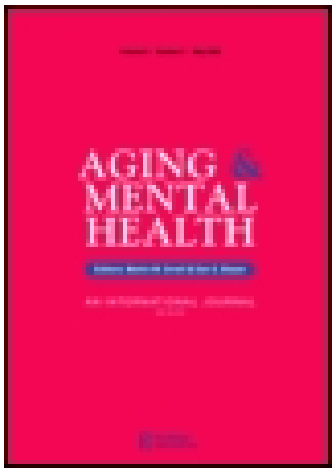

Aging & Mental Health
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/camh20

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Published online: 23 Jun 2014.

To cite this article: Nicolas Noiret, Nicolas Carvalho, Éric Laurent, Lauriane Vulliez, Djamila Bennabi, Gilles Chopard, Emmanuel Haffen, Magali Nicolier, Julie Monnin & Pierre Vandel (2014): Visual scanning behavior during processing of emotional faces in older adults with major depression, Aging & Mental Health, DOI: 10.1080/13607863.2014.926473

To link to this article: http://dx.doi.org/10.1080/13607863.2014.926473

Aging & Mental Health, 2014
http://dx.doi.org/10.1080/13607863.2014.926473

Visual scanning behavior during processing of emotional faces in older adults with major depression

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(*Received 21 February 2014; accepted 11 May 2014*)

Objectives: Although several reported studies have suggested that younger adults with depression display depression-related biases during the processing of emotional faces, there remains a lack of data concerning these biases in older adults. The aim of our study was to assess scanning behavior during the processing of emotional faces in depressed older adults.
Method: Older adults with and without depression viewed happy, neutral or sad portraits during an eye movement recording.
Results: Depressed older adults spent less time with fewer fixations on emotional features than healthy older adults, but only for sad and neutral portraits, with no significant difference for happy portraits.
Conclusion: These results suggest disengagement from sad and neutral faces in depressed older adults, which is not consistent with standard theoretical proposals on congruence biases in depression. Also, aging and associated emotional regulation change may explain the expression of depression-related biases. Our preliminary results suggest that information processing in depression consists of a more complex phenomenon than merely a general searching for mood-congruent stimuli or general disengagement from all kinds of stimuli. These findings underline that care must be used when evaluating potential variables, such as aging, which interact with depression and selectively influence the choice of relevant stimulus dimensions.

Keywords: depression; aging; faces; emotions; eye movements

Introduction

Abilities to process emotional facial expressions are very important to the understanding of others' feelings and intentions, which are crucial for social interactions. Emotion perception impairments have been linked to social interaction difficulties, such as loneliness and isolation. Depression in late life is also associated with impaired social support (Alexopoulos, 2005; Blazer, 2003). Although there is a considerable amount of literature on emotional facial expression processing in depression among younger adults, only one study, to our knowledge, examined this processing in depressed elderly patients (Phillips, Scott, Henry, Mowat, & Bell, 2010). As we will see below this study found inconsistent results with those carried out on depressed younger adults. There is a need to better understand emotional processing impairment in older depressive patients, because they can play a role not only in the entry but also in the maintenance of depression (Joormann & Siemer, 2011).

Several studies have revealed disruption during emotional face perception in depression, which is reflected in a bias to recognize facial expressions as sadder than they really are (Bediou, Saoud, Harmer, & Krolak-Salmon, 2009; Bourke, Douglas, & Porter, 2010; Elliott, Zahn, Deakin, & Anderson, 2011). Patients with depression tend to evaluate more negatively ambiguous and neutral facial expressions than controls (Gollan, Pane, McCloskey, & Coccaro, 2008; Gur et al., 1992; Leppänen, Milders, Bell, Terriere, & Hietanen, 2004). Patients generally fail more often than controls to recognize happy faces (Bourke et al., 2010; Gur et al., 1992; Harmer et al., 2009; Joormann & Gotlib, 2006). These data are consistent with cognitive models of depression postulating mood-congruent processing biases for negative information, including perception, attention, memory and interpretation (Beck, 2008; Joormann & Siemer, 2011; Mathews & MacLeod, 2005). However, it is important to note that the only study (Phillips et al., 2010) which has carried out an experiment on aged patients (M_{age} = 75 years) with mood disorders – depression and bipolar disorder – has revealed that these patients had a mild impairment in recognizing sad faces but not happy faces, compared to healthy controls.

Recognition or identification of emotional facial expressions requires specific visual strategies during face processing that can be assessed with eye movement recording (Eisenbarth & Alpers, 2011; Henderson, Williams, & Falk, 2005; Janik, Wellens, Goldberg, & Dell'Osso, 1978; Wong, Cronin-Golomb, & Neargarder, 2005). For instance, Wong et al. (2005) have carried out experiments in which healthy participants (younger vs. older adults) were asked to identify (experiment 1) and to view (experiment 3) facial expressions. Results have indicated that older adults were less accurate at identifying anger, fear and sadness but not happiness and surprise.

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They also made fewer gaze fixations on faces with longer gaze fixation duration, regardless of emotion. Moreover, they made more fixations to the lower half (i.e. the mouth and nose) than to the upper half of the faces (i.e. the forehead and eyes). Positive correlations between the accuracy of identification scores and the number of fixations made to the faces led the authors to suggest that difficulties to identify emotions and visual processing may be linked. These results are consistent with studies of facial analysis on healthy people which have shown that the regions of the eyes (with the eyebrows) and the mouth are important for emotion recognition (Eisenbarth & Alpers, 2011; Henderson et al., 2005; Janik et al., 1978; Sadr, Jarudi, & Sinha, 2003; Schwaninger, Wallraven, Cunningham, & Chiller-Glaus, 2006).

