ELSEVIER

Neurobiology of Aging 34 (2013) 809–821

NEUROBIOLOGY OF AGING

www.elsevier.com/locate/neuaging

Healthy aging is associated with increased neural processing of positive valence but attenuated processing of emotional arousal: an fMRI study

Elizabeth G. Kehoe[a,b,*], John M. Toomey[c], Joshua H. Balsters[b,d], Arun L.W. Bokde[a,b]

[a] Cognitive Systems Group, Discipline of Psychiatry, School of Medicine, Trinity College Dublin, Dublin, Ireland
[b] Trinity College Institute of Neuroscience, Trinity College Dublin, Dublin, Ireland
[c] School of Computing, Dublin Institute of Technology, Dublin, Ireland
[d] School of Psychology, Trinity College Dublin, Dublin, Ireland

Received 5 April 2012; received in revised form 3 July 2012; accepted 11 July 2012

Abstract

Arousal and valence play key roles in emotional perception, with normal aging leading to changes in the neural substrates supporting valence processing. The objective of this study was to investigate normal age-related changes in the neural substrates of emotional arousal processing. Twenty-three young and 23 older, healthy women underwent functional magnetic resonance imaging as they viewed images which were neutral or positive in valence and which varied in arousal level from low to high. Using a parametric modulation approach, we examined how the blood oxygen-level dependent signal varied with single trial subjective ratings of valence and arousal, and whether this differed with age. In accordance with previous studies we found that the older group showed greater activation in response to positive valence, in the left amygdala, left middle temporal gyrus and right lingual gyrus. In contrast however, they showed reduced reactivity to emotional arousal, in occipital and temporal visual cortices bilaterally, the left inferior parietal cortex, and the supplementary motor area bilaterally. This study represents the first of its kind to clearly dissociate how aging affects the neural correlates of emotional arousal and valence. The changes in arousal processing may in part be mediated by the functional reorganization evident in the aging brain, such as reduced activation of the posterior cortices as described by the posterior-anterior shift in ageing (PASA) effect.

Keywords: Aging; Emotion; fMRI; Arousal; Valence

1. Introduction

While a number of mental faculties decrease with age, emotional processing is well-preserved with healthy aging. Many older adults in fact enjoy improved emotional regulation and increased positive affect (Carstensen et al., 2003; Charles et al., 2001; Williams et al., 2006); and although cognitive control declines with age (Braver and Barch, 2002), emotional control does not, and may in fact improve (Gross et al., 1997). Older adults have been found to demonstrate a bias toward positive emotional stimuli and decreased processing of negative emotional stimuli, a finding that has been called "the positivity effect" (Mather and Carstensen, 2005). This positivity effect also appears to influence the retention of information, with older adults remembering more positive and less negative information than young people (Charles et al., 2003; Kennedy et al., 2004), and recalling autobiographical memories with more positivity (Comblain et al., 2005).

Functional magnetic resonance imaging (fMRI) studies have revealed significant age-related differences in the neural substrates of positive emotional valence, such as increased activation in response to positive versus neutral or negative stimuli in accordance with the positivity effect (Mather and Carstensen, 2005). For example, older adults showed greater amygdala activity to positive versus negative images on an emotional perception task (Mather et al.,

* Corresponding author at: LloydBuilding, Trinity College Institute of Neuroscience, Trinity College Dublin, Dublin 2, Ireland. Tel.: +353 (0)1 896 4102; fax: +353 (0)1 896 3183.
E-mail address: elkehoe@tcd.ie (E. Kehoe).

0197-4580/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.neurobiolaging.2012.07.006

2004); while during the successful encoding of positive but not negative images, older adults showed greater activation in the medial prefrontal (mPFC) and the anterior cingulate gyrus compared with younger adults (Kensinger and Schacter, 2008). Increasing age has been found to be positively associated with activation in the mPFC to happy faces, but negatively associated with activation to sad faces in the same region (Williams et al., 2006).

