EMOTIONAL EXPERIENCE, FACIAL EXPRESSION, AND STARTLE REFLEX MODULATION IN YOUNG ADULTS, HEALTHY OLDER ADULTS, AND ALZHEIMER'S DISEASE

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ABSTRACT

This study was designed to assess the impact of aging and Alzheimer's disease on conscious appraisal of emotional experience, facial expression, and emotion-modulated action tendencies. Participants included healthy young adults (YA), healthy older adults (OA), and individuals in the early stages of Alzheimer's disease (AD). Self-report of emotional experience while viewing emotionally-salient images was recorded, action tendencies in the form of eye-blink startle reflex modulation and its resolution over time (300ms and 3000ms post-stimulus offset) were recorded, and facial expression of emotion was assessed utilizing EMG recordings of corrugator and zygomatic facial muscles. Consistent with previous studies of emotion in YA, showed the predicted linear relationship with normatively-determined image type (positive, neutral, & negative), and arousal experience ratings were in the predicted quadratic pattern. Corrugator EMG activity increased while viewing negative images and zygomatic EMG activity increased while viewing positive images, as predicted. Startle reflex magnitude was observed in the predicted valenced direction (i.e., greatest for negative images) while viewing images and 300ms post-image removal, but this pattern inverted at the 3000ms probe-time. Similar findings were observed in a comparison of the YA and OA groups, however a difference was observed in the resolution of the startle reflex, with the expected valenced pattern dissipating by the 300ms probe-time for the OA group. Comparisons of the OA and AD groups were limited by small sample sizes, but the AD group was similar to the OA group on measures of self-report of emotional experience patterns and corrugator EMG activity. Zygomatic EMG activity while viewing positive images appeared reduced
in the AD group, and no effect of startle reflex modulation was observed in the AD group. The implications of these findings are discussed.
INTRODUCTION

*Men decide far more problems by hate, love, lust, rage, sorrow, joy, hope, fear, illusion, or some other inward emotion, than by reality, authority, any legal standard, judicial precedent, or statute.*

- Cicero (106 BC - 43 BC)

*Higher emotions are what separate us from the lower orders of life... Higher emotions, and table manners.*

- Deanna Troi, Star Trek - The Next Generation

Emotion is a nearly ubiquitous aspect of the human phenomenological experience that can serve as a powerful guide for our cognition and behavior. Emotions have served as the motivation for some of the most unspeakably vile acts in human history, as well as for acts of such beauty as to defy description. Yet the empirical study of emotion has been an historically neglected endeavor, largely owing to biases and methodological concerns of those who dominated the scientific mainstream for much of the last century. They relegated emotion research as a whole to take a back seat, relative to investigations of “reason.” Those who held sway over research agendas for most of the 20th century felt, as Damasio (2000) describes, that “emotion was not to be trusted, in real life or in the laboratory. Emotion was too subjective; it was too elusive and vague...It was probably irrational to study it” (p. 12).
Recent years, however, have seen a shift in the priorities of those who set research agendas, resulting in a remarkable resurgence of interest in emotion as a valid target for scientific investigation. Refinements in theory and methodological improvements have afforded emotion researchers the opportunity to learn a great deal about this aspect of human experience. Armed with new investigative tools and enhanced conceptualizations of emotion, several investigators have begun characterizing emotional processes and exploring how numerous variables, such as aging and biological conditions, may affect those emotional processes. The present study is the product of such an effort, and has as its aim the exploration of how the time course of emotions may change with age, and how emotional processing may be impacted by the biological processes accompanying normal, healthy aging and Alzheimer's Disease (AD).

What are emotions?

One product of the reemergence of emotion research has been a refinement of the conceptualization of "emotion," which will be briefly reviewed here prior to applying these concepts to the populations of interest in this study. Over the last several years, an increasing number of investigators have come to view emotion as consisting of several often-related, but distinct, measurable components. The first of these components is the conscious appraisal of the emotion-eliciting stimulus. This term is typically used to describe an individual's appraisal of the emotional significance of an object or event or the assignment of emotional worth to a proximal stimulus. This aspect of emotion is perhaps the most methodologically amenable to study, and accordingly the majority of the empirical studies of emotion in adulthood, in aging and in AD fall under this
A second emotion component is emotion-related behavior or a preparation for acting on the emotional information. As Lang (1995) has pointed out, emotions occur when something important is happening to the organism, but the organism's responsive actions are inhibited. This pause in behavior when emotions occur is presumably when action dispositions begin to form. Action dispositions involve particular behaviors that are enlisted or primed by emotions; they represent a preparation for action, and not the actions themselves. These can include, but are not limited to, preparation for approach and avoidance behaviors and expressions of emotion.

The third component of emotion is the physiologic arousal generated by an emotionally salient stimulus. Arousal related to emotional experience is thought to be detectible in several aspects of autonomic nervous system (ANS) activity, and examples of these measures include skin-conductance response and finger temperature. The typical paradigm for measuring physiologic arousal is to record the physiologic measures while inducing an emotional experience by either exposing subjects to emotionally salient stimuli or having them engage in emotionally stimulating imagery.

Emotion in young adults

Emotion has been studied fairly extensively in young adults, in part due to the ready availability of undergraduate students to participate in research projects. As such, a fair amount is known about the processing of emotions in this population, and several methodologies have been developed to identify discrete patterns of emotion processing across the above-described domains of emotional functioning. For the sake of brevity,
this review will focus primarily on the results generated by the use of the “picture perception paradigm,” the methodology employed in the present study. This methodology, developed by Peter Lang and colleagues (see Lang, 1995, for a review), utilizes brief exposures to emotionally salient stimuli and measures both self-report of emotional experience and emotion-related physiologic changes. Most of the work in this area has relied upon a large set of emotionally salient images, the *International Affective Picture System* (IAPS; Center for the Study of Emotion and Attention, 1999), to generate emotional responses. The IAPS has extensive normative ratings on valence and arousal dimensions. In this way, patterns of emotional experience ratings and physiological changes have been documented, and these patterns have frequently been used as the “normal” standard against which other populations are compared.

**Conscious appraisal of emotional experience** – The principle method for assessing conscious appraisal of emotion in the picture perception paradigm is through the use of the Self-Assessment Manikin (SAM; Lang, 1980). The SAM consists of two ordinal scales upon which self-report ratings of emotional valence and arousal are made (Fig. 1). The SAM was designed to allow subjects to report their subjective emotional experience ratings to the images while minimizing the effects language and culture can have on ratings.

The SAM has been used extensively to study emotional experiences, perhaps most importantly in the normative evaluation of emotional experiences subsequent to viewing the images in the IAPS stimulus set (CSEA-NIMH, 1999). These self-reports of emotional experiences have been compiled and used to classify the images in the IAPS
into the broad categories of positive, neutral, and negatively valenced images. Thus, the normative ratings serve as the “expected” ratings to be generated by young adult subjects in most laboratory studies.

Indeed, the expected ratings patterns are found in most studies that provide sufficient time for conscious visual processing. That is, IAPS images normatively rated as positive, neutral, or negative are typically rated as inducing similarly valenced emotional experiences in most studies (e.g., Vrana, Spence & Lang, 1988; Bradley, Lang, & Cuthbert, 1993; Lang, Greenwald, Bradley, & Hamm, 1993; Cuthbert, Bradley & Lang, 1996; Manber, Allen, Burton and Kaszniak, 2000; Reminger, Kaszniak & Dalby, 2000). Similarly, those same studies typically find that the positively and negatively normed images tend to be rated as inducing greater levels of emotional arousal than the neutral images. These findings tend to hold true regardless of the physiologic context of the study, and are so robust that few studies have the description of the emotional experience of young adults as their focus. Rather, these reliable patterns of self-reported emotional experience serve primarily to contrast unusual patterns of emotional experiences in populations of interest.

There are, however, some noteworthy exceptions to the typical, expected pattern of self-reported emotional experience in the picture perception paradigm. Perhaps the most intriguing example of deviation from this pattern is that of criminal psychopaths, who tend to experience some positive images as more positive than healthy adults, and view some negative images as inducing less negative emotional experiences than healthy adults (Levenston, Patrick, Bradley & Lang, 2000).
Expression and Action Tendencies – Most of the above-described studies examining subjective experience of emotion utilizing the picture perception paradigm have also measured physiological correlates of those emotional experiences. The physiologic measures that have received the most attention are in the domains of facial expression of emotion and in emotion-modulated reflex magnitudes. Facial expression of emotion has become a standard index of emotion measurement, and numerous studies have utilized facial electromyographic recordings or participants while they were exposed to affect-laden stimuli. Two of the more robust physiologic targets include facial EMG recordings of the zygomaticus major muscle, which pulls the lips back and up when “smiling,” and the corrugator supercilii muscle, which knits the brows together when “frowning” (Fridlund & Cacioppo, 1986). Increases in electrical activity along these muscle sites has been associated with increased positive and negative emotional experience reports, respectively, regardless of whether the emotionally evocative stimulus is mental imagery (Schwartz, Ahern, & Brown, 1979; Brown & Schwartz, 1980), sounds (Bradley & Lang, 2000), or images (Lang, Greenwald, Bradley & Hamm, 1993). The neural underpinnings for these phenomena are thought to arise from cortical regions (for volitional facial expression) and from the basal ganglia (for spontaneous emotional expression; Matsumoto & Lee, 1993).

The most frequently used measure of emotion-related action tendency is the startle reflex. The startle reflex is a whole-body series of defensive reflexive actions for which the apparent goal is to prepare the organism for dealing with a potential threat. In the “startle probe” methodology (summarized in Lang, 1995), a brief (50ms) burst of
white noise (95db) called a startle “probe” is used to trigger the reflex. The first element of this reflex to occur, typically within 50 ms of startle probe onset, is an eyeblink. Lang and colleagues have shown that the magnitude of the eyeblink component of the startle reflex can be modulated by the subjects’ affective or motivational state (Vrana, Spence & Lang, 1988). Being in a “primed” appetitive or aversive motivational state prepares one for action in either an approach or avoidant manner, respectively. When the motivational state and the environmental cues (in this case the probe) are matched, i.e. both are aversive, the defensive startle reflex is typically augmented. When the motivational state and foreground are mismatched, i.e. foreground is pleasant but the environmental cue is unpleasant, the reflex is expected to be reduced. Thus, viewing images of a negative nature induces a transient aversive motivational state and increases the magnitude of the reflexive response to an aversive probe. Likewise, viewing images of a positive nature induces a transient positive motivational state, which reduces the magnitude of the reflex when presented with an aversive probe. Viewing images of a neutral nature results in a reflex magnitude slightly higher than that of the positive images. Based on these findings, it is possible to use the modulation of the startle reflex as a measure of foreground emotional state.