As regards patients – although there are several eye movement studies examining emotional stimuli processing in younger depressed adults (Caseras, Garner, Bradley, & Mogg, 2007; Eizenman, et al., 2003; Kellough, Beevers, Ellis, & Wells, 2008) – only one experiment has used eye movement recording to specifically examine the analysis of emotional facial expressions in younger adults with affective disorders (i.e. depression and bipolar disorder) (Loughland, Williams, & Gordon, 2002). These authors displayed happy, neutral and negative facial pictures to participants who were asked to recognize emotions. Results have shown that patients with affective disorders 'avoided' facial features (i.e. eyes, nose and mouth) in all emotional facial pictures and they were less accurate than controls in recognizing neutral faces. These patients had fewer fixations and lower fixation duration to emotional facial features than control participants in all emotional expressions. These results are not consistent with mood-congruent model of depression, which posits a bias for negative stimuli (Beck, 2008; Joormann & Siemer, 2011; Mathews & MacLeod, 2005). However, they are in accordance with another hypothesis, the emotion context insensitivity (ECI), which holds that depression leads to a reduced reactivity to all emotion (Bylsma, Morris, & Rottenberg, 2008; Rottenberg, Gross, & Gotlib, 2005). According to ECI, depression prompts a reduction of motivational activity that results in an environmental disengagement. In terms of visual processing, ECI may be related to theoretical proposals suggesting that gaze can be influenced by motivation (Isaacowitz, 2006). If healthy individuals' gaze is goal-directed toward pertinent stimuli in order to optimize a positive state, depressed individuals' gaze would be subsequently influenced by a reduction of motivational activity and disengagement from all stimuli, regardless of emotional valence. This reduction of motivation might be thought of as a defensive mechanism used by depressed patients to deal with emotion regulation. Because depressive patients do not correctly analyze emotional features, we can suppose that disengagement from emotional facial feature leads to an inaccuracy to explicitly recognize emotional facial expressions.

Studies described above have shown that younger adults with depression have difficulties in accurately recognizing happy and neutral faces but not sad faces (Bourke et al., 2010; Gur et al., 1992; Harmer et al., 2009; Joormann & Gotlib, 2006). They also avoid emotional facial features regardless of emotional valences (Loughland et al., 2002). On the other hand, older adults with depression have difficulties in recognizing sad faces but not happy faces (Phillips et al., 2010). This would suggest that visual processing in depression is influenced by age. Further studies to explain these differences between younger and older depressed adults are needed and research on visual processing in aging may be useful. Previous research carried out on normal aging has shown that older people looked toward positive and away from negative stimuli (Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Knight et al., 2007; Mather & Carstensen, 2005). These authors interpreted this positivity effect within the framework of socioemotional selectivity theory (Carstensen, 2006; Carstensen, Isaacowitz, & Charles, 1999). According to this, as future appears limited, older adults prioritize emotion-regulatory goals, leading to preferential attentional processing of positive stimuli rather than negative stimuli. Isaacowitz, Toner, Goren, and Wilson (2008) brought new insights concerning positivity effect in older people. Using the eye tracking method during visual inspection of face pairs (i.e. negative-neutral or positive-neutral face pairs) they have shown that only older adults under 'bad mood' have a preference toward positive faces and avoid negative faces (unlike younger adults under 'bad mood' showing a mood-congruent preference toward negative faces). The authors concluded that positivity effect reflects older adults' mood-regulatory goals. Older adults should have this positive effect when they need to regulate their mood state.

Since explicit emotional face recognition is related to facial analysis (Wong et al., 2005), aging (i.e. positivity effect) could possibly influence a depression symptom (i.e. ECI) and therefore results in specific modifications of visual strategies in late-life depression. This would be manifested in the disengagement from emotional features, except for happy faces, which could explain difficulties in the recognition of sad faces. To date no reported research, to our knowledge, has studied the visual perception of emotional faces in aged patients with depression. Our experiment is the first to examine whether aged depressed patients have modifications of visual processing strategies in the analysis of emotional face compared to healthy aged participants.

In our research we used the eye tracking paradigm in order to characterize the influence of emotional facial expressions (i.e. happy, neutral and sad) on the analysis of facial features in depressive and healthy older adults. As neuropsychological deficits in older adults with depression have been well documented, we carried out a series of neuropsychological tests in order to control each of these potential deficits. More precisely, depression in older adults mainly leads to executive dysfunctions, impairment in processing speed, memory and language (Lockwood, Alexopoulos, & van Gorp, 2002; Naismith, Norrie, Mowszowski, & Hickie, 2012; Sheline et al., 2006).

Given the literature cited above, we supposed that the ECI and the positivity effect – as two mood-regulatory functions – should be worked together in depressive older

patients. Consistent with the ECI hypothesis stressing an emotional disengagement in depression, we hypothesized that depressive older patients should have fewer fixations and shorter fixation duration in emotional regions than healthy participants, except for happy portraits – because the positivity effect preserves preferential processing of positive emotion. Because the positivity effect is used to regulate mood state, we expected healthy participants – without depression or sad mood – to have no differences in the processing of happy, neutral and sad portraits. We also measured the first fixation time inside regions of portraits in order to examine whether characteristics of visual strategies in older patients start from the beginning of the processing or later.

Method

Participants

Twenty inpatients (16 females, M_{age} = 71 years, SD = 9.12) with the diagnosis of major depression were recruited in the psychiatry unit of Besançon University Hospital, France. Diagnosis of depression was done with a structured diagnosis interview using the Mini International Neuropsychiatric Interview (MINI; Lecrubier et al., 1997) by a trained psychiatrist. Comorbid conditions were also assessed and stated when relevant. Patients had to have a Montgomery and Asberg Depression Rating Scale (MADRS) score >25 (Montgomery & Asberg, 1979). This scale consisted of 10 items that allow assessing the presence of depressive symptoms. Three inpatients (out of 23) were excluded because they had a MADRS score <25. During the study all patients were taking psychotropic medications (e.g. anxiolytics, antidepressants and antipsychotics).

