517
p-value	.703	.297	.001*
Mean MT	-.1504	-.1151	-.0428
p-value	.293	.210	.122
Standard Deviation DT	.0999	.1093	.2116
p-value	.393	.999	.000*
Standard Deviation MT	.0860	.1071	.1417
p-value	.468	.063*	.000*

Table 2. Summary of Normality Testing on Transformed Data (cont'd.)

Low Arousal	**YC N = 16**	**OC N = 15**	**PD N = 15**
Mean DT	-.0937	-.0196	.0545
p-value	.434	.448	.006*
Mean MT	-.1578	-.1290	-.0523
p-value	.824	.107	.058
Standard Deviation DT	.1000	.1193	.2026
p-value	.041*	.000*	.000*
Standard Deviation MT	.0895	.1024	.1313
p-value	.208	.106	.000*
High Arousal			
Mean DT	-.0783	.0078	.0796
p-value	.824	.976	.003*
Mean MT	-.1434	-.1117	-.0439
p-value	.661	.226	.258
Standard Deviation DT	.1016	.1112	.1985
p-value	.960	.871	.000*
Standard Deviation MT	.0958	.1119	.1444
p-value	.067	.292	.000*
Ln Transformed Data			
	YC N = 16	**OC N = 15**	**PD N = 15**
Mean DT	-.1979	-.0140	.1561
p-value	.660	.648	.004
Mean MT	-.3470	-.2766	-.1105
p-value	.730	.268	.156
Standard Deviation DT	.2341	.2729	.4755
p-value	.368	.004	.000
Standard Deviation MT	.2166	.2507	.3183
p-value			
Negative Valence			
Mean DT	-.1406	.0489	.2145
p-value	.522	.516	.024
Mean MT	-.3329	-.2364	-.0973
p-value	.727	.132	.220
Standard Deviation DT	.2391	.2510	.4335
p-value	.636	.741	.000
Standard Deviation MT	.2068	.2637	.3152
p-value	.402	.464	.000

Table 2. Summary of Normality Testing on Transformed Data (cont'd.)

Neutral Valence	**YC N = 16**	**OC N = 15**	**PD N = 15**
Mean DT	-.2388	-.0636	.1368
p-value	.372	.779	.009
Mean MT	-.3619	-.3267	-.1312
p-value	.964	.776	.339
Standard Deviation DT	.2088	.2704	.4517
p-value	.636	.000	.000
Standard Deviation MT	.2175	.2195	.2939
p-value	.005	.035	.000
Positive Valence			
Mean DT	-.2166	-.0282	.1190
p-value	.703	.297	.001
Mean MT	-.3463	-.2651	-.0985
p-value	.293	.210	.122
Standard Deviation DT	.2300	.2516	.4873
p-value	.393	.999	.000
Standard Deviation MT	.1981	.2467	.3264
p-value	.468	.063	.000
Low Arousal			
Mean DT	-.2157	-.0450	.1256
p-value	.434	.448	.006
Mean MT	-.3633	-.2970	-.1205
p-value	.824	.107	.058
Standard Deviation DT	.2303	.2748	.4665
p-value	.041	.000	.000
Standard Deviation MT	.2060	.2358	.3022
p-value	.208	.106	.000
High Arousal			
Mean DT	-.1802	.0179	.1832
p-value	.824	.976	.003
Mean MT	-.3302	-.2573	-.1011
p-value	.661	.226	.258
Standard Deviation DT	.2339	.2560	.4572
p-value	.960	.871	.000
Standard Deviation MT	.2207	.2577	.3325
p-value	.067	.292	.000

Table 2. Summary of Normality Testing on Transformed Data (cont'd.)

