available at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/cortex

Special issue: Research report

Age-related differences in brain regions supporting successful encoding of emotional faces

Håkan Fischer[a], Lars Nyberg[b,c] and Lars Bäckman[a,*]

[a]Aging Research Center, Karolinska Institute, Stockholm, Sweden
[b]Department of Integrative Medical Biology, Umeå University, Sweden
[c]Department of Radiation Sciences, Umeå University, Sweden

ARTICLE INFO

Article history:
Received 28 November 2008
Reviewed 2 April 2009
Revised 29 April 2009
Accepted 7 May 2009
Published online 28 May 2009

Keywords:
Aging
Amygdala
Face recognition
Prefrontal cortex
Insula

ABSTRACT

In an event-related functional Magnetic Resonance Imaging (fMRI) study, younger and older adults were presented with negative emotional (i.e., fearful) and neutral face pictures under incidental learning conditions. They were subsequently given a test of face recognition outside the scanner. Both age groups activated amygdala bilaterally as well as the right hippocampus during successful encoding of the fearful faces. Direct age comparisons revealed greater activation in right amygdala and bilateral hippocampus in the young, whereas older adults showed greater activation in the left insular and right prefrontal cortices. None of these brain areas was activated during successful encoding of neutral faces, suggesting specificity of these brain activation patterns. The results indicate an age-related shift in the neural underpinnings of negative emotional face processing from medial–temporal to neocortical regions.

1. Introduction

Numerous studies have demonstrated better memory performance for emotionally laden compared with neutral information in young adults (e.g., Heuer and Reisberg, 1990; Christianson and Loftus, 1991; Bradley et al., 1992; Cahill and McGaugh, 1995; Hamann et al., 1997 for overviews, see Christianson, 1992; Hamann, 2001; LaBar and Cabeza, 2006). The memory advantage of emotional over neutral information has been attributed to factors operating at encoding, including increased attention, elaboration, and rehearsal, as well as to post-encoding effects related to the consolidation of information in memory (Hamann, 2001). Brain-imaging studies (e.g., Cahill et al., 1996; Hamann et al., 1999; Canli et al., 2000, 1998; Fischer et al., 2007) have linked amygdala activation during encoding to later recall or recognition of emotional information. In addition, a variety of other brain areas have been found to contribute to the emotional memory enhancement, including the insula, anterior cingulate cortex, as well as a number of distinct frontal regions (e.g., Canli et al., 1999; Canli et al., 2002). Recent studies have also demonstrated amygdala–hippocampal interactions during successful encoding of emotional information, indicating a mutual dependence of these structures in memory for emotional events (Kilpatrick and Cahill, 2003; Phelps, 2004; Richardson et al., 2004; Dolcos et al., 2005; Fischer et al., 2007).

* Corresponding author. Aging Research Center, Karolinska Institute, Gävlegatan 16, SE-113 30 Stockholm, Sweden.
E-mail address: lars.backman.1@ki.se (L. Bäckman).
0010-9452/$ – see front matter
doi:10.1016/j.cortex.2009.05.011

Interestingly, evidence suggests that amygdala and related medial–temporal regions may not play as critical a role in affective processing for older compared to younger adults. Studies on emotion perception have found that older adults show relatively less amygdala activity during passive viewing or discrimination of emotional faces. By contrast, older adults exhibit relatively more cortical activity (frontal and insular) than younger adults under the same task conditions (Gunning-Dixon et al., 2003; Fischer et al., 2005; Tessitore et al., 2005). At the same time, there is substantial evidence that memory is enhanced for emotional stimuli also in older adults. Such an effect has been demonstrated for a variety of learning materials including single words (Kensinger et al., 2002), stories (Kazui et al., 2000), and pictures of objects and scenes (Hamann et al., 2000; Denburg et al., 2003), as well as across different retrieval conditions such as recall and recognition (Hamann et al., 2000; Kensinger et al., 2002). In addition, the effect is present at immediate testing and after delays of one month (Denburg et al., 2003) up to one year (Gavazzeni et al., 2008).