The control group consisted of 62 elderly volunteers (38 females, M_{age} = 67 years, SD = 5.0) recruited from relatives of members of the research department and through advertisements in an extended learning program in the university. Like patients, these participants were assessed using the MINI by a trained psychiatrist. They had to have no previous medical history of major depression, and a MADRS score <10. None of the control participants were taking psychotropic medications.

Patients and controls were not included if: (1) they had any cognitive disorders, with a Mini Mental State Evaluation (MMSE) score <21 (Folstein, Folstein, & McHugh, 1975); and (2) they had other psychiatric disorders.

This study was approved by the local ethics committee for the protection of individuals (*Comité de protection des personnes Est 2*). All participants gave their written informed consent prior to inclusion in the study.

Complementary neuropsychological and psychiatric measures

In order to consolidate initial clinical diagnosis, complementary tests (described above) were performed within a month before the visual inspection task.

The Beck Depression Inventory II (BDI-II) psychiatric scale was used for our study (Beck, Steer, & Brown, 1996) – a self-report scale consisting of 21 items measuring the presence and severity of cognitive, affective, motivational and physiological symptoms of depression.

The neuropsychological evaluation consisted of nine tests. Eight of these tests were based on the neuropsychological test battery of the regional network for diagnostic aid and management of patients with cognitive impairment in the Franche-Comté, France, geographical area (RAPID), which includes neuropsychological tests calibrated on the same participant sample (Ferreira et al., 2010). Only the Stroop test (Stroop, 1935) is in fact not included in the RAPID battery. These tests included *verbal episodic memory*: the Memory Impairment Screen (MIS; Buschke et al., 1999; de Rotrou et al., 2007), the free and cued selective reminding test (FCSRT; Grober, Buschke, Crystal, Bang, & Dresner, 1988; Van der Linden et al., 2004); *language*: a picture naming test with 30 items (DO30; Galmiche et al., 2005); *semantic memory*: a categorical matching test (Galmiche et al., 2005); *information processing speed*: the Trail Making Test part A (TMT A; Reitan, 1958) and the Crossing Off Test (COT; Goldman, Baty, Buckles, Sahrmann, & Morris, 1999); *executive functions and attention*: the Isaacs Set Test (IST; Isaacs & Kennie, 1973), the Trail Making Test part B (TMTB; Reitan, 1958) and the Stroop test; and *visuo-perceptive abilities*: a test of coping geometric figures as part of the BEC96 (Signoret et al., 1998). All means and statistical analyses are shown in Table 1.

Material and stimuli

Participant's eye movements were recorded with a chinrest eye tracking system (ASL EYE-TRACK®6; Applied Science Laboratories; Bedford, MA) with a sampling rate of 120 Hz and a gaze position accuracy of 0.5° of visual angle. The gaze position was determined using pupil and corneal reflection. Eye behaviors were considered as fixations when they were within a 1° of visual angle during more than 100 ms.

Stimuli were presented using Inquisit 3.0.6.0 computer software (Millisecond Software; Seattle, WA), on an Intel Pentium Dual Core 2.50 GHz desktop computer, and were projected on a 19-inch monitor, with a resolution of 1280 × 1024 pixels and a screen refresh rate of 60 Hz.

In this experiment, 15 portraits (i.e. 5 sad, 5 neutral and 5 happy portraits) were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). Selection was based on the valence (feeling of pleasure vs. displeasure) and arousal (feeling of excitement vs. calm) scales of IAPS and portraits were ranked in the following three categories: 'sad portraits' (valence from 1 to 3, M = 2.48 and SD = 0.75), 'neutral portraits' (valence from 4 to 6, M = 4.74 and SD = 0.24) and 'happy portraits' (valence from 7 to 9, M = 6.78 and SD = 0.75). These three categories differed significantly from each other for valence scores, $F(2,12) = 47.48$, $p < .001$ and $\eta_p^2 = 0.88$. Arousal ratings were between 3 and 5 for each portrait. Portraits subtended 23.5° (horizontal) × 13.4° (vertical) of visual angle. They were shown to each participant in a random order. Each trial began with a black central fixation dot (0.6° of visual angle). Throughout the

Table 1. Mean (standard deviation) for demographic, psychiatric and neuropsychological data for patient and control groups.