Square Root Transformed Data			
	YC N = 16	**OC N = 15**	**PD N = 15**
Mean DT	.9188	1.0063	1.1399
p-value	.460	.564	.918
Mean MT	.8518	.8807	.9761
p-value	.927	.232	.002
Standard Deviation DT	.1144	.1364	.2156
p-value	.330	.328	.006
Standard Deviation MT	.1032	.1185	.1582
p-value	.141	.388	.004
Negative Valence			
Mean DT	.9474	1.0380	1.1726
p-value	.330	.406	.954
Mean MT	.8572	.9000	.9835
p-value	.786	.016	.006
Standard Deviation DT	.1187	.1379	.2058
p-value	.330	.727	.004
Standard Deviation MT	.0943	.1283	.1545
p-value	.095	.100	.025
Neutral Valence			
Mean DT	.8974	.9817	1.1271
p-value	.320	.916	.656
Mean MT	.8476	.8573	.9620
p-value	.864	.540	.015
Standard Deviation DT	.1002	.1239	.2146
p-value	.548	.015	.012
Standard Deviation MT	.1059	.0970	.1456
p-value	.002	.198	.001
Positive Valence			
Mean DT	.9103	.9988	1.1212
p-value	.324	.247	.726
Mean MT	.8506	.8858	.9845
p-value	.437	.089	.001
Standard Deviation DT	.1093	.1327	.2128
p-value	.274	.696	.003
Standard Deviation MT	.0899	.1169	.1636
p-value	.631	.158	.006

Table 2. Summary of Normality Testing on Transformed Data (cont'd.)

Low Arousal	**YC N = 16**	**OC N = 15**	**PD N = 15**
Mean DT	.9108	.9911	1.1180
p-value	.311	.342	.737
Mean MT	.8448	.8704	.9692
p-value	.907	.048	.001
Standard Deviation DT	.1124	.1308	.2008
p-value	.189	.820	.004
Standard Deviation MT	.0991	.1080	.1476
p-value	.041	.072	.003
High Arousal			
Mean DT	.9267	1.0220	1.1593
p-value	.573	.926	.899
Mean MT	.8589	.8906	.9829
p-value	.779	.097	.007
Standard Deviation DT	.1140	.1385	.2184
p-value	.698	.215	.004
Standard Deviation MT	.1027	.1240	.1675
p-value	.024	.162	.009

*significant at the 0.05 level

Table 3. Demographic Variables

	YC (N = 16)	OC (N = 15)	PD (N = 15)
Age			
Mean	27.06	57.73	61.93
Std. Deviation	3.91	9.63	11.79
Range	22-35	41-73	40-82
Education			
Mean	17.19	16.60	17.87
Std. Deviation	2.20	1.99	1.77
Range	14-23	12-20	14-20
MMSE			
Mean	29.63	28.73	28.27
Std. Deviation	0.719	2.604	1.356
Range	28-30	26-30	26-30
PhQ-D			
Mean	1.25	1.93	5.87
Std. Deviation	1.612	2.052	6.13
Range	0-5	0-7	0-21
PhQ-A			
Mean	0.19	0.20	0.40
Std. Deviation	0.544	0.775	1.298
Range	0-2	0-3	0-5
MDQ			
Mean	4.69	2.00	3.33
Std. Deviation	4.24	2.268	2.920
Range	0-15	0-7	0-9

Table 4. Post-Hoc Comparison of Demographic Variables

			Age			**PhQ-D**		
			Mean Difference	Std. Error	*p*-value	Mean Difference	Std. Error	*p*-value
Tukey HSD	YC N = 16	OC	-30.671	3.18	0.000*	-0.683	1.37	0.872
		PD	-34.871	3.18	0.000*	-4.417	1.37	0.007*
	OC N = 15	YC	30.671	3.18	0.000*	0.683	1.37	0.872
		PD	-4.200	3.24	.404	-3.733	1.39	0.027*
	PD N = 15	YC	34.871	3.18	0.000*	4.417	1.37	0.007*
		OC	4.200	3.24	.404	3.733	1.39	0.027*

*significant at the 0.05 level

Table 5. Effect of Valence on mean DT and Standard Deviation of DT among PD and OC, all participants