While there have been numerous studies investigating age-related differences in emotional valence processing, there is a relative dearth of research into whether there are age-related differences in the processing of emotional arousal. Emotional arousal or intensity is thought to reflect the motivational value of an emotion (Lang et al., 1998), and has a strong effect on cognition, enhancing attention (Davis and Whalen, 2001; Fox et al., 2001) and also memory, via the increased activation of the amygdala and hippocampus (Cahill et al., 1996; Dolcos et al., 2004; Kensinger and Schacter, 2006; Richardson et al., 2004). There is some evidence that automatic arousal processing is relatively stable in old age, with older adults showing the same ability as young adults to detect high arousing stimuli (Leclerc and Kensinger, 2008), and threatening stimuli such as highly arousing negative scenes from the international affective picture system (IAPS) (Rösler et al., 2005), or threatening faces (Mather and Knight, 2006). There have been conflicting reports of older adults' autonomic response to emotional arousal however. Older adults have been found to show less increases in the skin conductance response (SCR) to highly-arousing negative images compared with younger adults, despite higher self-reports of arousal levels (Gavazzeni et al., 2008). This would imply that aging is associated with a decreased autonomic response to emotional arousal; however, other studies have contradicted this result (Denburg et al., 2003). Several behavioral studies have also reported age-related changes in arousal responses, with older adults rating positive emotional images as less arousing than young adults (Grühn and Scheibe, 2008; Pôrto et al., 2011).

As yet however, it is unknown whether the neural response to emotional arousal changes in healthy aging. The influence of aging on arousal processing is an important question given the central role that arousal plays in orienting attention (Vuilleumier, 2005), and in successful memory encoding (Sharot and Phelps, 2004). Because older adults tend to show decline on attention and memory tasks (Finnigan et al., 2011; Glisky, 2007) which benefit from moderately high levels of arousal (Bradley et al., 2003; McGaugh, 2006), altered arousal processing may play a pivotal role in this deterioration of function. This study therefore sought to clarify whether there are age-related differences in emotional arousal processing.

In the current study we investigated how healthy aging modulates the brain's response to the two emotional dimensions valence and arousal. A group of young and older healthy women viewed images which were either neutral or positive in emotional valence and which varied in arousal level as they underwent fMRI. Only women were included in the study because there have been considerable differences found between genders in emotional reactivity (Bradley et al., 2001) and in the neural representation of emotion (Beck et al., 1996; Cahill et al., 2001; Wager et al., 2003; Wrase et al., 2003). Similar to several other fMRI studies of emotional processing (Heinzel et al., 2005; Kehoe et al., 2011; Lewis et al., 2007; Phan et al., 2004), we utilized a parametric modulation approach, including the participants' subjective emotional ratings as parametric modulators in the fMRI analysis. This method allowed us to isolate the brain regions where the blood oxygen-level dependent (BOLD) response varied linearly with valence and arousal, and investigate whether this differed in the aging brain.

We predicted, given the findings of previous neuroimaging studies (Mather and Carstensen, 2005; Mather et al., 2004), that the older adults would show a greater BOLD response to positive emotional valence than the young adults, possibly in the amygdala and prefrontal cortex (PFC), in accordance with the predictions of the positivity effect. Given that it has previously been reported that older adults rate emotional images as less arousing (Grühn and Scheibe, 2008; Pôrto et al., 2011) and show a reduced SCR in response to arousal (Gavazzeni et al., 2008), we predicted that the older adults would show less BOLD modulation than the young group in response to increasing levels of arousal.

2. Methods

2.1. Participants

Twenty-three young (mean age = 23.04 ± 3.48 years; age range = 19–30 years) and 23 older, healthy, right-handed women (mean age = 61.0 ± 5.24 years; age range = 55–71 years) took part in this study. The young cohort is the same as those described in Kehoe et al. (2011); however this study additionally contains data from an older cohort and concentrates on aging differences. The groups did not differ in their educational attainment ($t = 1.15$, $p > 0.05$). Depression scores on the Beck Depression Inventory (BDI-II; Beck et al., 1996) were 4.22 ± 3.38 and 3.73 ± 3.60 respectively, indicating an absence of depressive symptoms, and the scores did not differ statistically between the groups ($t = -0.34$, $p = 0.74$). We wished to exclude any participants with possible depression as the disorder is associated with significant alterations in emotional processing (Fales et al., 2008; Leppänen, 2006; Liu et al., 2011).

Personality was assessed using the Eysenck Personality Questionnaire, short-scale (EPQ-R) (Eysenck and Eysenck, 1991), and although not a focus of this study it is worth noting that while the groups did not differ in terms of extraversion levels, the young adults had on average higher