	Controls	Patients	F	U	χ^2	p	Cohen's d [95% CI]
Age	67 (5.0)	71 (9.12)		483		.138	0.56 [−0.72, 1.83]
Sex F/M	38/24	16/4			2.35	.125	
Education	2.34 (0.74)	2.31 (0.79)			0.08	.962	0.04 [−0.09, 0.17]
Psychiatric scales							
MADRS	2.31 (2.34)	30.74 (4.54)		0		<.001	7.87 [7.17, 8.57]
BDI-II	5.47 (4.29)	26.39 (14.32)		67.5		<.001	1.98 [0.15, 3.84]
Neuropsychological tests							
MMSE	29.10 (0.86)	26.40 (2.96)		266		<.001	1.24 [0.86, 1.62]
MIS 2 min	7.87 (0.42)	7.50 (0.69)		434		<.01	0.65 [0.55, 0.75]
MIS 10 min	7.89 (0.37)	7.75 (0.44)		527.5		.091	0.34 [0.27, 0.41]
IST	44.11 (6.11)	31.55 (6.48)	62.05			<.001	1.99 [0.87, 3.11]
FCSRT immediate recall	15.53 (0.84)	15.00 (1.21)	4.94			<.05	0.51 [0.33, 0.69]
FCSRT free recall	27.40 (5.33)	21.80 (8.19)		401		<.05	0.81 [−0.38, 2.02]
FCSRT total recall	46.0 (2.36)	42.15 (9.10)		487		.144	0.58 [−0.58, 1.74]
COT	214.14 (41.50)	157.90 (55.84)	23.31			<.001	1.14 [−7.46, 9.74]
TMTA	32.63 (8.76)	64.37 (46.80)		201		<.001	0.94 [−4.95, 6.83]
TMTB	102.87 (48.06)	243.71 (200.93)		242.5		<.01	0.96 [−24.54, 26.48]
Coping figure test	5.95 (0.22)	5.85 (0.37)		557		.132	0.32 [0.28, 0.38]
DO30	29.81 (0.51)	29.50 (0.83)		493		<.05	0.45 [0.33, 0.57]
Matching category	9.97 (0.18)	9.90 (0.31)		578		.22	0.28 [0.23, 0.32]
Stroop test (M score)	109.16 (22.91)	110.61 (21.88)	0.06			.812	0.06 [−3.85, 3.98]
Stroop test (C score)	82.56 (11.09)	76.28 (12.92)	4.12			<.05	0.52 [−1.58, 2.63]
Stroop test (C/M score)	45.16 (8.14)	36.56 (14.30)		311.5		<.01	0.74 [−1.29, 2.78]
Stroop test (Inter. score)	−2.44 (6.91)	−8.72 (9.02)		360.5		<.05	0.78 [−0.61, 2.19]

Notes: For the name in full, see complementary neuropsychological and psychiatric measures. Values for the ANOVA F-tests are indicated in the F column. If the data did not comply with the ANOVA parameters (heterogeneity and normality), we used Mann−Whitney U-test as non-parametric statistical test (U column). For frequency data, we used chi-square (χ^2 column). Educational level scale was built as follows: 1 = elementary school; 2 = junior high school; 3 = high school and more. CI: confidence interval; IST: Isaacs Set Test.

task, dots and portraits were shown against a gray background (with red green blue values of 128).

Procedure

On the day of the visual inspection task administration, the participant was seated 60 cm in front of the screen, with the head in the chinrest. When the participant's left eye was correctly detected by the eye-tracking system, a nine-point calibration was started.

Once the calibration was successfully completed, participants were instructed, via the computer screen and verbally by the experimenter, to freely watch pictures, without specific instruction except staring at the black dot (i.e. preparatory signal preceding image presentation) when it appeared. This procedure allowed us to obtain the most naturalistic information processing. After instructions, they viewed the series of 15 portraits. Each portrait was displayed for 15 seconds and a trial triggered by the experimenter once the participant fixated the dot (Figure 1). The task lasted for about 10 minutes.

Data analysis

Eye movement parameters were computed with ASL-Results Standard 2.3.13 computer software (Applied Science Laboratories; Bedford, MA). In order to simplify the analyses of eye fixations, we divided each portrait into eight areas of interest (AOIs) corresponding to principal facial features: eyes, nose, cheeks, mouth, chin, forehead, ears and hair. Figure 1 shows a stimulus example with these eight AOIs and detailed size information. According to a previous eye-tracking study indicating the relevance of eyes and mouth in emotional decoding (Eisenbarth & Alpers, 2011), we gathered AOIs to form three main AOIs (MAOIs): the emotional regions (eyes and mouth), the rest of the face (nose, cheeks, chin, forehead, ears and hair) and the outside of the face (corresponding to the rest of the picture: backgrounds, clothes and neck). The three dependent variables were: the percentage of fixation duration (i.e. the total time attended to each MAOI for each portrait category), the percentage of fixations (i.e. the number of fixations in each MAOI for each portrait category) and the first fixation time (i.e. the start time of the first fixation inside each MAOI for each portrait category). Mixed-plot analyses of variance and the Newman−Keuls' *post hoc* test were used and computed with Statistica 7.1 computer software (StatSoft, Inc., Maisons-Alfort, France) for these three dependent variables. If Mauchly's test indicated a violation of the assumption of sphericity, we then used the Greenhouse−Geisser's correction. Finally, as illustrated in Table 1, patients had different scores in comparison with controls, concerning some neuropsychological and psychiatric measures. In order to take into account the possible covariation between visual face