	Mean DT	**Mean DT for Negative Valence**	**Mean DT for Neutral Valence**	**Mean DT for Positive Valence**
OC N = 15	1.0337	1.1021	.9809	1.0169
PD N = 15	1.3809	1.4587	1.3519	1.3356
Chi-Square	8.795	7.839	10.874	7.839
Df	1	1	1	1
Asymp. Sig.	.003*	.005*	.001*	.005*
	Standard Deviation DT	**Standard Deviation of DT for Negative Valence**	**Standard Deviation of DT for Neutral Valence**	**Standard Deviation of DT for Positive Valence**
Older Adults N = 15	.2970	.3084	.2564	.2897
PD N = 15	.5191	.5055	.5222	.4972
Chi-Square	6.091	4.563	7.157	5.299
Df	1	1	1	1
Asymp. Sig.	.014*	.033*	.007*	.021*

*significant at the 0.05 level

Table 6. Effect of Valence on mean DT and Standard Deviation of DT among PD and OC, without PhQ-D $\geq$10

	Mean DT	**Mean DT for Negative Valence**	**Mean DT for Neutral Valence**	**Mean DT for Positive Valence**
Older Adults N = 15	1.0337	1.1021	.9809	1.0169
PD N = 12	1.3596	1.4211	1.3448	1.3133
Chi-Square	8.010	7.202	9.450	6.438
Df	1	1	1	1
Asymp. Sig.	.005*	.007*	.002*	.011*
	Standard Deviation DT	**Standard Deviation DT for Negative Valence**	**Standard Deviation DT for Neutral Valence**	**Mean standard DT for Positive Valence**
Older Adults N = 15	.2970	.3084	.2564	.2897
PD N = 12	.4812	.4783	.4932	.4425
Chi-Square	5.717	4.002	6.438	4.002
Df	1	1	1	1
Asymp. Sig.	.017*	.045*	.011*	.045*

*significant at the 0.05 level

Table 7. Effect of Valence on mean MT and Standard Deviation of MT among PD and OC, all participants

	Mean MT	**Mean MT for Negative Valence**	**Mean MT for Neutral Valence**	**Mean MT for Positive Valence**
Older Adults N = 15	.8016	.8369	.7602	.8106
PD N = 15	1.0173	1.0345	.9794	1.0413
Chi-Square	2.292	1.397	5.299	2.550
Df	1	1	1	1
Asymp. Sig.	.130	.237	.021*	.110
	Standard Deviation MT	**Standard Deviation of MT for Negative Valence**	**Standard Deviation of MT for Neutral Valence**	**Standard Deviation of MT for Positive Valence**
Older Adults N = 15	.2279	.2477	.1807	.2252
PD N = 15	.3569	.3450	.3181	.3758
Chi-Square	2.963	1.600	4.924	1.301
Df	1	1	1	1
Asymp. Sig.	.085	.206	.026*	.254

*significant at the 0.05 level

Table 8. Effect of Valence on mean MT and Standard Deviation of MT among PD and OC, without PhQ ≥10

	Mean MT	**Mean MT for Negative Valence**	**Mean MT for Neutral Valence**	**Mean MT for Positive Valence**
Older Adults N = 15	.8016	.8369	.7602	.8106
PD N = 12	1.0852	1.0982	1.0559	1.1067
Chi-Square	4.610	2.593	10.060	4.610
Df	1	1	1	1
Asymp. Sig.	.032*	.107	.002*	.032*
	Standard Deviation MT	**Standard Deviation of MT for Negative Valence**	**Standard Deviation of MT for Neutral Valence**	**Standard Deviation of MT for Positive Valence**
Older Adults N = 15	.2279	.2477	.1807	.2252
PD N = 12	.3827	.3566	.3482	.4222
Chi-Square	3.260	1.488	5.952	2.438
Df	1	1	1	1
Asymp. Sig.	.071	.223	.015*	.118

