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Age-Related Differences in Sensitivity to Emotional Facial Stimuli but Age-Independent Association between Arousal Ratings and Visual Search Efficiency

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Abstract

The latter part of the lifespan is commonly associated with a decline of cognitive functions, but also with changes in emotional responding. To explore the effect of age on processing of emotional stimuli, we used a two-task design. In a stimulus-rating task, we investigated the emotional responses to 15 different schematic facial emotional stimuli (one neutral, seven positive, seven negative) on Arousal, Valence and Potency measures in 20 younger (21-32 yrs, *M*=26, *SD*=3.7) and 20 older (65-81 yrs, *M*=72, *SD*=4.9) participants. In a visual attention task, we used the same 15 stimuli in a visual search paradigm to investigate differences between younger and older participants in how the emotional properties of these emotional stimuli influence visual attention.

The results from the stimulus-rating task showed significantly reduced range in responses to emotional stimuli in the older compared to the younger group. This difference was found on both emotional Arousal and Potency measures, but not on emotional Valence measures; indicating an age-related flattening of affect on two of the three emotional key dimensions. The results from the visual search task showed – apart from the general extension of response latencies in older – no general emotion-related differences between how emotional stimuli influences attention in the younger and older groups.

Analysis of the relationships between attention and emotion measures showed that higher ratings on Arousal and Potency were associated with both shorter reaction times and fewer errors in the attention task. This correlation was age-independent, indicating a similar influence from emotional Arousal on detection of angry faces in younger and older adults.

Keywords: visual attention, emotion, aging, visual search, facial stimuli

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Introduction

Emotion psychology is an exceptionally large and fast-growing research area. One of the reasons for this broad interest is the fundamental importance of emotions in human daily life. According to emotion theorists, one of the central functions of emotions is to emphasize things in the environment that are significant to us, and help us select and prioritize among large numbers of simultaneously occurring sensory inputs, thoughts, and potential actions (Izard, 2011; Oatley & Jenkins, 1996; Panksepp & Watt, 2011). From this perspective, emotion acts as an influential "auto pilot", helping us navigate through everyday socio-emotional life. However, because of this function, overly strong emotional reactions (e.g. in phobic fears or PTSD; see e.g. Öhman, 1993) or lack of appropriate responses to socio-emotional stimuli (e.g. Autism; see e.g. Baron-Cohen, 1995) becomes a large problem for normal socio-emotional interaction and inclusion.

The latter part of the lifespan is commonly associated with a decline of cognitive functions, but it is also associated with changes in emotional responding. Although traditionally coined as an *age-related positivity effect* (see e.g. Mather & Carstensen, 2005; Reed & Carstensen, 2012) there is yet no consensus on what underlies such changes. It is for instance debated whether the positivity effect stems from a change in positivity itself, or whether the increase in positivity is a side-effect from an acquired insensitivity to negative information in older adults (e.g. Langeslag & van Strien, 2009). A growing literature indicates age-related differences in responses to emotional pictorial stimulus (e.g. Grühn & Scheibe, 2008; Kehoe, Toomey, Balsters, & Bokde, 2013; Keil & Freund, 2009). However, also within this field the results are inconclusive. For example, compared to younger adults, older adults rated positive pictures as more positive, and negative pictures as more negative (Grühn & Scheibe, 2008). In addition, older adults perceived negative pictures as more arousing, and positive pictures as less arousing compared to younger adults. Another study showed that, although older adults rated positive pictures as less positive and less arousing than younger, there were no age-related differences in valence or arousal ratings for negative pictures (Keil & Freund, 2009). Although inconclusive, these results indicate age-related differences in sensitivity to emotional pictures. Furthermore, a related concern is whether a change in emotional sensitivity may have consequences also on the degree by which emotion may influence and ”pilot” cognitive processes, such as visual attention. This issue has earlier been partly explored by using emotional (facial or other) stimuli in visual search paradigms. However, the pattern of results is not conclusive. While most results indicate that emotional valence is maintained across the life span (Leclerc & Kensinger, 2008, 2010; Ruffman, Ng, & Jenkin, 2009), other reports indicate age-related effects that stems from changes in how angry faces are processed (e.g. Hahn, Carlson, Singer, & Gronlund, 2006).