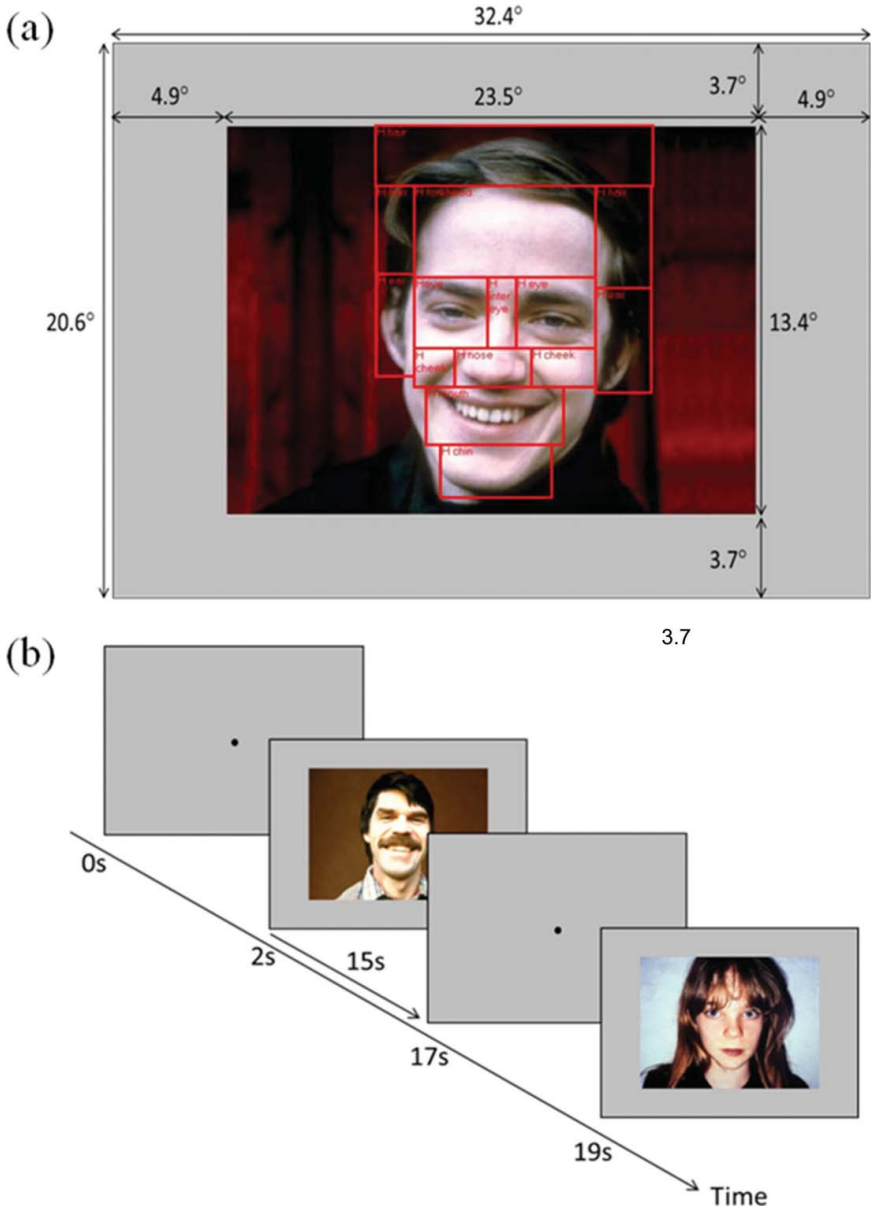

Figure 1. (a) A stimulus example with size specifications in degrees of visual angle and areas of interest (red rectangles). (b) Time sequence of two experimental trials.

processing on the one hand, and age, sex, cognitive capacities or depression symptoms on the other hand, we carried out correlation analyses using the Pearson r and analyses of covariance (ANCOVA).

Results

Percentage of total fixation duration

A 2 (groups: patients and controls) × 3 (portrait valence: happy, neutral and sad) × 3 (MAOIs: emotional regions, the rest of the face and the outside of the face) mixed-plot analysis of variance examined whether the patient group had a different visual processing of MAOIs as a function of portrait valence. Analyses indicated a significant main effect of MAOIs, $F(2, 136) = 85.82$, $p < .001$ and $\eta_p^2 = .52$, as participants have a higher percentage of fixation duration on emotional regions ($M = 41.03$ and $SD = 5.83$) than on the outside of the face ($M = 18.37$ and $SD = 7.24$), $p < .001$, $d = 3.45$ and 95% confidence interval for the effect size (CI_d) [2.33, 4.62] and a higher percentage of fixation duration on the rest of the face ($M = 40.04$ and $SD = 4.28$) than on the outside of the face ($p < .001$, $d = 3.64$ and 95% CI_d [2.33, 4.71]).

There was also a significant portrait valence × MAOIs interaction, $F(3, 277) = 39.99$, $p < .001$ and $\eta_p^2 = .33$, which was qualified by a significant group × portrait valence × MAOIs interaction, $F(3, 277) = 4.19$, $p = .002$ and $\eta_p^2 = .05$, which we will now examine further. Significant Newman−Keuls tests showed that patients had a lower percentage of fixation duration on the emotional regions than control participants for sad portraits ($p = .015$, $d = 0.71$ and 95% CI_d [−1.28, 2.72]) and neutral portraits ($p < .001$, $d = 0.64$ and 95% CI_d [−2.12, 3.40]). Moreover, patients had a higher percentage of fixation duration on the rest of the face than control participants