The proposed neural model for the startle reflex is based upon fear-conditioning research with rats (as described in Lang, 1995). The primary startle pathway begins with auditory input traveling through the cochlear root neurons to the reticular nucleus. The efferent pathway proceeds from the reticular nucleus to the facial and spinal neurons’ reflex effectors. The modulatory effects of emotional states appear to occur via the
amygdala, which has direct and indirect (via the central gray) connections to the reticular nucleus. Electrical stimulation of the amygdala results in increased startle magnitude, and lesioning of the amygdala results in elimination of fear-conditioned startle potentiation.

The discovery that this readily measurable eyeblink response is influenced by emotional experience has led to its popularization as a tool for measuring emotion-related action tendency (Vrana, Spence & Lang, 1988). This observation has been widely replicated (Bradley, Lang, & Cuthbert, 1993; Lang, Greenwald, Bradley, & Hamm, 1993; Cuthbert, Bradley & Lang, 1996; Manber, Allen, Burton and Kaszniak, 2000). Thus, examination of eyeblink magnitudes in response to a startling stimulus can be used to “probe” an individual’s foreground emotional state.

Physiologic arousal – In addition to the above-described measures of conscious emotion appraisal, emotional expression, and action tendency, autonomic nervous system responses have received considerable attention as reliable measures of emotional arousal. For example, several studies have examined the autonomically-mediated skin conductance response (SCR) in young adults engaged in a picture perception task. The typical finding is that SCRs to the more arousing positive and negative images are greater than those to the less arousing neutral images (Greenwald, Cook, & Lang, 1989; Lang, Greenwald, Bradley, & Hamm, 1993; Cuthbert, Bradley & Lang, 1996). Given that the self-report of arousal correlates positively with SCR magnitude, SCR has come to be taken as an indicator of emotional arousal. The pattern of greater SCRs to arousing, emotionally valenced stimuli compared to neutral stimuli in young adults has come to be taken as the expected “normal” pattern of physiologic arousal.
The temporal characteristics of emotion - Many unanswered questions about emotion in young adulthood remain, and the most relevant to the present study is this: how do the physiological manifestations of emotion episodes resolve over time? The time course of emotional experiences is an important aspect of emotion, and one which has received relatively little investigation to date. However, important theoretical contributions have been made by several individuals. One such contributor is Davidson (1998), who has described a set of proposed emotional characteristics that he considers to comprise affective style. He considers this concept to be a combination of emotion regulation, the processes that help in attenuating or enhancing emotional experiences, and emotional reactivity. Several specific elements of emotional reactivity were described by Davidson: 1) a threshold of stimulation necessary to initiate an emotional reaction; 2) the amplitude or crest of emotional responding; 3) the rise time to peak, or the amount of time an individual requires to attain maximal emotional responsivity; and 4) the recovery time, or time necessary for an emotional response to return to a baseline, or non-emotional level of functioning. Taken together, these latter two characteristics comprise what Davidson calls affective chronometry, or the temporal processes involved in emotional responses. At present, none of the aspects of affective chronometry have been extensively studied, which serves in part as a motivation for the present study.

Frijda (1993) has also provided important theoretical insight into the time course of what he calls emotion episodes. He emphasizes that emotions are not so much discrete states as they are unfolding processes which develop over time. The way they develop is a function of emotionally sequenced “transactions” between the subject and an emotional
target in the environment. These transactions can occur in complex ways, with the subject and emotional target often involved in a series of responses aimed at affective “moving targets,” frequently resulting in distinct periods of emotional “peaks.” It is the unfolding of these transactions and their fluctuation over time that Frijda calls emotion episodes, and he emphasizes that the temporal component of affective processes are key to understanding the complexity of emotions more broadly.

There have been but two studies addressing the temporal changes in affective processes utilizing the picture perception paradigm. The first was by Bradley, Cuthbert & Lang (1993), which examined startle reflex responses early on in the emotionally salient image presentation period (800ms post onset), during the latter half of the image presentation interval, and after image presentation. Their findings suggested a prepulse inhibition period both immediately after image onset and immediately after image offset, resulting in an overall inhibition of startle reflex magnitudes. However, despite this overall inhibition, probes early in the image presentation process revealed greater inhibition of the reflex while viewing emotionally arousing images (positive and negative images), compared to unarousing neutral images. As the image presentation period continued, the typical pattern of startle reflex modulation was observed, i.e., probes during positive image exposure revealed inhibited reflexes compared to neutral images, and probes during negative image exposure revealed enhanced reflex magnitude compared to positive images. Within 800ms of image offset, the emotion-modulation effect on the startle eyeblink dissipated, and by 3800 seconds no modulation effect was observable. The authors concluded that attentional prepulse inhibition phenomena were
critical for the early, arousal-related inhibition of reflexes, and that the resolution of these affective processes’ influence on reflexes was rapid.

Similarly, a recent study by Dichter, Tomarken and Baucom (2002) described the use of the picture perception paradigm to investigate the temporal characteristics of the startle reflex. For each trial, subjects were presented with a cue as to the valence of the upcoming image, allowing for elucidation of any modulatory effects anticipation may have on emotional processes. Probes were administered either during the anticipatory phase, during image viewing, or 1.5-2.5s after image offset. They found that during the anticipatory phase, startle probes resulted in heightened reflex magnitudes for both anticipated positive and negative images, suggesting a role for arousal in the modulation of startle in anticipation. They found the typical pattern of reflex modulation when subjects were probed during the image viewing period. Emotion-related modulation of the startle reflex was found to be absent during the image offset condition, again suggesting that the resolution of these affective processes occurs quickly.

In summary, there are both theoretical and empirical reasons to suspect that the startle reflex should have readily detectible temporal characteristics. Elucidating these characteristics, specifically the resolution phase of the startle reflex, was one of the goals of the present study.

Why study emotion in healthy aging and AD?

Considerably less is known about the emotion processing characteristics of the two other populations with which the present study concerns itself, healthy older adults and individuals with AD. There are reasons to suspect that the processing of emotional
information may be affected by both aging and AD. In the case of healthy aging, the argument for changes in emotional functioning originates in theorization, clinical observations and anecdotal evidence dating back to Jung (1933) and Erikson (1959), who suggested that old age is a time of great pensiveness and is accompanied by a reduction in emotional intensity. Others have suggested that anxiety and affective disorders increase with age, although the evidence for this contention is mixed, at best (see Koenig, 1997, and Schramke, 1997 for a review).

More recently, studies of cerebral laterality have suggested a mechanism by which the aging process may affect emotion processing. Several studies have suggested that the right hemisphere plays a greater role in the processing of emotional information than the left hemisphere in healthy adults, based largely on the observation that the left side of the face is more expressive than the right in many types of emotion conditions (Moreno, Borod, Welkowitz & Alpert, 1990; Oscar-Berman, Hancock, Mildworf, Hunter, & Weber, 1990; Moscovitch, & Olds, 1982; see Davidson , Jackson & Kalin, 2000, for a review of a differing conceptualization of cerebral laterality and emotion). This well-accepted finding, combined with the contention by some investigators that right hemispheric cognitive functions appear to decline at a relatively faster rate than left hemispheric functions (Ellis & Oscar-Berman, 1989; however, see Kaszniak & Newman, 2000, for a critique of this interpretation), provides a foundation for suspicion that the processing of emotional information may be changed with age.

A competing hypothesis regarding brain changes in normal aging has been offered by Albert & Kaplan (1980). Their systematic review of neuropsychological task
performances by young and older adults led them to conclude that older adults
demonstrated greater difficulty with tasks requiring selective attention and strategic
skills. These functions are thought to be mediated by the frontal lobes and their
subcortical connections. In addition, there is considerable evidence that the frontal lobe
regions atrophy in normal aging (Sandor, Albert, Stafford, & Kemper, 1990; Coffey et
al., 1992). Given these observations and the importance that the frontal lobes play in the
processing of emotion, there may be reason to suspect mild changes in emotion
processing in normal aging.

Likewise, many have observed increased irritability, suspiciousness, agitation,
and restlessness in persons with AD (Wagner, Teri & Orr-Rainey, 1995; Rabins, Mace, &
Lucas, 1982; Schneck, Reisberg & Ferris, 1982). Such observations were useful for
framing the initial questions regarding emotion and AD, but they did not provide
sufficient information to address the more important practical needs of the patients and
those who care for them. Given that emotions are an omnipresent component of our lives
that inform cognitions and directly influence behavior, any possibility of emotional
impairment in AD needs to be addressed via systematic research. As an example of how
emotion research is needed for practical use, some clinicians have observed persons with
AD and concluded that they can adequately perceive emotional information (Bartol,
1979). Others have advised caregivers to utilize nonverbal emotional communication as a
way relate to those with AD after language abilities have failed (Tappen, Williams-
Burgess, Edelstein, Touhy & Fishman, 1997). However, relatively little basic research
has addressed the overall status of emotion in AD, leaving the utility of those suggestions open to question.

In addition, several investigators have found that neural structures thought to be involved in emotion, including the amygdala (Heun, et al. 1997; Vogt, Hyman, VanHoesen & Damasio, 1990; Herzog & Kemper, 1980; Hooper and Vogel, 1976; Corsellis, 1970) and semi-closed frontal-subcortical circuits (Hyman, Van Hoesen, Damasio & Barnes, 1984; Terry & Katzman, 1983), are affected by the degenerative process associated with AD. The amygdala has previously been implicated in the processing of negative emotional information, with much of this work investigating its role in fear (LeDoux, 2000). Frontal-subcortical circuits have been similarly implicated in the processing of positive emotional information (Lane, et al., 1997). These findings, coupled with the observations described above, suggest that there are reasons to believe the processing of emotional information may be impaired in AD.

Emotion research in aging and AD

The current evidence from empirical studies of emotion is summarized below, and is classified according to the emotion components described earlier.

Conscious emotion appraisal and appraisal of emotionally-salient stimuli - Carstensen and her colleagues have studied emotion worth within the elderly in the context of socioemotional selectivity theory, which postulates that any observed reduction in social contacts in old age are likely a result of healthy “pruning” of less emotionally important or rewarding relationships (Carstensen and Turk-Charles, 1998). This has the advantage of allowing older adults to focus more exclusively on the close relationships that are most
rewarding to them, and stands in stark contrast to earlier theorists' arguments that dwindling social contacts were a negative consequence of aging. In a series of studies, Carstensen and her colleagues have shown that the perception of available time is the critical component in the move toward focusing on rewarding relationships to the exclusion of others, regardless of age (Fredrickson & Carstensen, 1990; Fung, Carstensen & Lutz, 1999). They found that younger adults engaged in a similar strategy of relationship pruning when they perceive that they have limited time available for socializing. Thus, older adults maximize their use of the perceived time available to them, and this appears to be an adaptive strategy for older adults who typically perceive that they are closer to the end of the life cycle than younger adults.

The few other investigations focusing on the cognitive appraisal and perception of emotion in old age have yielded mixed results. One such study failed to detect any age-related differences in the typical left-sided bias of hemispace preference for perception of emotional (Moreno, Borod, Welkowitz, & Alpert, 1990). However, another study described consistent age-related deficits on several tasks of emotional stimulus perception in both visual and auditory modalities (Oscar-Berman, Hancock, Mildwor, Hutner, & Weber, 1990).