*significant at the 0.05 level

Table 9. Mean Valence and Standard Deviation of Valence Ratings in PD and OC

	Mean Valence Rating for Negative Pictures	**Mean Valence Rating for Neutral Pictures**	**Mean Valence Rating for Positive Pictures**
With All participants			
Older Adults N = 15	2.6889	5.3333	7.1926
PD N = 15	3.4791	5.4426	6.8400
Chi-Square	4.225	.339	.248
Df	1	1	1
Asymp. Sig.	.040*	.560	.618
Without PhQ-D ≥10			
Older Adults N = 15	2.6889	5.3333	7.1926
PD N = 12	3.4553	5.4375	6.9158
Chi-Square	3.095	.374	.005
Df	1	1	1
Asymp. Sig.	.079	.541	.942
	Standard Deviation of Valence Rating for Negative Pictures	**Standard Deviation of Valence Rating for Neutral Pictures**	**Standard Deviation of Valence Rating for Positive Pictures**
With All participants			
Older Adults N = 15	1.7651	1.3312	1.5631
PD N = 15	2.0008	1.3611	1.6310
Chi-Square	1.549	.172	.015
Df	1	1	1
Asymp. Sig.	.213	.678	.901
Without PhQ-D ≥10			
Older Adults N = 15	1.7651	1.3312	1.5631
PD N = 12	2.0847	1.4453	1.6695
Chi-Square	2.594	.015	.315
Df	1	1	1
Asymp. Sig.	.107	.903	.575

*significant at the 0.05 level

Table 10. Mean Arousal Ratings and Standard Deviation Arousal Ratings in PD and OC.

	Mean Arousal for Low Arousal	**Mean Arousal Rating for High Arousal**
With All participants		
Older Adults N = 15	2.9312	4.1931
PD N = 15	3.5723	4.7966
Chi-Square	1.445	2.681
Df	1	1
Asymp. Sig.	.229	.102
Without PhQ-D ≥10		
Older Adults N = 15	2.9312	4.1931
PD N = 12	3.6444	5.0235
Chi-Square	1.468	3.821
Df	1	1
Asymp. Sig.	.226	.051*
	Standard Deviation of Arousal for Low Arousal	**Standard Deviation of Arousal Rating for High Arousal**
With All participants		
Older Adults N = 15	1.9161	2.3852
PD N = 15	2.0680	2.4591
Chi-Square	.298	.002
Df	1	1
Asymp. Sig.	.585	.965
Without PhQ-D ≥10		
Older Adults N = 15	1.9161	2.3852
PD N = 12	2.1851	2.5213
Chi-Square	1.224	.042
Df	1	1
Asymp. Sig.	.269	.837

*significant at the 0.05 level

Table 11. Effect of Valence on mean DT and Standard Deviation of DT among YC and OC

	Mean DT	**Mean DT for Negative Valence**	**Mean DT for Neutral Valence**	**Mean DT for Positive Valence**
Young Adults N = 16	0.8709	0.9296	0.8251	0.8550
Older Adults N = 15	1.0337	1.1021	0.9809	1.0169
Chi-Square	4.556	3.752	4.389	4.064
Df	1	1	1	1
Asymp. Sig.	0.033*	0.053*	0.036*	0.044*
	Standard Deviation DT	**Standard Deviation of DT for Negative Valence**	**Standard Deviation of DT for Neutral Valence**	**Standard Deviation of DT for Positive Valence**
Young Adults N = 16	0.2352	0.2475	0.2001	0.2177
Older Adults N = 15	0.2970	0.3084	0.2564	0.2897
Chi-Square	2.627	2.377	1.806	2.627
Df	1	1	1	1
Asymp. Sig.	0.105	0.123	0.179	0.105

*significant at the 0.05 level

Table 12. Effect of Valence on mean MT and Standard Deviation of MT among YC and OC

	Mean MT	**Mean MT for Negative Valence**	**Mean MT for Neutral Valence**	**Mean MT for Positive Valence**
Young Adults N = 16	0.7466	0.7538	0.7455	0.7404
Older Adults N = 15	0.8016	0.8369	0.7602	0.8106
Chi-Square	0.977	2.025	0.564	0.756
Df	1	1	1	1
Asymp. Sig.	0.323	0.155	0.453	0.385
	Standard Deviation MT	**Standard Deviation of MT for Negative Valence**	**Standard Deviation of MT for Neutral Valence**	**Standard Deviation of MT for Positive Valence**
Young Adults N = 16	0.2086	0.1797	0.2203	0.1691
Older Adults N = 15	0.2279	0.2477	0.1807	0.2252
Chi-Square	0.156	1.702	0.056	0.827
Df	1	1	1	1
Asymp. Sig.	0.963	0.192	0.813	0.363