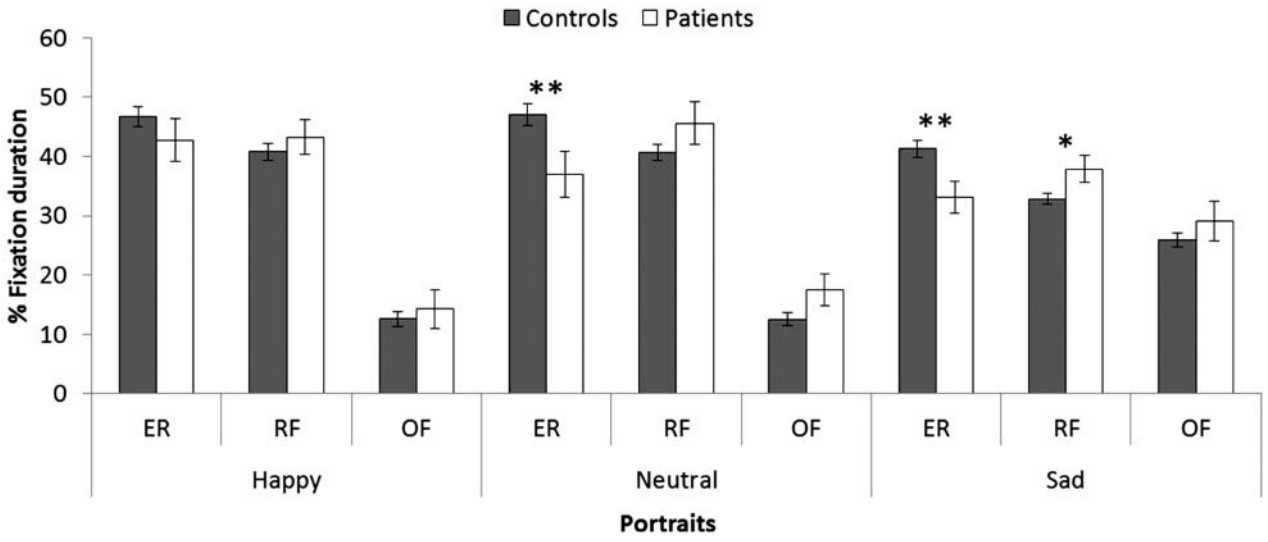

Figure 2. Percentage of total fixation duration for patient and control groups across each main areas of interest in each portrait category (ER: emotional regions; RF: rest of the face; and OF: outside of the face). Between group differences: $^{*}p < .05$; $^{**}p < .01$.

for sad portraits ($p = .021$, $d = 0.75$ and 95% CI_d [−0.62, 2.12]). There were no other significant differences observed between the two groups (all $p_s > .18$ and all $d_s < 0.70$).

When we analyzed results within each group, patients showed a lower percentage of fixation duration on emotional regions for sad than for happy portraits ($p = .002$, $d = 0.69$ and 95% CI_d [−1.75, 3.13]), and for neutral than for happy portraits ($p = .031$, $d = 0.46$ and 95% CI_d [−2.29, 3.21]), while control participants did not show any difference on emotional regions between the three portrait categories (all $p_s > .19$ and all $d_s < 0.45$). Concerning the rest of the face, patients showed no difference on percentage of fixation duration on the rest of the face between the three portrait valences (all $p_s > .07$ and all $d_s < 0.54$), while control participants had a lower percentage of fixation duration for sad than for happy portraits ($p = .020$, $d = 0.80$ and 95% CI_d [−0.94, 2.54]), and for sad than for neutral portraits ($p = .017$, $d = 0.82$ and 95% CI_d [−0.83, 2.47]). Finally, patients and control participants had a higher percentage of fixation duration on the outside of the face for sad than for happy portraits (all $p_s < .001$ and all $d_s > 1.45$), and for sad than for neutral portraits (all $p_s < .001$ and all $d_s > 1.53$; see Figure 2).

Percentage of fixations

A 2 (groups: patients and controls) × 3 (portrait valence: happy, neutral and sad) × 3 (MAOIs: the emotional regions, the rest of the face and the outside of the face) mixed-plot analysis indicated a significant main effect for MAOIs, $F(2, 152) = 89.14$, $p < .001$ and $\eta_p^2 = .53$; percentage of fixations was higher in emotional regions ($M = 40.24$ and $SD = 12.81$) than on the outside of the face ($M = 19.18$ and $SD = 12.23$), $p < .001$, $d = 1.71$ and 95% CI_d [−0.48, 3.88], and higher on the rest of the face ($M = 40.36$ and $SD = 10.06$) than on the outside of the face, $p < .001$, $d = 1.89$ and 95% CI_d [−0.08, 3.86].

Portrait valence × MAOIs interaction was also significant, $F(2, 175) = 43.36$, $p < .001$ and $\eta_p^2 = .35$, and was qualified by a significant group × portrait valence × MAOIs interaction, $F(2, 175) = 3.28$, $p = .012$ and $\eta_p^2 = .05$. *Post hoc* analyses of this three-way interaction showed that compared to control participants, patients had a lower percentage of fixations on emotional regions for sad portraits ($p < .001$, $d = 0.70$ and 95% CI_d [−1.01, 2.40]) and neutral portraits ($p = .011$, $d = 0.64$ and 95% CI_d [−1.85, 3.13]). Patients also had a higher percentage of fixations on the rest of the face for sad portraits ($p < .001$, $d = 0.51$ and 95% CI_d [−0.80, 1.81]) than controls. There were no other significant differences observed between the two groups (all $p_s > .17$ and all $d_s < 0.33$).

Concerning each of the two groups, patients had a lower percentage of fixations on emotional regions for sad than for happy portraits ($p < .001$, $d = 0.93$ and 95% CI_d [−1.01, 2.87]), and for neutral than for happy portraits ($p = .005$, $d = 0.40$ and 95% CI_d [−2.10, 2.91]), while there was no significant difference between the three portrait valences for control participants (all $p_s > .11$ and all $d_s < 0.52$). Concerning the rest of the face, patient results did not show any significant difference between the three portrait valences (all $p_s > .07$ and all $d_s < 0.69$), while control participants had a lower percentage of fixations for sad than happy portraits ($p = .005$, $d = 0.88$ and 95% CI_d [−0.47, 2.23]), and for sad than for neutral portraits ($p = .002$, $d = 1.03$ and 95% CI_d [−0.41, 2.47]). Both patient and control participants showed a higher percentage of fixations on the outside of the face for sad than for happy portraits (all $p_s < .001$ and all $d_s > 1.25$), and for sad than for neutral portraits (all $p_s < .001$ and all $d_s > 0.94$).

First fixation time

A 2 (groups: patients and controls) × 3 (portrait valence: happy, neutral and sad) × 3 (MAOIs: the emotional regions, the rest of the face and the outside of the face) mixed-plot analysis indicated only a significant main

Table 2. Mean (standard deviation) for total fixation duration, fixations and first fixation time, for patient and control groups for the emotional regions (ER), the rest of the face (RF) and the outside of the face (OF) in each portrait category.