Other research efforts have compared the cognitive appraisal of emotional stimuli of healthy older adults with AD subjects. One of the earliest such studies was by Allender and Kaszniak (1989), who examined AD subjects' performance on a variety of emotional processing tasks, including a facial emotion recognition task and identification and discrimination of emotional speech prosody. Their initial finding was that AD
subjects’ performance on all emotional processing tasks was significantly worse than that of control subjects. However, they were concerned that cognitive deficits may have impacted AD subjects’ performances and sought to determine if the emotion task deficits would persist if the cognitive deficits were statistically controlled. A number of other cognitive tests were administered which had task requirements similar to the emotion tasks, but did not involve an emotional component. The Boston Naming Test was included as naming ability was reasoned to be a component of both emotion tasks, the Benton Facial Recognition test served as a non-emotional control task for the facial emotion task, and the Seashore Rhythm test served as a non-emotional control task for the auditory-verbal emotion identification task. Two hierarchical multiple regression analyses were computed, using one emotion task as one of the independent variables, and the other as a dependent variable. The cognitive task relevant to the dependent variable was entered at the first step, the Boston Naming test was entered at the second step, and the other emotion task was entered at the last step. They found that, after controlling for cognitive deficits in such a fashion, the emotion tasks were still significant predictors of each other. Thus, the authors suggested that cognitive deficits alone could not explain the AD subjects’ performance on the emotion tasks and a more primary deficit in the processing of emotional stimuli better explained their data.

Others have differed from Allender and Kaszniak in their conclusions. Albert, Cohen & Koff (1991) conducted a similar study in which they administered nine tasks of affect perception to AD and control subjects. These tasks consisted of facial recognition tasks, verbal labeling tasks, and recognition of both drawn and heard emotional
situations. Their initial findings indicated that AD subjects were significantly impaired on these tasks when compared to controls. However, after controlling for specific cognitive deficits thought to be required for each of the emotion tasks, such as performance on tests of abstraction (Similarities Subtest of WAIS-R) and verbal labeling (Boston Naming Test), they found significant group differences on just two emotion tasks: a task requiring recognition of verbal labels of emotion when the faces of different people are shown; and recognition of emotion in verbal descriptions of emotional situations. However, the authors also opted, atheoretically, to control for other cognitive deficits, such as attention, verbal memory, and global dementia, and found that when these cognitive deficits were also controlled for they eliminated the significant differences between the groups on those two emotion tasks. The authors concluded that AD subjects’ impaired performance on emotion tasks was best explained by a deficit in cognitive, rather than emotional, functioning. It should be pointed out that the authors did not provide any a priori theoretical rationale for the final inclusion of the additional cognitive tasks. This is problematic insofar as the addition of variables in a multiple regression analysis, even if they are not strongly correlated with the dependent variable, can account for a portion of the variance of the dependent variable, thus leaving less variation available to be explained by subsequent variables, which in this case were the emotion tasks. This use of numerous variables may have effectively eliminated any possibility that the emotion tasks could be useful predictors. In addition, the subject populations in this study were considerably older than those of the Allender and Kaszniak study, limiting the direct comparison of their findings.
Albert and colleagues attempted to replicate their findings using a smaller set of similar emotion tasks (Koff, Zaitchik, Montepare, and Albert, 1999). AD subject performances were again impaired compared to controls on visuospatially oriented emotion tasks, but not on verbal emotion tasks. Once they controlled for visuospatial and abstraction abilities just two of the four visuospatial tasks continued to differentiate the groups: a task requiring interpretation of the emotional experience of individuals videotaped making certain gestures; and a task requiring similar emotional interpretation of videotaped vignettes of body movements. The authors concluded that this evidence supported their earlier argument that cognitive deficits best explain AD subjects' impaired performance on tasks of emotion processing.

Others have argued against Allender and Kaszniak's conclusions regarding discrimination of emotional facial expression. Roudier and colleagues (1998) investigated AD subjects' abilities to discriminate between human facial identities and to discriminate between emotional expressions. They hypothesized that the mechanisms for facial identity discrimination may be dissociated from those for discriminating facial emotional expressions. They investigated their hypothesis by examining AD subject performance across six conditions: 1) discrimination of facial identity where pairs of same and different faces display the same emotion; 2) discrimination of facial identity where pairs of same and different faces display different emotional expressions; 3) discrimination of same and different facial emotional expressions with the same face; 4) discrimination of same and different facial emotional expressions across different faces; 5) verbal identification of faces displaying the emotions of happy, sad, angry and
indifference; and 6) pointing out faces displaying each of the four emotions. They found significant differences between the AD group and an age-matched control group on both facial identity discrimination tasks and on both emotion identification tasks, but not on the emotion discrimination tasks. The authors concluded that their hypothesis was supported by the data, and suggested that the processes of facial identification and facial emotional expression are separable in the AD population. They interpreted their results as failing to support Allender and Kasznia’s contention that there is a specific emotional processing deficit in AD, and as more consistent with Albert et al.’s findings.

Lavenu, Pasquier, Lebert, Petit, and Linden (1999) also investigated the perception of facial expressions of emotion in both AD and in Frontotemporal Dementia (FTD) subjects compared to control subjects. They employed two tasks: 1) detection of whether a face displayed an emotion or was neutral; and 2) identification of the emotional expression of faces displaying anger, disgust, fear, happiness, sadness, surprise, and contempt. The emotional labels were provided, and the subjects were asked to point out the appropriate label. The groups did not differ on the emotion detection task, suggesting that neither patient group was impaired in their ability to detect the existence of a facial emotional expression. The FTD group performed significantly worse overall than both AD and NC groups on the first trial of the identification task. The authors were primarily interested in the FTD group’s poorer overall performance and interpreted their results as suggestive of differing neural substrates for recognition of these basic emotions. However, it is worth noting that the AD group performed significantly worse than the control group in recognizing the specific emotions of fear and contempt. Unfortunately,
the authors did not attempt to statistically control for the patient groups’ cognitive deficits, thus leaving a possible alternative explanation unexplored.

Given that most of the above findings show evidence of poor AD performance on emotion tasks, at least initially, Bortz & Kaszniak (1994) sought to determine if AD subjects’ poor performances were in part a result of an impoverished semantic store of affective knowledge, or if they were perhaps due to disorganization of intact semantic affective knowledge. They had AD and control subjects identify the specific emotion depicted in each of 14 line drawings of emotionally laden scenes, in which a target figure had no facial features. The subjects were to choose from a selection of faces which displayed seven primary emotions, adapted from Ekman and Friesen’s (1976) Pictures of Facial Affect: 1) happiness, 2) sadness, 3) disgust, 4) fear, 5) anger, 6) surprise, and 7) indifference. Three versions of the task were administered to all of the subjects. In the free-encoding version, subjects were shown each of the images sequentially and asked to identify the facial expression that was most appropriate for the target figure. In the subject-directed version, subjects were asked to identify two key features that had been pointed to by the experimenter before they completed the same facial expression selection task. In the experimenter-directed version, the experimenter pointed out the same two key features and provided a brief, non-emotive description of the situation prior to having the subjects match the facial emotion. The larger AD group was split into “high” and “low” AD groups based on MMSE scores and compared to normal controls on the three versions of the experimental task. Both patient and control groups showed facilitation effects across the three task versions. The low AD group did not show any
improvement between subject-directed encoding and free-encoding conditions, but they scored significantly higher in the experimenter-encoding condition when compared to the free-encoding and subject-directed encoding conditions. High AD and control subjects also showed this same pattern of facilitation, but with overall higher score values. The authors took this as evidence in support of their hypothesis that the semantic stores of affective information are still present in AD, but that the stores are either disorganized or inefficiently accessed.

Finally, Burton and Kaszniak (2001) examined the emotional experiences of individuals with mild AD after brief (6 sec) exposure to images selected from the International Affective Picture Series (IAPS, CSEA-NIMH, 1999). The IAPS has been thoroughly evaluated, and subsets of positive, neutral, and negative images were selected from this set based on their normative ratings of valence and arousal. Immediately after image presentation, the 12 AD subjects and 21 control subjects rated their experience of happiness/sadness and arousal/relaxation on two separate 9-point scales of a Self-Assessment Manikin (SAM, Lang, 1980) for each of the 36 images they viewed. No significant group or group x image valence type differences were found on either the valence (happiness/sadness) self-report scale nor the arousal/relaxation scale, and the authors concluded that emotional experience may remain intact in the early stages of AD.

Action tendencies and Emotion expression – Relatively few studies have examined ratings of facial expression or physiologic aspects of emotion expression in healthy older adults. In addition to the finding discussed earlier regarding emotion perception in older adults, Moreno and colleagues measured the asymmetries of posed facial expression of
emotion in young, middle-aged, and older women (Moreno, Borod, Welkowitz, & Alpert, 1990). Women were selected as the study subjects as they are typically more emotionally expressive and feature greater laterality in their facial expressions. The subjects were asked to pose four emotional expressions: happiness, pleasant surprise, sadness, and disgust. Three expression raters, also female and naïve to the study's purpose, rated photographs of these expressions. Overall, all subjects demonstrated greater left-sided emotional expression, and there was no effect for age group. Thus, the authors concluded that the continued asymmetry in facial emotional expression supported the notion that the right-hemisphere mediates emotional processing throughout the life cycle. A limitation to the interpretation of these results is the fact that Moreno and colleagues had subjects pose emotional expressions. Voluntary emotional expression is under different neural control than stimulus-elicited or spontaneous expressions (Matsumoto & Lee, 1993).

Evidence of age-invariant stimulus-elicited emotional expression was provided by Reminger, Kaszniak and Dalby (2000), who investigated emotional experience and facial expression in older (mean age = 68.4 years) and younger (mean age = 26.4 years) healthy adults using a picture perception methodology similar to the one used in the present project. Bilateral EMG recordings were made of the zygomatic and corrugator muscle regions during presentation of emotionally salient images and SAM ratings of valence and arousal were made immediately thereafter. Despite having sufficient statistical power to detect potential group differences, no significant differences were found on any of the emotion measures. The authors concluded that emotional experience and emotional expression remain invariant from younger to older adulthood, which contrasts
with the conclusions of some previous investigators suggesting that emotional experience and expression is diminished with age.

As with the normal aging literature, there are relatively few studies which address emotional expression or action disposition in AD. One such study, by Smith (1995), measured facial expression of AD subjects while viewing 10-second video clip vignettes. The Facial Action Coding System (Ekman and Friesen, 1978) was used to rate videotaped facial expressions of both AD and control groups, and subjects were also asked to rate their level of happiness after each vignette. Although the subjective ratings of emotional experience were similar across groups, the individuals with AD demonstrated a greater number of negative facial expressions while viewing sad vignettes. The individuals with AD also evidenced a significantly lower correlation between emotional experience ratings while viewing positive vignettes and facial expressions than controls. Smith interpreted these findings as suggestive of deterioration in the abilities of AD subjects to inhibit the expression of negative emotions.