In this article, we aim to explore these issues further. To do this, we adopt a two-task approach. In one task, we target the sensitivity to emotional stimuli itself, by assessing age-related changes in emotional discrimination between facial emotional stimuli. This question is explored by using subjective emotional rating of 15 schematic emotional (angry and happy) facial stimuli, by means of semantic differential scales denoting the three major emotional dimensions of Valence, Arousal and Potency. In a visual search task, we also target changes in the emotion-cognition relationship, by investigating age-related changes in the influence of the abovementioned 15 emotional stimuli on visual attention. This two-task design is adopted from Experiment 4 of Lundqvist & Öhman (2005). In that article, the authors showed that this selection of stimuli gave differentiating effects across a wide range of responses on all three emotional dimensions (Arousal, Valence and Potency). Furthermore, the authors also demonstrate that the two-task combination provide data on the relationship between emotion measures and attention measures.

To give a background to the choice of these tasks, the stimuli and stimulus rating task in the article by Lundqvist & Öhman (2005) was, in turn, adopted from earlier work on the emotional impression of facial stimuli (most directly from Lundqvist, Esteves, & Öhman, 1999, 2004); but ultimately from Aronoff, Barclay, & Stevens, 1988; and Aronoff, Woike, & Hyman, 1992). In turn, this work leans on the tradition of identifying underlying emotional dimension in the formation of affective responses to emotional stimuli pioneered by, for instance, Schlosberg (1954), Osgood (1966) and Russell (2003; Russell & Bullock, 1985), an approach which repeatedly identifies Valence, Arousal and Potency as the three key dimensions underlying subjective emotional responses (see also Lundqvist, Bruce, & Öhman, 2013; Lundqvist, Juth, & Öhman, 2013).

The design of the visual search task in Lundqvist & Öhman (2005), in turn, built directly on earlier work from these authors (see e.g. Öhman, Lundqvist, & Esteves, 2001). Both of these articles belong to a tradition of using schematic/line-drawn (rather than photographed) facial emotional stimuli in visual search experiments. This choice of stimulus type addresses a potentially problematic issue with the visual search paradigm: its sensitivity to perceptual factors. Indeed, within the portion of this research field that uses *photographed* stimuli, the results from visual search experiments have been notoriously contradictory, and there has been a steady debate of whether possible perceptual confounds influence results (see e.g. Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Calvo & Nummenmaa, 2008; Lundqvist, Bruce, et al., 2013). However, within the portion of this research field which uses *schematic* facial stimuli, results have been very homogenous (for an overview, see Lundqvist, Juth, et al., 2013), and in support of a relationship between the valence of facial emotional stimuli and visual attention. Despite discussions of perceptual artifacts also within this research area (see e.g. Coelho, Cloete, & Wallis, 2010; Mak-Fan, Thompson, & Green, 2011), several studies demonstrate that effects of emotional stimuli on visual attention are independent of single facial features and perceptual factors (see e.g. Fox et al., 2000; Lundqvist, Bruce, et al., 2013; Lundqvist & Öhman, 2005; Öhman, Juth, & Lundqvist, 2010; Tipples, Atkinson, & Young, 2002).

In sum, by using the two-task design from Experiment 4 of Lundqvist & Öhman (2005), we choose a combination of tasks, each of which has a history as an established and sensitive tool to assess subjective emotional responses, and emotion-attention influences, respectively. In the present experiment, this task design is combined with a between-group design, to compare the performance of younger versus older participants on these tasks.

Method

Participants

A total of 40 participants took part in the experiment (*N*=40; 19-81 yrs). Half of the participants were of younger age (*N*=20; 21-32 years; *M*=26: *SD*=3.7; 10 females, 10 males) and the other half was older (*N*=20; 65-81 years; *M*=72; *SD*=4.9; 10 females, 10 males).

Apparatus

The experimental tasks included in the experiment were all programmed using Adobe Director 11.5 software (Adobe Inc.). Using a Pentium IV PC computer, the tasks were presented on a 19'' OLED monitor, run in 1600* 1200 pixel native resolution.

Stimuli

A total of 15 schematic facial emotional stimuli were used in the experiment. These stimuli were recruited from Lundqvist & Öhman (2005), Experiment 4. For a detailed background to the development of these stimuli, see also Lundqvist et al. (1999, 2004). The stimuli (see Figure 1) consist of 1 neutral face, 7 angry (negative) faces and 7 happy (positive) faces. For details on the design of these stimuli, see Lundqvist & Öhman (2005).