		Total fixation duration (%)		Fixations (%)		First fixation time (s)	
Portraits	MAOIs	Controls	Patients	Controls	Patients	Controls	Patients
Happy	ER	46.74 (13.60)	42.67 (15.76)	43.69 (12.43)	41.47 (12.21)	0.81 (0.65)	1.53 (1.17)
	RF	40.73 (11.74)	43.13 (12.81)	41.88 (9.95)	44.25 (9.55)	1.01 (0.82)	1.01 (0.80)
	OF	12.53 (1.24)	14.20 (3.27)	14.43 (9.87)	14.28 (12.44)	4.13 (1.92)	4.53 (2.29)
Neutral	ER	47.03 (14.59)	36.97 (16.95)	43.44 (13.56)	35.71 (16.19)	1.64 (1.44)	1.45 (1.11)
	RF	40.54 (10.90)	45.57 (15.69)	42.83 (9.42)	45.83 (14.54)	1.06 (1.04)	1.23 (1.38)
	OF	12.43 (8.61)	17.46 (11.67)	13.73 (8.65)	18.46 (14.02)	4.35 (1.94)	3.99 (1.70)
Sad	ER	41.28 (10.97)	33.11 (11.91)	37.96 (9.64)	31.21 (9.87)	1.22 (1.11)	1.71 (1.05)
	RF	32.84 (7.76)	37.81 (9.92)	34.41 (6.88)	38.17 (8.05)	1.41 (1.18)	1.53 (1.28)
	OF	25.88 (9.79)	29.08 (3.31)	27.63 (9.23)	30.62 (13.66)	2.51 (1.27)	3.14 (1.88)

Note: MAOIs – main areas of interest.

effect for MAOIs, $F(2, 106) = 79.88$, $p < .001$ and $\eta_p^2 = .54$, which was qualified by a significant portrait valence × MAOIs interaction, $F(3, 235) = 8.53$, $p < .001$ and $\eta_p^2 = .12$. There were no other significant main effects or interactions.

Post hoc analyses of portrait valence × MAOIs interaction showed that the first fixation time was shorter on the outside of the face for sad portraits than on the outside of the face for happy portraits ($p < .001$, $d = 0.91$ and 95% CI_d [0.62, 1.22]) or neutral portraits ($p < .001$, $d = 0.99$ and 95% CI_d [0.71, 1.29]). The first fixation time was shorter on the emotional regions for happy portraits than on the emotional region for neutral portraits ($p = .026$, $d = 0.56$ and 95% CI_d [0.37, 0.77]). The first fixation time was shorter on the emotional regions than on the outside of the faces for sad portraits (respectively, $M = 1.32$, $SD = 1.11$ vs. $M = 2.63$, $SD = 1.42$), happy portraits (respectively, $M = 0.96$, $SD = 0.83$ vs. $M = 4.21$, $SD = 1.99$), and neutral portraits (respectively, $M = 1.60$, $SD = 1.37$ vs. $M = 4.28$, $SD = 1.88$), all $p_s < .001$ and all $d_s > 1.0$. Similarly, the first fixation time was shorter on the rest of the face (sad portraits: $M = 1.43$ and $SD = 1.20$; happy portraits: $M = 1.01$ and $SD = 0.81$; neutral portraits: $M = 1.10$ and $SD = 1.10$) than on the outside of the faces (all $p_s < .001$ and all $d_s > 0.91$). There were no significant differences between the emotional region and the rest of the face for each of the three portraits (all $p_s > .05$ and all $d_s < 0.40$; see Table 2).

Correlations and covariance

We analyzed correlations between eye movement variables and neuropsychological test scores for depressed and healthy older adults overall. We did not find any significant correlation between eye movement variables and neuropsychological test scores.

We also analyzed possible relationships between psychiatric scale and eye movement variables. Correlation analysis revealed that the MADRS scores were correlated with the percentage of total fixation duration ($r = -.29$ and $p = .017$) and the percentage of fixations ($r = -.28$ and $p = .016$), only for the emotional regions of sad portraits. There was no correlation found between BDI-II and eye movement variables.

As to whether age, sex, neuropsychological or depression measures change statistical differences found above, we also carried out analyses of covariance. ANCOVA with age as covariate did not change results ($F_s > 2$ and $p_s < .05$) as well as ANCOVA with sex as covariate ($F_s > 4$ and $p_s < .01$). ANCOVAs with neuropsychological tests as covariates did not change the statistical results ($F_s > 2$ and $p_s < .05$). ANCOVA with the BDI-II as covariate also did not change statistical results ($F_s > 2$ and $p_s < .05$). ANCOVA with the MADRS as covariate showed a loss of statistical effects ($F_s < 3$ and $p_s > .05$). These results indicated that the eye movement differences found between patients and controls are only influenced by the depression score (evaluated with the MADRS).

Discussion

The main purpose of this study was to examine the characteristics of visual face processing in depressive older patients compared to healthy participants. We recorded eye movements to examine visual strategies used viewing emotional facial expressions (i.e. happy, sad and neutral) in depressive and healthy older adults. We hypothesized that depressive older adults would make fewer fixations and a shorter fixation duration than healthy participants in emotional regions (i.e. ECI), except for happy portraits (i.e. positivity effect). As expected, our results showed that older patients with depression spent less time and had fewer fixations on emotional features (i.e. eyes and mouth) than healthy participants only on sad and neutral portraits. There were no significant differences observed between the two groups on happy portraits. Also note that our results did not vary over time, as indicated by time sequence analyses. Another interesting aspect of our findings is the lack of significant difference between the two groups concerning the first fixation time. Individuals engaged eye movements on emotional regions or on the rest of the face before the outside of the face regardless portrait categories. This finding indicates that the

modifications of the visual strategies in older patients did not take place at the early stage of the processing.