In addition to the well known effects AD has on the hippocampal formation, the amygdala has been shown at post-mortem evaluation to undergo significantly more atrophy in individuals with AD than in normal age-matched control subjects (Herzog & Kemper, 1980). Given what is known about the amygdala’s involvement in Lang’s model of emotion (1995), it is possible that amygdaloid degeneration may play a role in any emotional processing difficulties that individuals with AD experience, and startle reflex modulation would seem a useful metric for the detection thereof. Toward that end, Burton and Kaszniak (2001) examined facial expression and action tendencies in AD by
measuring orbicularis oculi, corrugator supercilii and zygomaticus major
electromyographic (EMG) activity during presentation of valenced (positive, neutral, and
negative) images selected from the IAPS (1999). Orbicularis oculi recording was used to
assess emotion-related modulation of the startle reflex. No significant differences were
detected between the AD group and age-matched controls on magnitude or direction of
startle reflex modulations, however this may be a reflection of limited statistical power
available with the study’s sample sizes. Nor were there any significant differences in
corrugator activity in response to the varying image types, and both groups displayed the
expected pattern of increased corrugator activity in response to negative images and
decreased corrugator activity in response to positive images. However, the zygomatic
muscle activity was significantly different between the groups. The control subjects
displayed the expected pattern of zygomatic activity, with maximum muscle activity
detected during exposure to positive images and the least muscle activity in response to
negative images. The AD group, however, displayed the opposite pattern: increased
zygomatic activity during exposure to negative images, and decreased activity in
response to positive images. The authors stressed that these results are tentative due to
their small sample size (12 AD subjects), but speculated that an increase in grimacing
behavior in the AD group may explain these results. This finding may be in line with that
of Smith’s (1995), which suggested that cognitive control over negative affective
expressions is reduced in early AD.

**Physiological arousal** – There is, to this author’s knowledge, only one published study
has examined autonomic nervous system (ANS) activity in healthy aging. This study, by
Levenson, Carstensen, Friesen & Ekman (1991), examined emotion-specific changes in ANS functioning, in young and old age groups. They attempted to induce ANS changes by utilizing posed facial expressions of emotion and relived past emotional experiences, and measured heart rate change and finger temperature as their index of ANS activity. They found that, while overall magnitudes of ANS changes were smaller in the older group, the patterns of activity were similar to the younger group and generalized across the two emotion induction techniques. Interestingly and in contrast to folk wisdom, there were no gender differences within the elderly group with regard to the ANS measures across both techniques, but the elderly women in their study did report experiencing more intense emotions than the elderly men.

No studies have directly examined ANS arousal as it relates to emotion in AD. However, several studies have examined the overt arousal-related behaviors of AD subjects in clinical settings. These studies have generally found significantly increased levels of agitation, irritability, suspiciousness, and restlessness in AD subjects (Wagner, Teri & Orr-Rainey, 1995).

Summary - In sum, few studies have found evidence for adult age-group differences in the pattern of emotion components in healthy aging, but numerous studies have found some type of impairment of emotion processing abilities in AD. However, the explanations for the AD groups’ performances have ranged from primary deficits in emotion processing to primary deficits in cognition. One possible explanation for the discrepancy between the findings in the two most directly comparable and contradictory studies, those by Allender and Kaszniak and by Albert et al., can be found in the
demographic characteristics of the subject populations. The study by Allender and Kaszniak included two groups of individuals with AD, split by age (above and below 72), whose mean ages were 66.3 and 79.9 years, respectively. Their control group had a mean age of 68.1 years. In contrast, the study by Albert et al. used a group of individuals with AD whose mean age was 89.6 years, and their control group’s mean age was 87.5. With such large age differences in both patient and control groups, it may be inappropriate to directly compare their results. It is possible that cognitive decline that could occur with normal aging between the ages of 68 and 87 may have brought Albert et al.’s control group much closer to the AD group in terms of performance, eliminating any possible effect for emotion processing deficits. Also, the subjects in Albert et al.’s study, both patients and controls, were recruited from a nursing home. This raises the possibility that those subjects may have had other illness or been receiving medications that could affect cognitive and emotional processing and raises questions about generalizability.

Another possibility is that the studies did not, in fact, differ in their findings. The emotion tasks that Allender and Kaszniak used were very similar to two tests used by Albert et al. that remained significantly different between the AD and control groups after equating for the cognitive tasks they selected on an a priori basis. The individuals with AD’ relative deficits on these tasks were eliminated only after the authors included other cognitive tasks in a second multiple regression analysis, and the rationale for inclusion of those tasks was unclear. In multiple regression analyses, the proportion of target variance accounted for may be artificially inflated by the inclusion of large numbers of predictor variables. Given that the authors did not provide a clear rationale for including the
additional variables, it is plausible to consider that their findings were artificially affected by those variables, and that the results of these two studies were in fact similar.

Clinical assessment of emotion - Behavioral problems related to emotion are among the most trying symptoms with which caregivers and clinicians must cope when interacting with persons with AD. The importance of applying what is known about emotion in AD to behavioral management is perhaps one of the most important contributions this field can make. Below is a review of some of the recent, relevant literature on this topic.

Lawton, Van Haitsma and Klapper (1996) attempted to assess affect in a nursing home AD population. They constructed a 6-item affect rating scale, taken from the previously developed 10-item Philadelphia Geriatric Center Positive Affect and Negative Affect Scales (Lawton, et al., 1992), for use in direct observation and assessment of the patients, and included items assessing pleasure, interest, contentment, sadness, worry/anxiety, and anger. Each of these item’s criteria relied upon observable changes in behavior, including facial expression, bodily movements, posture, and gestures. Raters were asked to observe patients for 10-minute periods and to rate how much time each patient spent exhibiting each of the six types of affect. 224 individuals with AD were observed 16 times over a four-week period, and 29 were observed between eight and 15 times for a total of 253 subjects. 43 nondemented residents of the nursing home were also observed and used as a comparison group. These 10-minute observations yielded good intrarater reliability on each of the items (kappas between .76 and .89), and several significant differences were found in emotional expression between the groups. AD subjects spent significantly more time exhibiting anxiety and significantly less time
exhibiting pleasure, interest and contentment. The authors also attempted to determine the nature of affective space for AD subjects by factor analyzing their ratings. They obtained support for both a two-factor and a bipolar single-factor affective structure. The authors speculated that the support for a single-factor structure, which did not account for their measure of anger, could reflect a disease-induced simplification of emotion. The observed two-factor solution featured only partially independent positive and negative affective factors, which was accounted for by dual loadings of interest, contentment, and sadness. The authors suggested that the relationship between interest, anger, and anxiety might be due to their shared higher levels of activation or vigorous involvement, and that contentment and sadness appear to have been more "global" states, resulting in considerable crossover.

Starkstein and colleagues (1995) sought to describe the prevalence of pathological affect in AD as well as to elucidate the psychiatric and neuropsychological variables to which it is related. Pathological affect was defined as emotional lability or pathological laughing or crying, i.e., laughter or crying that occurred suddenly without the presence of a mood disorder. On the basis of clinical assessment results, these pathological affect criteria were used to assess the prevalence of pathological affect in 103 individuals with AD. They found that 39% of the AD subjects displayed pathological affect of some kind; 26 were found to display pathological crying, 14 displayed pathological laughing or mixed affect, and 63 displayed no pathological affect. In addition to the neuropsychological and psychiatric tests, AD subjects received the pathological laughing and crying scale (PLACS), which was originally developed for use in assessing affect in
stroke victims (Robinson, Parikh, Lipsey, Starkstein & Price 1993). The PLACS is a 16-item scale consisting of eight items measuring pathological laughter and eight items measuring pathological crying, and it was given to both the patients and one of their caretakers. The PLACS measures affective characteristics such as the duration of the affective episodes, inappropriateness in relation to emotions, and the degree of distress. The authors found that those subjects described as displaying pathological affect did indeed score higher on the PLACS than those who did not, and they took this as partial validation for their pathological affect diagnostic criteria. In addition, those subjects who displayed pathological crying were found to have significantly higher scores on tests of depression and anxiety as well as a higher frequency of depression than those who did not display pathological affect, suggesting that mood disorders may in part be responsible for pathological affect in AD. No relationship was detected between pathological affect and neuropsychological test performance.

Roberts, Ingram, Lamar & Green (1996) investigated the abilities of AD subjects to comprehend, produce, and repeat emotional prosody, and attempted to ascertain whether there were any relationships between prosody impairments and disturbances of affect in AD. 20 subjects with probable AD (with 10 classified as mildly demented and 10 classified as moderately demented) and 11 elderly control subjects were asked to: 1) reproduce prerecorded, neutrally spoken sentences using either an angry, surprised, or sad tone of voice; 2) reproduce emotionally neutral prerecorded sentences which were conveyed with either an angry, surprised, or sad tone of voice, using the same emotional tone; and 3) identify the emotional tone of prerecorded sentences conveyed with either
anger, surprise, or sadness. Subjects were asked if the speaker’s emotional intonation was angry, surprised, sad, or neutral, and were allowed to point to cartoon pictures representing these emotions to reduce problems associated with anomia. In addition, family members completed the Cohen-Mansfield Agitation Inventory, a questionnaire assessing 29 agitation-related behaviors on likert scales over a 2-week period, and the Cornell Depression Inventory, with regard to the patient. The authors found that the moderately demented AD group performed significantly worse on the prosody elicitation and prosody repetition tasks than the control and mildly demented AD groups, and both AD groups performed significantly worse on the prosody comprehension task than the controls. They also found significant negative correlations between the moderate AD group’s Cohen-Mansfield scores (in which higher scores signify greater agitation) and their performances on the prosody elicitation task, prosody repetition task, and on tasks that required angry and surprise prosody. Significant negative correlations were also observed between the moderate AD group’s Cornell scores (in which higher scores signify greater depression) and performance on tasks that required angry prosody. The authors concluded that the affective components of language are impaired in AD, and that they parallel, perhaps in a more accelerated manner, the typical language deficits observed in AD. In addition, they noted that there is a relationship between communication impairments in emotional prosody and disturbances in affective behavior, and that these findings are particularly important when one considers the potential for amelioration of behavioral problems via caregiver assistance with emotional expression.

Summary - The body of literature addressing emotion in young adults, healthy aging and
AD remains small but is experiencing rapid growth. From this review it is clear that conscious appraisal emotional experience and the assignment of emotional significance have been the most intensively investigated aspects of emotion in these populations, yet the conclusions from that subset of the literature remains in disagreement with regard to the latter two groups. Methodological difficulties and differing conceptualizations of emotion have contributed to our limited understanding of cognitive appraisal of emotion, particularly amongst the healthy elderly and AD populations. None of the three components of emotion, namely conscious appraisal, expression/action tendencies, and physiological arousal have been thoroughly investigated in the elderly and AD populations, and debate within those areas of emotion has yet to be rigorously engaged. We are thus left with the same questions as we began: What is the best way to characterize the processing of emotional information in healthy aging and AD? Is there a primary deficit in the emotion processing abilities of individuals with AD? If so, at what point is there a breakdown in the processing of emotional stimuli? And are there any differences in the time course of emotion processing, or what Davidson (1998) has referred to as affective chronometry?