The age-related subcortical-to-cortical alterations in brain activation patterns during emotion perception (Gunning-Dixon et al., 2003; Fischer et al., 2005; Tessitore et al., 2005) may reflect an increased tendency to process emotional information in a conscious manner with advancing age. Amygdala activation by an emotional stimulus is known to occur rapidly and proceed relatively automatically, whereas neocortical activation is driven more by regulatory and attentional processes (e.g., Canli et al., 2002; Ochsner et al., 2004). Toward this end, it is of interest to note that self-report data indicate that individuals may modulate their emotional reactions more effectively over the adult years (e.g., Lawton et al., 1992, 1993; Gross et al., 1997). Analogously, a recurrent theme in life-span theories of emotional development is that individuals become more efficient in regulating emotional states during the life course (e.g., Labouvie-Vief et al., 2003; Carstensen, 2006).

It is important to note, however, that age differences in brain activation patterns when confronted with emotional stimuli may be quantitative rather than qualitative. Specifically, older adults exhibit a similar amygdala response as young adults when perceiving novel fearful faces compared to familiar neutral faces (Wright et al., 2008), and young adults may show frontal activation during encoding of emotional information (Dolcos et al., 2004; Kensinger and Corkin, 2004; Sergerie et al, 2005). Thus, age differences in subcortical–cortical recruitment may best be conceptualized in relative terms.

No age-related differences in the neural underpinnings of successful encoding of negative objects were found in a recent fMRI study (Kensinger and Schacter, 2008). In that study, both younger and older adults recruited the right amygdala as well as the orbito-frontal and parietal cortices during successful encoding of both negative and positive objects, suggesting age-related preservation of the neural networks engaged during encoding of emotional objects. Whether these findings generalize to other categories of emotional stimuli such as faces remains unclear.

In the current research, we extended the aging work on the neural basis of emotional face perception to explicit recognition memory for emotional faces. In an event-related fMRI design, younger and older adults were scanned while viewing fearful and neutral faces under incidental learning conditions, and were later tested for their recognition memory outside the scanner. We hypothesized that the two age groups would show different activation patterns at encoding for correctly recognized fearful faces, resembling patterns previously observed during discrimination and passive viewing (Gunning-Dixon et al., 2003; Fischer et al., 2005; Tessitore et al., 2005). Such an outcome would indicate an intriguing continuity between emotional face perception and memory with regard to age-related differences in neural recruitment, and suggest general age-related neural differences in how emotion affects human cognition. The inclusion of neutral faces served to assess the extent to which potential age-related differences in activation of subcortical versus cortical brain regions were unique to emotionally laden faces.

2. Method

2.1. Participants

Forty-five right-handed individuals (24 younger, 21 older) participated in the study (50% males in the younger group and 55% males in the older group). The average age was 24.7 years (SD = 2.8) in the younger group, and 74.1 years (SD = 4.2) in the older group. Three older adults (two men, one woman) were excluded because their memory performance was at chance level, preventing subsequent-memory analyses. No subject had any previous or current psychiatric, neurological, or medical disease, and none was taking psychoactive medication or abused any substances. The two age groups did not differ in a test of global cognitive ability, the Mini-Mental State Examination (MMSE) (Folstein et al., 1975), years of education, vocabulary (Dureman, 1960), or on the personality dimensions extroversion and neuroticism (Swedish version of the NEO PI-R; Costa and McCrae, 1992; Table 1). The MMSE and vocabulary tests were used to screen older subjects for early dementia

Table 1 – Mean subject characteristics and ratings of emotionality across age group.

	Young	Old	p-Value
Subject characteristics			
Age	24.7 (2.8)	74.3 (4.0)	<.0001
Years of education	14.2 (1.5)	13.1 (2.4)	.08
MMSE	29.3 (.7)	28.9 (.7)	.09
Vocabulary[a]	23.5 (3.2)	25.0 (4.1)	.17
Extroversion	109.5 (15.6)	100.1 (22.1)	.11
Neuroticism	83.4 (14.8)	74.1 (25.4)	.13
State anxiety[b]	39.0 (9.9)	35.5 (13.5)	.31
Ratings of emotionality			
Fearful faces	26.2 (10.0)	30.2 (8.5)	.80
Neutral faces	2.2 (2.2)	6.7 (4.4)	.0001

Note: standard deviations are given within parentheses.
a SRB:1 (Dureman, 1960).
b State Anxiety Scale (Spielberger et al., 1983).