These results suggest that depressed older patients had a disengagement from emotional regions compared to healthy participants for the negative and neutral portraits. We did not find exactly the same results as reported by Loughland et al. (2002). These authors found that depressive younger subjects had a disengagement from facial features for all expressions (i.e. happy, neutral and sad). Our results on older depressed adults have also found disengagement from emotional facial features, but only for sad and neutral portraits. The only previous study (Phillips et al., 2010) conducted on changes in emotional facial recognition in older depressed patients reported a mild impairment for recognizing sad faces, and no difficulty for recognizing happy faces. This pattern seems to be coherent with our findings. Indeed, a disengagement from emotional features can lead to a poorer ability to recognize emotions (Wong et al., 2005). Thus, the disengagement from emotional features on sad faces (and neutral faces) would result in a poor recognition of sad faces (and neutral faces). In our study we did not ask participants to explicitly recognize emotional facial expressions of portraits and we cannot deliberate on this hypothesis. Future experiments should control emotional recognition after the visual inspection task in order to confirm a link between visual processing and recognition ability.

Healthy participants showed the same pattern of results for all three categories: they spent more time and had a greater number of fixations on the emotional regions than on the rest of the face on happy, neutral and sad portraits. These results are consistent with the idea that positivity effect is used as mood-regulatory strategy to optimize mood state (Carstensen, 2006; Carstensen et al., 1999; Isaacowitz et al., 2008; Mather & Carstensen, 2005). According to Isaacowitz et al. (2008), the preferential processing toward positive stimuli occurs when older people need to regulate and improve their mood (such as in negative mood state). We may assume that our older participants did not need to regulate their mood state during the experiment, and so they did not use processing toward positive stimulus strategy.

Limitations of the current study should be noted. Our patient sample was relatively small ($N = 20$). Larger sample size should allow increasing statistical power, detecting some other differences between the groups, and so, further specifying characteristics of face processing in depressed older adults. We highlighted difference between healthy and depressed older adults, but more explanatory power may be afforded by the co-inclusion of younger groups in order to measure the effect of aging on the visual processing of emotional stimuli in depression. As the participants of most of the studies cited above, our depressed patients had antidepressant medications. This is a classical research limitation given the structure of health care services. Since some studies found antidepressant effects on depression-related biases (Harmer et al., 2009; Fu et al, 2004; Wells, Clerkin, Ellis, & Beevers, 2014) and others did not (García-Blanco, Salmerón, Perea, & Livianos, 2014; Surguladze et al., 2004), it would be interesting to analyze the potential effects of antidepressant medications on these biases in the elderly in order to identify the potential interactions between medication and depression.

Finally, although we conducted clinical interviews and neuropsychological measures to diagnose major depressive disorders and control cognitive capacities, we did not precisely investigate all subclinical potential disorders. For instance, even if a recent meta-analysis showed that emotional bias in depression was not dependent on anxiety comorbidity (Peckham, McHugh, & Otto, 2010), the impact of anxiety on the positivity effect remains unclear. Certain studies found that anxiety leads to an attentional bias to negative stimuli in older people (Fox & Knight, 2005), whereas others found bias away from negative information (Demeyer & De Raedt, 2013) or a lack of attentional bias (Mohlman, Price, & Vietri, 2013). As written by Demeyer and De Raedt (2013), these inconsistent findings could be due to a too large generalization of the 'older people' category. Within-group differences should be taken into account in order to better understand the positivity effect. We found that depression can modify the positivity effect. However, the latter can also be influenced by anxiety. Further research should investigate the interaction between depressive disorders and various affective variables if one wants to better understand the positivity effect in the elderly.

Our experiment provides a supplementary argument for the specificity of depression in the elderly. According to the ECI hypothesis (Bylsma et al., 2008; Rottenberg et al., 2005), depression prompts a reduction of motivational activity that results in an environmental disengagement, which can explain Loughland et al. (2002) results on younger adults. According to socioemotional selectivity theory, older adults are motivated to prioritize mood regulation. This mood regulation leads to preferential interest toward positive stimuli and to the avoidance of negative stimuli, when they need to optimize their current mood (Isaacowitz et al., 2008). The positivity effect could influence the visual strategies in depressive older adults. This could result in a greater disengagement from emotional features of faces, excepted for happy faces. We suggest that positivity effect and emotional context insensitivity interact as mood-regulatory mechanisms to deal with negative mood state in the depressed elderly. Future research must be carried out in depressive younger patients compared to depressive older patients in order to verify that there is an influence of aging on the visual processing of emotional stimuli in depression.

Conclusion

The current study suggests that visual face processing of depressive older patients significantly differs from healthy older participants. In fact, older patients spend less time analyzing sad and neutral faces compared to healthy participants. These results suggest disengagement from sad and neutral stimuli in depression in older adults compared to happy stimuli, which seem to be normally analyzed (i.e. higher time spent on emotional regions). Our findings indicated changes in visual processing in older adults with depression. These modifications are different from those

pointed out in the literature concerning depressed younger adults. We proposed that mood-regulatory mechanisms present in depression and normal aging work together to deal with mood state. Longitudinal methods are warranted to better understand the dynamics and the modification of processing bias in depression.

This is the first study to examine eye movements during inspection of emotional faces in old age depression. Although further studies are needed, our preliminary results suggest that information processing in depression consists of a more complex phenomenon than merely a general searching for mood-congruent stimuli or a general disengagement of all kinds of stimuli. These findings underline that care must be used when evaluating potential variables, such as aging, that interact with depression and selectively influence the choice of relevant stimulus dimensions.

Acknowledgements

The authors are grateful to Richard Medeiros, medical editor of Medical Editing International for his help in the process of editing the final manuscript.

Funding

This work was supported by the National Hospital Clinical Research Program [grant number 2009-A00942-55].

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