The present study attempts to less ambiguously address these conflicting findings regarding the processing of emotional stimuli in healthy aging and in AD by examining their responses to emotion-eliciting images and sounds, using both self-report and physiological measures. If emotion processing is impaired in AD, differences between the groups would be expected on either or both types of proposed measures. If emotion processing is intact in AD, no differences would be found, or the differences that are
found would be better explained by non-emotional, cognitive deficits. Before proceeding with a more detailed description of the present study and the hypotheses to be tested, the research and theory pertaining to the stimuli and physiological measures that were used will be briefly reviewed.

The Present Study

The aim of the present research was to characterize several aspects of emotion in young adults, healthy older adults, and individuals with AD by assessing subjective experience, facial muscle activity, and startle reflex modulation when exposed to emotionally salient images. Three experiments were designed toward this end, the first of which studied affective chronometry in YA by utilizing startle probes both during and after stimulus presentation, similar to the methodology used by Bradley, Cuthbert & Lang (1993). The second experiment compared YA and OA on several measures of emotion, including conscious appraisal of emotional experience, startle reflex modulation and its temporal resolution, and facial EMG. The third and final study compared OA and AD groups on those same measures.

It should be noted that conscious appraisal of emotional experience is not expected to differ systematically by group in these experiments. This expectation is based on previous pilot observations, which is likely a function of the fact that while we are asking individuals to rate their emotional experiences, their responses are probably overly determined by previous, similar emotional experiences to stimuli resembling those to be employed. That is, despite instruction to focus upon and rate their emotional experience in viewing the scenes, it is likely that the AD subjects base these ratings on
previously established (and now part of semantic memory) responses to these kind of stimuli.
Experiment 1

Hypotheses: The YA group will demonstrate the expected pattern of emotion-modulation of the startle reflex when probes are administered during the image presentation period. It is predicted that the reflex pattern will resolve within 3 seconds of the removal of the image, consistent with previous findings. In addition, they will demonstrate the expected patterns of facial muscle activity when viewing images.

METHODS

Participants

51 young adults (age range: 18-26; see Table 1) participated in the experiment. They were recruited from an introductory psychology course and received course credit as compensation. The experiment was approved by the University of Arizona’s Human Subjects’ Committee.

Table 1

Demographic Characteristics of Subject Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Gender (M/F)</th>
<th>Mean Age (SD)</th>
<th>Mean Ed (SD)</th>
<th>MMSE (SD)</th>
<th>GDS (SD)</th>
<th>CSDD (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD</td>
<td>7</td>
<td>6/1</td>
<td>69.7 (9.0)</td>
<td>17.1 (1.9)</td>
<td>21.9 (5.3)</td>
<td>4.0 (2.8)</td>
<td>2.5 (3.1)</td>
</tr>
<tr>
<td>OA</td>
<td>15</td>
<td>4/11</td>
<td>67.2 (7.7)</td>
<td>17.2 (2.4)</td>
<td>28.5 (1.9)</td>
<td>2.6 (1.1)</td>
<td>NA</td>
</tr>
<tr>
<td>YA</td>
<td>46</td>
<td>19/27</td>
<td>19.7 (2.2)</td>
<td>12.8 (1.0)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

AD = Alzheimer’s Disease group; OA – Older adult group; YA – Young adult group; Ed = Years of education; MMSE = Mini-Mental State Examination; GDS = Geriatric Depression Scale; CSDD – Cornell Scale of Depression in Dementia.
and all subjects were provided with informed consent. Subjects were required to see well enough to read and to hear well enough to comprehend spoken instructions. All subjects were queried regarding any history of psychiatric disorder, neurological diagnosis, history of facial muscle injury, and current prescription medication use. A history of any of the first three criteria disqualified subjects from participating, which was the case with two of the YA subjects who were diagnosed with depression and attention deficit disorder. The current medication list was tabulated to ensure subjects were not consuming medications that have known effects on emotion, including anxiolytics, stimulants, and antidepressants. No subjects were excluded for this reason. Three subjects were excluded from these analyses due to technical difficulties with the psychophysiological hardware and software.

**Materials**

Pictures were selected from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, 1999) to represent positive, neutral, and negative emotional valences. This image set, which contains nearly 1000 images, was carefully designed to investigate how positive/negative (valence) and calm/excited (arousal) the images made people feel. Lang and colleagues have provided extensive normative data on these images, and have arrived at consensus subjective emotional ratings provoked by the stimuli. The consensus ratings for each emotional experience in response to each image were obtained by displaying sets of 60 images to group samples of approximately 100. After viewing an image, subject will utilize a Self-Assessment
Manikin (SAM, see Fig. 1; Lang, 1980) to rate their emotional experience along the two
dimensions (valence and arousal). The SAM was designed to allow subjects to report
their subjective emotional experience in response to the images while minimizing the
effects language and culture can have on rating. Both the arousal and valence ratings
were ordinally scaled along with five figures which allowed for a rating of 1 to 9 on each
dimension. The SAM ratings have been found to be correlated with physiological
responses to the images (Lang, Greenwald, Bradley & Hamm, 1993). Ratings of valence
correlated negatively with corrugator EMG activity, and positively with zygomatic EMG
activity and cardiac acceleration. Ratings of arousal correlated positively with
electrodermal activity. These findings provided a firm basis for using the SAM as a
measure of self-evaluation of emotional experience in response to the images. We
utilized the SAM for subjective ratings of emotional experience.

Two sets of 76 images were prepared, with the first four images used as practice
trials, leaving a total of 72 images (24 each from the three valence categories). The
image sets were matched using the IAPS normative data (Center for the Study of
Emotion and Attention, 1999) for valence and arousal. The positive and negative image
groups were also matched for arousal level. A trend for differential arousal amongst the
neutral images used at the differing time points for startle probe trials (during, 300ms
after and 3000ms after image offset) was discovered subsequent to study commencement,
and while not significant was of sufficient concern for us to modify the image sets and
create two additional sets of the same images, but with a better distribution of neutral
arousal ratings across the image groups for the differing startle probe times.
During each of the four practice images a startle probe was administered to allow for and accelerate any habituation effects. Previous research from our lab had found substantial startle magnitude habituation, so much so that the normal pattern of startle modulation was skewed, resulting in a higher average startle response to neutral images (which were among the first images shown) than to negative (Manber, Burton, Kaszniak, & Allen, from unpublished data). Bradley, Lang & Cuthbert (1993) also found a general trend of habituation across time, but the affective potentiation and inhibition effects persisted. The presently selected image sets were block randomized, so as to approximate an even distribution of image types throughout the presentation.

These image sets were used in each of the following experiments. Since the IAPS images were normed on college students, efforts were made to include images relevant to an older population (e.g., a grandfather playing with his grandchildren).

Procedure

Behavioral and physiological data were collected in a single, two-hour session. Image set presentation was counterbalanced across subjects. Image presentation was controlled by a computerized script, with a seven-second presentation of a blank screen preceding a six-second presentation of the stimulus. Startle probes were administered between four and six seconds after stimulus onset and at 300 and 3000 ms after stimulus offset. A total of 54 of the 72 trials contained startle probes. After the image was removed, a blank screen was shown for seven seconds to allow for the 3000ms probe presentation condition, after which the participants made their subjective ratings. Spoken, digitized instructions, also controlled by the computerized script, accompanied the image
A computerized version of the SAM was used in this experiment. A digitized image depicting the same figures as the SAM was presented during the image rating period, with each of them numbered 1 (highest) through 5 (lowest). The computerized script asked the subjects to rate the images verbally at the appropriate time.

Figure 1

The Self-Assessment Manikin (SAM; Lang, 1980), Valence and Arousal Scales, respectively.

Electrophysiological measures were recorded for three seconds before, six seconds during and seven seconds after image presentation, for a total of 16 seconds per
EMG recordings were made of the left corrugator supercilii and zygomaticus major facial muscles (see Fig. 2) and were sampled at 1000 Hz. EMG recordings of the orbicularis oculi muscle were sampled at 2000 Hz to allow for clearer resolution of the startle reflex phenomena. The EMG data was processed off-line and included band-pass filtering over a range of 10 to 500 Hz for corrugator and zygomatic channels and 10 to 1000 Hz for the orbicularis channel, signal rectification, and waveform smoothing over a moving window of 20 points for the corrugator and zygomatic channels and 10 points for the orbicularis channel.

Figure 2
Facial muscle sites of interest.

The EMG recordings were made using 4mm surface electrodes connected to BioPac bioamplifiers and a BioPac MP150 system. Electrophysiologic data was recorded onto an AMD Athlon-class computer. The target EMG muscle sites were prepared using standard cleaning techniques. They were cleansed with rubbing alcohol and then abraded with NuPrep skin preparation gel. The electrodes were filled with Signa Gel electrode
gel and attached using highly adhesive collars. Two electrodes were attached to each site, 1 cm apart, with a common ground attached to the center of the forehead. After electrode attachment, the impedences of the electrode sites were checked, and any sites that exceeded 10 kohms were removed and cleansed again. Once all impedences were at a satisfactory level, baseline EMG recordings were taken of each site as the subjects were asked to “show their teeth,” “furrow their brow,” and blink, to ensure that the electrodes were properly placed and that the computer was receiving the data.

Subjects were seated in an upright reclining chair, located in a temperature-controlled, dimly lit room during electrode connection and throughout the testing session. Visual stimuli of approximately 800 x 600 resolution were displayed on a 17” computer monitor approximately 2 feet from the subject. The experimenter was located in a separate control room throughout the experiment.

After electrode attachment, the experimenter read standardized instructions for the task and allowed an opportunity for clarification questions. The subjects were told that they would view images that vary in their content, and that some of the images may be difficult to look at, but that they must attend to the images for the entire time they are shown. They were also told that there would be a brief, loud noise, during some of the images, but that they should do their best to ignore it. They were told to rate the images after each presentation on two dimensions: valence and arousal. These dimensions were explained in the instructions and the rating system was demonstrated.

Psychophysiological data scoring and Exclusion criteria

Startle reflexes were defined as positive peak-to-peak orbicularis activity within a
150ms time window after startle probe onset. Valid startle responses were defined as those changes in orbicularis activity that exceeded averaged resting baseline levels. Trials in which orbicularis data did not meet that criterion were dropped from the analysis. Outliers were identified as scores three or more standard deviations above or below the mean startle response for an individual. Outliers were then eliminated from the data set as it these will likely represent muscle artifact or inadvertent muscle movement. The total percentage of startle reflex trials lost due to technical difficulty, non-startle responses, or outliers was 5.7%. Subjects for whom there was a greater than 50% orbicularis data loss were to be excluded from the orbicularis analysis entirely, but none met this criterion. Those dropped subjects’ zygomatic and corrugator data were to be retained for the other psychophysiological analyses.