*significant at the 0.05 level

Table 13. Mean Valence and Standard Deviation of Valence Ratings in YC and OC

	Mean Valence Rating for Negative Pictures	**Mean Valence Rating for Neutral Pictures**	**Mean Valence Rating for Positive Pictures**
Young Adults N = 16	3.0313	5.3854	6.8924
Older Adults N = 15	2.6889	5.3333	7.1926
Chi-Square	1.817	0.077	1.361
Df	1	1	1
Asymp. Sig.	0.178	0.781	0.243
	Standard Deviation of Valence Rating for Negative Pictures	**Standard Deviation of Valence Rating for Neutral Pictures**	**Standard Deviation of Valence Rating for Positive Pictures**
Young Adults N = 16	1.8333	1.0750	1.4925
Older Adults N = 15	1.7651	1.3312	1.5631
Chi-Square	.156	2.139	.127
Df	1	1	1
Asymp. Sig.	.692	.144	.722

Table 14. Mean Arousal Ratings and Standard Deviation Arousal Ratings in YC and OC

	Mean Arousal for Low Arousal	**Mean Arousal Rating for High Arousal**
Young Adults N = 16	2.7708	3.9722
Older Adults N = 15	2.9312	4.1931
Chi-Square	.593	.085
Df	1	1
Asymp. Sig.	.441	.771
	Standard Deviation of Arousal for Low Arousal	**Standard Deviation of Arousal Rating for High Arousal**
Young Adults N = 16	1.6506	2.2817
Older Adults N = 15	1.9161	2.3852
Chi-Square	.837	.209
Df	1	1
Asymp. Sig.	.360	.647

APPENDIX A: IAPS Images Presented To Participants

IAPS Picture Number	Standardized Valence Rating	Standardized Arousal Rating
Version A		
"Old Pictures"		
1070	3.96	6.16
1090	3.7	5.88
1275	3.3	4.81
1540	7.15	4.54
1750	8.28	4.1
2050	8.2	4.57
2160	7.58	5.16
2200	4.79	3.18
2214	5.01	3.46
2250	6.64	4.19
2340	8.03	4.9
2381	5.25	3.04
2520	4.13	4.22
2722	3.47	3.52
2890	4.95	2.95
3030	1.91	6.76
3100	1.6	6.49
3140	1.83	6.36
3150	2.26	6.55
4210	5.72	6.08
4572	6.15	4.8
4610	7.29	5.1
4659	6.87	6.93
5200	7.36	3.2
5500	5.42	3
5510	5.15	2.82
5600	7.57	5.19
5760	8.05	3.22
6010	3.73	3.95
6200	2.71	6.21
6350	1.9	7.29
7004	5.04	2
7025	4.63	2.71
7034	4.95	3.06
7037	4.81	3.71
7041	4.99	2.6
7050	4.93	2.75
7060	4.43	2.55
7150	4.72	2.61

IAPS Picture Number	Standardized Valence Rating	Standardized Arousal Rating
7160	5.02	3.07
7175	4.87	1.72
7182	5.16	4.02
7184	4.84	3.66
7260	7.21	5.11
7270	7.53	5.76
7705	4.77	2.65
8030	7.33	7.35
8090	7.02	5.71
8200	7.54	6.35
9010	3.94	4.14
9110	3.76	3.98
9330	2.89	4.35
9331	2.87	3.85
9390	3.67	4.14
Version A		
"New Pictures"		
1112	4.71	4.6
1113	3.81	6.06
1205	3.65	5.79
1270	3.68	4.77
1460	8.21	4.31
1670	5.82	3.33
1740	6.91	4.27
2100	3.85	4.53
2150	7.92	5
2215	4.63	3.38
2280	4.22	3.77
2320	6.17	2.9
2530	7.8	3.99
2540	7.63	3.97
3015	1.52	5.9
3064	1.45	6.41
3160	2.63	5.35
3280	3.72	5.39
3350	1.88	5.72
4180	6.21	5.54
4490	6.27	6.06
4603	7.1	4.89
4650	6.96	5.67
4660	7.4	6.58
5001	7.16	3.79
5520	5.33	2.95
5530	5.38	2.87