Corrugator and zygomatic EMG data were obtained by subtracting the baseline mean muscle activity measured over a three-second interval before stimulus presentation from the mean muscle activity measured over a three-second interval immediately after stimulus onset. Again, outliers were defined as change scores exceeding three standard deviations from the individual’s mean change score, and those scores were excluded. The percentage of trials lost due to technical difficulty or outliers was 0.7%.

Raw data from all physiologic measures were converted into z-scores on a within-subject basis across all trials for startle reflex, corrugator, and zygomatic variables. Z-score transformation of raw physiologic data is a common method for eliminating the obfuscating effects of high levels of between-subjects variability in overall response magnitudes characteristic of these physiologic measures. By eliminating this variability
we are better able to describe the overall patterns of activity of interest and identify outliers.
RESULTS

Subjective rating data. To check for equivalent responses across the four stimulus sets, 3 (image valence) x 2 (gender) x 4 (stimulus set) repeated measures ANOVAs were conducted for both valence and arousal ratings. No significant effect of the time point of startle probes on valence ratings was detected, that is, no overall rating differences were found between those trials in which probes were administered during, 300ms after, or 3000 ms after stimulus presentation, F (2, 76)=.72, p=.48. As expected, a main effect of image valence was detected, F (2, 76) = 460.0, p<.000, with the ratings following the expected pattern (see Fig. 3). However, unexpected interactions involving valence ratings were detected, including a time by valence interaction, F(4, 152) = 5.4, p=.001, a time by gender interaction, F(2, 76) = 4.2, p=.02, a time by valence by stimulus set interaction, F(12, 152)=3.5, p=.001, and a time by gender by valence interaction, F(4, 152) = 2.8, p=.03. It should be noted, however, that none of these interaction effects explained much of the variance of the valence ratings, with partial etas of .124, .101, .216, and .069, respectively. In comparison, the main effect for valence provided a partial eta of .924. These subtle interaction differences across valence categories did not affect the overall patterns of subjective ratings, which were as expected for each time point and in each stimulus set. The between subjects effect of the stimulus set was also not significant, F (3, 38) = .68, p=.56. Given that there were no such differences in the normative valence and arousal data for the stimulus sets, it was decided to retain them in their current form.
Figure 3

SAM Valence ratings of emotional experience across the different probe-time trials for YA group.

Arousal ratings were also examined with a 3 (valence) x 2 (gender) x 4 (stimulus set) repeated measures ANOVA. A significant effect of probe-time was detected, F(2, 76) = 5.0, p = .01. As expected, a significant main effect of valence was found, F(2, 76) = 65.4, p < .000 (see Fig. 4). A three-way interaction between time, valence, and stimulus set was also noted, F(12, 152) = 4.8, p < .000. This interaction effect did not explain large amounts of the variance in arousal ratings, with a partial eta of .276. The valence effect,
in contrast, had a partial eta of .631. Between subjects effects were not significant for either gender, $F(1, 38) = .21, p = .7$, nor stimulus set, $F(3, 38) = .54, p = .7$.

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**Figure 4**

SAM Arousal ratings of emotional experience across the different probe-time trials for YA group.

![SAM Arousal Ratings](image)

- SAM = Self-Assessment Manikin; YA = Young adult group

**Startle reflex image set data.** To check for equivalent responses to the image sets, a 4 (stimulus sets) x 3 (image valence) repeated measures ANOVA was conducted for the startle reflex data of the YA group. Consistent with our expectations and in keeping with
the intent of our valence- and arousal-matched stimulus set construction, no significant effect of stimulus set was observed, $F(3, 41) = .5, p = .68$.

**Startle reflex modulation.** Startle reflex modulation was tested with a 3 (image valence) x 2 (gender) x 4 (stimulus set) repeated measures ANOVA of the valence variable’s effect on EMG recordings from the orbicularis oculi muscle site when probed during image presentation. The predicted significant within-subjects effect for the valence variable was detected, $F(2, 76) = 9.0, p < .000$, with the emotion modulation effect present in the predicted valenced pattern, $F(1,38) = 13.0, p < .000$ (Fig. 5). There were no between-subjects effects for gender, $F(1, 38) = .74, p = .4$, nor stimulus set, $F(3, 38) = .94, p = .4$.

**Chronometry of Startle reflex modulation.** A 3 (time of probe) x 3 (valence) repeated measures ANOVA of the startle reflex modulation data detected a significant main effect for time, $F(2, 76) = 20.25, p < .000$, as predicted. The principle effect was a reduction in startle reflexes elicited 300ms after stimulus offset, as evidenced by a within-subject contrast of the time variable fitting a quadratic function, $F(1,45) = 71.9, p < .000$. This finding was consistent with previous research suggesting a prepulse inhibition effect for startle reflex magnitudes elicited shortly after stimulus removal. The predicted overall main effect of valence was also found, with the linear function providing the best fit, $F(1,45) = 4.6, p = .01$. However, there was a significant time by valence interaction, such that the expected pattern of startle reflex modulation was still present not only during image presentation, as described above, but also at the 300ms probe-time, with the negative images found to solicit a greater magnitude of reflex than the neutral or positive
images $F(1,45) = 22.9$, $p < .000$. The expected pattern of startle reflex modulation not only disappeared at the 3000ms probe-time, as had been predicted, but had in fact inverted, such that the greatest reflex magnitude was observed after viewing positive images, compared to neutral and negative images, $F(1,45) = 6.9, p = .01$ (Fig. 5).

**Figure 5**

Startle reflex modulation during image viewing and at the 300ms and 3000ms probe times for YA group.

YA = Young adult group; During = startle probes administered during image presentation; 300ms = startle probes administered 300ms after image offset; 3000ms = startle probes administered 3s after image offset.
**EMG data.** Facial EMG activity was tested with a 2 (gender) x 3 (image type) repeated measures ANOVA for mean corrugator and mean zygomatic change scores. Corrugator analyses found the predicted significant effect for image valence, $F(2,88)=64.4, p<.000$. This effect was best explained by a linear model in an within-subjects contrast, $F(1,45), F=90.8, p<.000$ (Fig. 6). No gender by image valence effect was observed, $F(2,88) = 1.99, p=.14$.

Analyses of the zygomatic EMG data revealed a significant effect for valence, $F(2, 74)=8.2, p=.001$. A within-subjects contrast analysis demonstrated that a linear model best fit this effect, $F(1, 44) = 40.9, p<.000$ (Fig. 6). A valence by gender trend was also observed, $F(1,44) = 3.0, p=.06$. 
Figure 6

Corrugator and Zygomatic EMG recordings for YA group.
DISCUSSION

In most ways, the results of Experiment 1 were exactly as predicted and replicated most of the previous findings regarding emotional experience, facial expression, and startle reflex modulation in young adults. Self-report of conscious appraised emotional experience coincided with normative ratings and did not demonstrate significant gender or stimulus set effects. EMG recordings of facial expression of emotion, as indexed by EMG activity at the zygomatic and corrugator muscle sites, documented the expected patterns of activity, that is, an increase in zygomatic activity was observed during positive trials compared to negative trials, and the inverse was true for the corrugator muscle activity. In addition, startle reflex modulation measured in the standard method, with startle probes administered during the second half of the image viewing period, demonstrated the expected pattern of emotion modulation, with eyeblink responses greatest when startled during negative image trials, and weakest when startled during positive image trials.

Perhaps the most intriguing finding from this experiment was that of the temporal resolution of the startle reflex. The resolution observed in the present study differed substantially from what was observed in the two previous studies that have examined this phenomenon, both of which found that emotion-modulation of the startle reflex dissipated very rapidly and remained so up to 3800ms after stimulus offset. The present results found that emotion modulation was still present at 300ms post-offset, albeit in a reduced magnitude owing to prepulse inhibition effects as had been found in the Bradley, et al., study (1993). This is precisely the same probe-time that Bradley et al. had used,
yet they did not detect a significant effect for emotional valence. Interestingly, visual inspection of the graphs of emotion modulation they documented suggests the expected pattern of reflex modulation at the 300ms probe-time, but since they did not report the F statistic for that analysis it is impossible to say whether this trend might have become significant with enhanced statistical power. Thus, it may be the case that the emotion-modulation effect on startle eyeblink responses is of slightly greater duration than had been previously reported.

The present finding of an enhanced startle eyeblink response 3000ms after positive image offset, compared to neutral and negative image trials, was also somewhat surprising, as neither Bradley et al. (1993) nor Dichter et al. (2002) described anything resembling this phenomenon. Both of those studies documented a resolution of the emotion-modulated startle reflex by 3800ms and approximately 2000ms, respectively, but neither had looked at the 3000ms time point. One possible explanation for the discrepancy in these findings is that an event occurs about 3s after stimulus offset, one which is not detectable either at 2000 or 3800ms. The interpretation offered here for this finding is that of a startle reflex “rebound” effect subsequent to viewing positive images. Descending inhibitory projections from frontal cortical regions to the amygdala may be responsible for the inhibition of the startle reflex during positive emotional experiences. However, such inhibitory circuits would have to release their inhibition at some point, and doing so fairly shortly after viewing pleasant pictures would seem to be a sensible feature for this circuit. Thus, a release from inhibition effect, with a slight overshoot in the degree of disinhibition, may be resulting in a temporally discrete period of
exaggerated startle reflex response.

The unexpected interactions observed above present a potential limitation to the interpretation of these results. However, these interaction terms, while statistically significant, did not explain much of the variance in self-report of emotional experience nor in startle reflex modulation. In addition, there was nothing in the normative dataset of IAPS to suggest that the construction of the stimulus sets, specifically regarding ratings of images distributed over probe-times, which would suggest any differential emotional experiences at the differing probe-times.

One final note regarding Experiment 1 is that there were no detectable main effects for gender or stimulus set. Given this, it was decided to drop these variables from the analyses in Experiments 2 & 3.
Experiment 2

Hypotheses: Based on previous findings (Reminger, Kaszniak & Dalby, 2000), no differences were expected between YA and OA groups on measures of startle reflex modulation and facial expression. We predicted that the resolution of the emotion modulation of the startle reflex in YA and OA will occur within 3 seconds of image offset, based on previous work by Bradley, Cuthbert & Lang (1993) and Dichter, Tomarken & Baucom (2002). However, it is predicted that the OA group will demonstrate a more rapid dissolution of the startle modulation effect. This hypothesis is based on the established observation that prefrontal cortical regions lose volume and some functionality with normal aging. These cortical regions are responsible for the inhibition of excitatory amygdaloid projections to brainstem nuclei governing the eyeblink reflex observed during positive emotional experiences. Thus, it is hypothesized that the frontal cortical inhibitory circuit is still functional in normal aging, but may be weakened such that its inhibition is released more quickly.

METHODS

Participants

To test the hypotheses regarding aging's impact on affective processing systems, 15 non-demented older adults (OA; aged 55-82) were recruited. Older adult subjects were recruited from the spouses and caregivers of the individuals with AD, ongoing studies at the University of Arizona Medical Center’s Department of Neurology and Southern Arizona VA Healthcare System, as well as from the community at large. All
older adult subjects were compensated $10 for their participation. All subjects were required to see well enough to read and to hear well enough to comprehend spoken instructions. Subjects were also screened for clinical depression. We administered the Geriatric Depression Scale (GDS; Sheikh & Yesavage, 1986), with a cutoff of a score of 11 or greater. None of the subjects fit this criterion. All participants were screened for any history of prior brain injury or psychiatric illnesses, as well as for any illness or injuries that may have affected their voluntary facial musculature. None of the subjects met these criteria. Current medications were also recorded, and none of the subjects were taking medications thought to influence emotion. All older adult subjects were given the Mini-Mental State Examination (MMSE; Folstein, Folstein & McHugh, 1975), and healthy older adults who scored below a cutoff of 25 were to be excluded from the study, however none met this criterion.

Materials and Procedure

Because no significant effects of stimulus sets were detected in Experiment 1, it was decided to utilize just the first two stimulus sets we created. Aside from this and the population of interest, all other aspects of the methodology were identical to Experiment 1.

The percentage of trials lost due to technical difficulty, non startle responses, or outliers for the OA group’s startle reflex measure was 14%. The percentage of facial EMG trials lost due to those same problems was 0.3%.
RESULTS

Subjective rating data. 3 (valence) x 2 (age group) repeated measures ANOVAs were conducted for valence and arousal ratings. As expected, a main effect of image valence was detected, $F(2, 118) = 602.2$, $p < .000$, with the ratings following the expected pattern (Fig. 7). A within-subjects image valence by group interaction was also detected, $F (2, 118) = 5.99, p = .003$, suggesting that the groups varied in their valence ratings patterns. This appears to be a very subtle effect, as its partial eta is .092, compared to the .911 partial eta of the valence effect. No overall between-subjects effect of group was found, $F(1, 59) = .45, p = .5$.

Arousal ratings were also examined with 3 (valence) x 2 (age group) repeated measures ANOVA. As with the valence analysis, the expected main effect of image valence was detected, $F(2, 118) = 81.4$, $p < .000$, with the ratings following the expected pattern (Fig. 7). No valence by group interaction was found, $F(2, 118) = .8, p = .44$. No between subjects effect was found either, $F (1, 59) = 2.0, p = .16$. 
Figure 7

SAM Valence ratings comparison of OA and YA groups.

OA = Older adult group; YA = Young adult group;

Startle reflex modulation. Startle reflex modulation was tested with a repeated measures ANOVA of the valence variable’s effect on EMG recordings of the orbicularis oculi muscle when probed during image presentation. The predicted significant within-subjects effect for the valence variable was detected, F (2, 118) = 8.7, p<.000, with the emotion modulation effect in the predicted direction, F (1, 59) = 20.1, p<.000 (Fig. 9).
There was no valence by age group interaction, $F(2, 118) = .57, p=.56$.

Figure 8

SAM Arousal ratings comparison for OA and YA groups.

SAM = Self-Assessment Manikin; OA = Older adult group; YA = Young adult group.

**Chronometry of Startle reflex modulation.** A 3 (probe-time) x 3 (valence) x 2 (age group) repeated measures ANOVA of the startle reflex modulation data detected a significant main effect for time, $F(2, 118) = 14.4, p<.000$, as predicted. The principle
effect was a reduction in startle reflexes elicited 300ms after stimulus offset, as evidenced by a within-subject contrast of the time variable fitting a quadratic function, $F(1,59) = 8.4, p<.000$. A time by group effect was also noted, $F(2,118) = 2.3, p=.002$ (Fig. 9). This effect was examined more closely with independent repeated measures ANOVAs for the OA group, which found that the expected valence effect on startle reflex.

Figure 9

Startle reflex modulation across probe-times in OA and YA groups.

OA = Older adult group; YA = Younger adult group; During = startle probes administered during image presentation; 300ms = startle probes administered 300ms after image offset; 3000ms = startle probes administered 3s after image offset.
modulation had disappeared by 300ms after stimulus offset, $F(2,28) = 1.5, p=.23$, and remained that way at the 3000ms probe-time, $F(2,29) = 1.5, p=.23$. Thus, it appears that the startle reflex modulation may dissipate more rapidly in the OA group than the YA group. The predicted overall main effect of valence was significant and trended in the predicted linear fashion, $F(2,118)=3.3, p=.04$.

EMG data. Facial EMG activity was tested with a 2 (group) x 3 (image type) repeated measures ANOVA for mean corrugator and mean zygomatic change scores. Corrugator analyses found the predicted significant effect for image valence, $F(2,116)=76.6, p<.000$. No valence by group effect was noted, $F(2, 116) = .60, p=.49$, nor was there a between-subjects main effect for group, $F(1, 58) = .94, p=.34$.

Analyses of the zygomatic EMG data revealed a significant effect for valence, $F(2, 116)=31.9, p<.000$. No valence by group interaction was observed, $F(2, 116) = .15, p = .85$. No between-subjects main effect was found for group, $F(1, 58) = .07, p=.79$. The main effect was detecting an overall increase in magnitude of zygomatic activity in the OA group, compared to the YA (Fig 10).
Figure 10

Corrugator and Zygomatic EMG recordings for OA and YA groups.

OA = Older adult group; YA = Young adult group
DISCUSSION

Most of the results of Experiment 2 were in keeping with our hypotheses regarding aging’s impact on affective processes. As had been demonstrated previously, conscious appraisal of emotional experiences did not differ between the YA and OA groups, and both demonstrated the expected patterns of responses. Startle reflex magnitudes measured during stimulus presentation were also found to fit the expected pattern in the OA group, and did not differ from the YA group. Likewise, facial expression of emotion in the zygomatic and corrugator muscles fit the expected patterns in the OA group and did not differ significantly from the YA group, with the exception of an overall increase in magnitude of EMG activity in the zygomatic channel for the OA group. Thus, no effect of aging was discernable in these measurable emotion output systems, as expected.

The one measure that revealed a difference between the OA and YA groups was that of the affective chronometry of startle reflex modulation. Temporal resolution of the emotion-related startle response appeared to occur more rapidly in the OA group, disappearing by 300ms after stimulus offset, and remaining so at the 3000ms probe time. This stands in contrast to the finding in YA, which saw a continued emotion-modulation of the reflex at 300ms and a “rebound” effect at 3000ms. If our interpretations of these phenomena in YA are correct, it would suggest that release of the frontal-cortically mediated inhibition of the startle reflex occurs more rapidly in the OA group. This may be a function of weakened inhibitory circuit functioning that accompanies aging.

Closer inspection of the means of startle reflex modulation at the differing probe-
times suggests that the OA group may be experiencing a slight "rebound" effect as well, although it is not statistically reliable. Or, if the notion of a speedier resolution of the startle reflex phenomenon is accurate, what we may be seeing at the 3000ms probe time is the resolution of the "rebound" effect, which may have occurred sometime between the 300 and 3000ms probe times. This is speculation, of course, but is certainly an intriguing possibility and clearly warrants further study.

A limitation of this experiment is the unbalanced gender distribution, featuring 11 women and just 3 men. This distribution places some limits on the generalizability of these findings, and may not accurately reflect the affective processing abilities of older men. However, it should again be noted that no main effects for gender were observed in Experiment 1.
Experiment 3

Hypotheses: We predicted that modulation of the startle reflex during emotional experiences would be reduced, if not eliminated, in AD subjects when compared with the OA group. This hypothesis was based on the above-described neuroanatomical changes associated with AD, and early observations of potential trends on this measure from our previous study. More specifically, it may be the case that the inhibition of the startle reflex during positive emotional experiences may be muted or lost in AD, which would be in line with both our earlier observations and Smith’s (1995) findings. As we were not expecting significant emotion modulation in AD, there can be no resolution and thus no effect of probe-time is expected. Similarly, we predicted that facial expression of emotions will be altered in AD relative to YA and OA controls. Based upon the neuropathological changes in the frontal cortices in AD, observations from our previous pilot study, and the findings of Smith (1995), we expected that individuals with AD would display significantly greater levels of negative facial expression (i.e., corrugator facial EMG), and significantly fewer positive facial expressions (i.e., zygomatic facial EMG).

METHODS

Participants

Eight persons diagnosed with Probable AD participated in the study. Individuals with AD were recruited from ongoing studies at the University Medical Center’s Department of Neurology, from the local chapter of the Alzheimer’s Association, and the
Southern Arizona VA Healthcare System. All older adult subjects were compensated $10 for their participation. OA and AD subjects were matched for age and education levels (Table 1). All subjects were required to see well enough to read and to hear well enough to comprehend spoken instructions. Subjects were also screened for clinical depression. The Geriatric Depression Scale was administered (GDS; Sheikh & Yesavage, 1986), with a cutoff for inclusion in the study set to a score of 11 or greater. None of the subjects were excluded for this reason. Equivalent reliability and validity of the GDS has been reported for AD patients compared to cognitively intact institutional residents (Parmelee & Katz, 1990; Yesavage, Rose, & Lapp, 1981). Since it is possible that AD patients may under-report depression-related symptoms (for review of evidence, see Kaszniak & Christenson, 1994), available informants (typically, the spouse or other closest relative of the AD patient) were interviewed concerning patient behavior utilizing the Cornell Scale for Depression in Dementia (CSDD; Alexopoulos, Abrams, Young & Shamoian, 1988). Again, no subjects were excluded for this reason. All participants were screened for any history of prior brain injury or psychiatric illnesses unrelated to AD, as well as for any illness or injuries that may have affected their voluntary facial musculature. Current medications were also recorded, with the aim of excluding those taking medications with known effects on emotion. None of the subjects were taking such medications, and thus none were excluded.

AD participants had received a diagnosis of probable AD per NINCDS-ADRDA criteria (McKhann, et al., 1984): 1) Dementia is established by clinical examination and documented by performance on the Mini-Mental State Examination (Folstein, Folstein, &
McHugh, 1975), the Blessed Dementia Scale (Blessed, Tomlinson, & Roth, 1968) or a similar mental status examination, and; 2) Confirmed by neuropsychological testing, documenting deficits in two or more areas of cognition, and; 3) Characterized by a history of progressive worsening of memory and other cognitive deficits, with; 4) No disturbance in level of consciousness, and; 5) Symptom onset between the ages of 40 and 90 years, most typically after age 65, and; 6) There is an absence of systemic disorders or other brain diseases that of themselves could account for the progressive deficits.

One AD subject was dropped from the analyses as he appeared to have difficulty comprehending the task instructions.