IAPS Picture Number	Standardized Valence Rating	Standardized Arousal Rating
5830	8	4.92
6000	4.04	4.91
6150	5.08	3.22
7000	5	2.42
7010	4.94	1.76
7020	4.97	2.17
7030	4.69	2.99
7080	5.27	2.32
7100	5.24	2.89
7110	4.55	2.27
7161	4.98	2.98
7187	5.07	2.3
7200	7.63	4.87
7235	4.96	2.83
7330	7.69	5.14
7400	7	5.06
7580	7.51	4.59
8170	7.63	6.12
8185	7.57	7.27
9040	1.67	5.82
9041	2.98	4.64
9045	3.75	3.89
9090	3.56	3.97
9101	3.62	4.02
9190	3.9	3.91
9290	2.88	4.4
9500	2.42	5.82
Version B		
“Old Pictures”		
1600	7.37	4.05
1610	7.69	3.98
2030	6.71	4.54
2040	8.17	4.64
2057	7.81	4.54
2190	4.83	2.41
2230	4.53	4.13
2240	6.53	3.75
2312	3.71	4.02
2590	3.26	3.93
3063	1.49	6.35
3068	1.8	6.77
3102	1.4	6.58
3170	1.46	7.21
3180	1.92	5.77

IAPS Picture Number	Standardized Valence Rating	Standardized Arousal Rating
3230	2.02	5.41
3550	2.54	5.92
4250	6.79	5.16
4530	6.19	5.31
4624	6.84	5.02
4680	7.25	6.02
5534	4.84	3.14
5740	5.21	2.59
7002	4.97	3.16
7006	4.88	2.33
7031	4.52	2.03
7035	4.98	2.66
7090	5.19	2.61
7130	4.77	3.35
7185	4.97	2.64
7190	5.55	3.84
7207	5.15	3.57
7234	4.23	2.96
7280	7.2	4.46
7350	7.1	4.97
7460	6.81	5.12
7493	5.35	3.39
7550	5.27	3.95
7700	4.25	2.95
7820	5.39	4.21
7950	4.94	2.28
8120	7.09	4.85
8180	7.12	6.59
8186	7.01	6.84
8210	7.53	5.94
8500	6.96	5.6
9000	2.55	4.06
9001	3.1	3.67
9070	5.01	3.63
9140	2.19	5.38
9180	2.99	5.02
9250	2.57	6.6
9265	2.6	4.34
9700	4.77	3.21
“New Pictures”		
1200	3.95	6.03
1590	7.24	4.8
1620	7.37	3.54
2071	7.86	5

IAPS Picture Number	Standardized Valence Rating	Standardized Arousal Rating
2080	8.09	4.7
2110	3.34	5.18
2270	6.28	3.15
2276	2.67	4.63
2510	6.91	4
2810	4.31	4.47
2840	4.91	2.43
2880	5.18	2.96
3080	1.48	7.22
3101	1.91	5.6
3168	1.56	6
3181	2.3	5.06
3261	1.82	5.75
3266	1.56	6.79
3301	1.8	5.21
4220	8.02	7.17
4520	6.16	4.8
4599	7.12	5.69
4652	6.79	6.62
4800	6.44	7.07
5130	4.45	2.51
5390	5.59	2.88
5731	5.39	2.74
6311	2.58	4.95
7040	4.69	2.69
7170	5.14	3.21
7179	5.06	2.88
7205	5.56	2.93
7217	4.82	2.43
7224	4.45	2.81
7230	7.38	5.52
7233	5.09	2.77
7237	5.43	3.88
7325	7.06	3.55
7470	7.08	4.64
7481	6.53	4.92
7490	5.52	2.42
7491	4.82	2.39
7500	5.33	3.26
7560	4.47	5.24
7830	5.26	4.08
8010	4.38	4.12
8080	7.73	6.65
8190	8.1	6.28

IAPS Picture Number	Standardized Valence Rating	Standardized Arousal Rating
8460	6.4	4.55
9007	3.1	3.67
9046	3.32	4.31
9220	2.06	4
9360	4.03	2.63
9440	3.67	4.55

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