Materials and Procedure

Because no significant effects of stimulus sets were detected in Experiment 1, it was decided to utilize just the first two stimulus sets we created. Aside from this and the population of interest, all other aspects of the methodology were identical to Experiment 1. The OA group will be used for comparison.

The percentage of startle reflex trials lost to technical difficulty, non-startle responses, or outliers for the AD group was 12.1%. The percentage of facial EMG trials lost to those same problems was 1.5%.
RESULTS

Subjective rating data. 3 (valence) x 2 (age group) repeated measures ANOVAs were conducted for valence and arousal ratings. As expected, a significant main effect of valence was observed, $F(2, 40) = 170.1$, $p<.000$. There was also a trend toward a valence by group interaction, $F(2, 38) = 2.86$, $p=.07$, which appeared to be influenced by the AD group's tendency to rate the negative images as somewhat less negative than the OA group.

Figure 11

SAM Valence ratings of AD and OA groups.

SAM = Self-Assessment Manikin; AD = Alzheimer's Disease; OA = Older adults.
Arousal ratings were also examined with 3 (valence) x 2 (age group) repeated measures ANOVA. As expected, a significant main effect of valence was found, $F(2, 40) = 15.5$, $p=.000$ (see Fig. 12). A trend toward a group by valence interaction was also found, $F(4, 80)= 2.9$, $p=.06$. The between subjects group factor was not significant, $F(1, 19) = .86$, $p=.37$.

**Figure 12**

SAM Arousal ratings of AD and OA groups.

SAM = Self-Assessment Manikin; AD = Alzheimer’s Disease group; OA = Older adult group.
Startle reflex modulation. Startle reflex modulation was tested with a repeated measures ANOVA of the valence variable's effect on EMG recordings of the orbicularis oculi muscle when probed during image presentation. The within-subjects effect for the valence variable was not detected, $F(2, 40) = .23, p=.8$. A valence by group interaction trend was observed, $F(2,40) = 1.5, p=.15$. The within-subjects effect for the valence variable was not detected in the AD group, $F(2, 12) = .42, p=.6$, as predicted (Fig. 13).

Figure 13
Startle reflex modulation in AD and OA groups.

AD = Alzheimer's Disease group; OA = Older adult group.
Chronometry of Startle reflex modulation. No chronometric analysis of the resolution of the startle reflex effect was conducted, as there was no evidence to suggest a startle reflex modulation effect was present.

EMG data. Facial EMG activity was tested with a 2 (group) x 3 (image type) repeated measures ANOVA for mean corrugator and mean zygomatic change scores. Corrugator analyses found the predicted significant effect for image valence, F(2,38) =

Figure 14
Corrugator and Zygomatic EMG recordings for AD and OA groups.

AD = Alzheimer’s disease group; OA = Older adult group.
28.6, p=.000. No valence by group effect was noted, F(2, 38) = 1.17, p=.3, nor was there a between-subjects main effect for group, F(1, 19) = 1.2., p=.28 (Fig. 14).

Analyses of the zygomatic EMG data revealed a significant effect for valence, F(2, 38)=10.8, p=.000. No valence by group interaction was observed, F(2, 38) = 1.1, p = .3. A between-subjects comparison found no main effect for group, F(1, 19) = .06, p=.8. While no main effect was detected for group, visual inspection of the means suggested little differentiation across valence categories for the AD group on the zygomatic measure, which may not be statistically detectable due to the small sample sizes involved (Fig. 14).
DISCUSSION

The analyses comparing the OA and AD groups are likely premature, as they are all affected by the statistical power limitations of small sample sizes. Despite this limitation, there were a few findings of note. With the exception of a subtle alteration in their report of emotional experience to neutral images at the 300ms probe-time, the AD group’s conscious appraisal of emotional experience did not significantly differ from the OA group, and their ratings of both valence and arousal aspects of emotion were in the predicted directions. While the limitations of small sample sizes preclude any definitive conclusion regarding the conscious appraisal of emotion in AD, the lack of any trends in the data suggesting otherwise may support our hypothesis regarding emotional experience in AD. If this is the case, it would be a replication of the findings of Burton and Kaszniak (2001).

Likewise, the present study appears to support the Burton and Kaszniak (2001) findings in that AD and OA groups did not differ in their pattern of EMG activity in the corrugator muscle while viewing the emotionally salient images. Again, interpretations of this data must be made with caution due to the small sample sizes involved, but the patterns are certainly suggestive of unimpaired expression of negative emotion via the facial musculature.

With regard to zygomatic EMG activity, no significant differences between AD and OA groups were observed, however a trend toward less differentiation of zygomatic activity across the emotionally valenced trials was observed. If this trend continues with the addition of more AD subjects, it would be consistent with the prior findings of Burton
and Kaszniak (2001), at least insofar as the zygomatic activity while viewing positively valenced images was reduced. The current trend does not appear to replicate the Burton and Kaszniak finding of increased zygomatic activity while viewing negatively valenced images.

The final finding of interest is the failure to see even a trend toward the typical pattern of startle reflex modulation in the AD group. The absence of this effect would support our hypothesis regarding amygdala functioning in AD, but again this conclusion would be premature. Nevertheless, it is an intriguing possibility and will require further study.
GENERAL DISCUSSION

Now that we have all this useful information, it would be nice to do something with it. (Actually, it can be emotionally fulfilling just to get the information. This is usually only true, however, if you have the social life of a kumquat.)

- Unix Programmer's Manual

Taken together, the findings from this study provide an intriguing glimpse into the nature of the temporal characteristics of some emotion measures, and the impact of biological processes on those affective processes. Perhaps the most intriguing findings were those pertaining to the temporal characteristics of the startle reflex in the younger and older adult groups. The younger group’s pattern of startle reflex modulation, readily apparent both during and 300ms after stimulus offset, dissipated at 3000ms post stimulus offset. In contrast to Bradley, et al.’s (1993) earlier study, we observed the emotion-modulation effect at the 300ms probe-time. Why this might be remains unclear, but one possible explanation is that our stimulus set may have had greater arousal properties than those of the previous study, resulting in a stronger or more durable emotional effect.

Further, there appeared to be a “rebound” of the startle reflex observed subsequent to the positive image trials at the 3000ms probe times, such that the startle reflex elicited in those positive emotion conditions was greater than the reflex elicited subsequent to viewing negative images. This created, in effect, an inversion of the typical pattern of emotion modulated startle reflex. The reasons for this are not
immediately clear, but one possible emotion circuit-based explanation was noted in the discussion section of Experiment 1. That is, this finding may reflect a release of the frontally-mediated inhibitory circuits that result in the attenuation of the amygdala-mediated startle reflex during positive emotional experiences approximately 3 seconds after the removal of the emotion elicitor. This release may be accompanied by a subsequent, transitory “overshoot” of the disinhibition.

Only two previous studies have examined the resolution of the startle response modulation, and neither described this type of rebound effect. Neither of those studies utilized probe-times of 3000ms post-stimulus offset, however, utilizing probe-times of approximately 2000 and 3800ms post-stimulus offset instead. It may be that, within the context of this type of experimental method, this rebound effect occurs at a circumscribed time and is very short-lived, thus rendering it not detectable at the probe-times others have selected.

The combination of the emotion-modulated startle reflex methodology and the theory of affective chronometry have provided what appears to be an intriguing finding, and further study of this phenomena is clearly required. Should replication and clarification of this “rebound” phenomena establish it as a reliable measure of affective chronometry, the applications could be numerous and fruitful. This measure could provide a relatively easy way to examine the affective chronometry of patient groups known to experience emotional dysfunction, and may help to characterize the basic nature of some types of emotion processing disorders.
The second finding of interest was that of aging’s impact on affective processing. The majority of the literature on emotion and aging suggests that there is no reason to suspect any dysfunction in emotion processing systems as a result of healthy aging, and the majority of our measures of emotion in our OA group are in agreement with the literature’s consensus. Measures of conscious appraisal of emotion, startle reflex modulation during stimulus viewing, and facial expression of emotion did not differ systematically with age in the present study.

However, the one known aspect of aging which might impact emotional systems is that of aging-related prefrontal cortex volume loss, a region of the brain associated with affective processing. This feature led to our hypothesis regarding and subsequent discovery of the one aspect of emotion that did appear to be influenced by age, that is, the temporal characteristics of emotion-related startle reflex modulation. Specifically, the emotion effects appeared to dissipate by the 300ms probe-time in the OA group, and remained so at the 3000ms probe-time. The OA group’s temporal patterns differed from the YA group in two ways: 1) they no longer demonstrated the emotion modulation effect on startle reflexes at the 300ms probe-time; and 2) the OA group did not demonstrate the “rebound” effect noted in the YA group at the 3000ms probe-time. One way to interpret this finding is in keeping with our interpretations of the YA group, namely that the faster resolution and lack of a positive-emotion “rebound” at the 3000ms probe-time may both reflect aging-related weakening of the prefrontal cortical regions. This finding should be considered tentative, as the OA group consisted of just 14 subjects, and was not a gender balanced sample.
In some ways it is premature to draw conclusions from this data regarding emotion processing in AD. With this relatively small sample size, any anticipated mid-to-small sized effects in the psychophysiological variables likely would not have been detected due to insufficient statistical power. However, even with this power limitation we were able to observe the expected, and statistically significant, pattern of ratings of self-report of emotional experience on the valence scale, with higher valence ratings for the positive image trials than for the negative image trials. A similar trend in the expected direction was observed for the arousal ratings, with higher arousal ratings of the positive and negative image trials than for the neutral image trials. These observations generally support the hypothesis predicting normal patterns of self-report of emotional experience, perhaps a result of reliance on semantic stores of information about the stimuli in question instead of reflecting upon one's emotional experiences. This observation does not provide conclusive evidence that AD subjects are relying solely upon their semantic representational stores of the emotional stimuli, as opposed to actually reporting their emotional experience. This remains an open question and would best be answered by further examination utilizing this methodology.

It is also worth noting that, while the AD sample size was small, there was no evidence of the startle-modulation effect at all. This admittedly tentative finding would be consistent with our hypothesis regarding amygdala functioning in AD. Similarly, there was relatively little zygomatic EMG activity evidenced by the AD group while viewing positive images, which is consistent with our present hypothesis as well as our earlier findings of atypical zygomatic activity in AD.
Future Directions – The characterization of the temporal characteristics of the emotion-modulated startle reflex hold considerable promise as a means to examine emotion processing in many groups of interest. The present study managed to describe the resolution phase of the reflex, but relatively little is known about the rise time characteristics. Further research in this area could prove very illuminating, and if reliable patterns can be described in healthy adults it would provide a “normal” pattern against which to compare patient groups.

Clearly, one of the limitations of this study is the small sample sizes of the OA and AD groups. As such, the conclusions we draw from their data must be considered tentative, and our present goal is to better characterize their emotion processing abilities. To achieve this goal, additional OA and AD subjects will be recruited to address the statistical power concerns and further evaluate the hypotheses with regard to emotion in OA and AD.
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