Figure 1. *The Schematic Facial Emotional Stimuli Used in the Experiment*

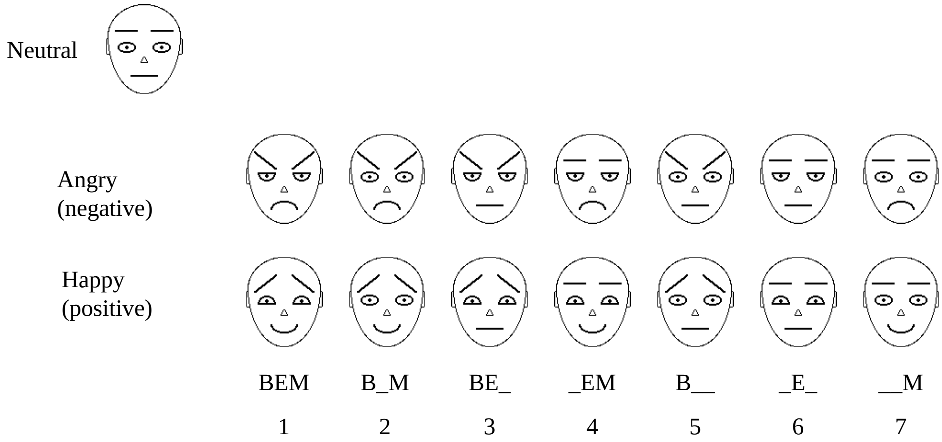

Figure 1 show the schematic facial emotional stimuli used both in the emotional rating task and the visual search task. These 15 stimuli consist of 1 neutral face, 7 angry and 7 happy faces. The letters below each faces denotes what facial features that discriminate between the happy and angry expression. In stimulus 1, all three features (B=eyebrows, E=eyes, M=mouth) changes, in stimuli 2-4 only two features change, and in stimuli 5-7 only one feature changes between expressions.

*Visual search***.** During the visual search task, the stimuli were presented in circular stimulus displays, each containing 8 schematic faces. Individual faces were drawn in black and white, with a size of 84 x 98 pixels. In half of the stimulus displays, all 8 faces where of the same expression (neutral). In the other half of the displays, one of the 8 faces was replaced by a target face. This target face could be any of the 7 angry or 7 happy faces. Each target face was presented once at each position in the circular display. In total the participant was presented to 224 randomly ordered trials (122 of which were all-neutral displays, the other 122 distributed across the 14 target stimuli, each target presented 8 times, once at each position in the display).

Rating. During the rating task, each of the 15 facial stimuli used in the visual search task (7 angry, 7 happy, 1 neutral) were presented one by one in random order.

Procedure

The participants were tested individually. They were seated approximately 1 meter from the computer screen.

Visual search. In the visual search task, self-paced instructions were presented on the computer screen. The instructions explained that the task was to decide whether all 8 faces in a display were similar (and if so, press a key with the left index finger), or if one face deviated from the other (and if so, press a key with the right index finger) and to do this as quickly and accurately as possible. Before the start of the experiment, the participants were taken through a series of self-paced training trials, which exemplified the different stimuli displays. A trial was initiated by a fixation point (10 pixels in diameter) appearing at the center of the screen. The fixation point was exposed for 2 seconds, and was then replaced by a stimulus display, exposed until the participant responded. After each response, there was a 3 second inter-trial interval before the fixation point reappeared on the screen, initiating a new trial.

Rating. In the rating task, participants were instructed to rate their emotional impression all the 15 faces that were used in the visual search task. A trial was initiated by presentation of a facial stimulus in the middle of the computer screen. Below a face, three VAS-scales were presented. The selection of VAS-scales was the same as those used by Lundqvist & Öhman (2005), selected to tap the three semantic dimensions of Arousal, Valence, and Potency. Stimuli were presented in random order. For each trial, scale order and scale polarity were randomized.

Data Treatment and Statistical Analysis

Tests for normality in the distribution of RT data suggested that a logarithmic transformation was warranted (see e.g. Ratcliff, 1993).

ANOVAs. Separate ANOVAs were planned for each of the dependent measures. For these analyzes, average scores were accumulated separately for the three categories of neutral, angry and happy stimuli (the scores for angry and happy are thus an average of the 7 stimuli within each category). For the visual search data (since the neutral faces are never used as targets in the visual search task), a 2 (AGE: Younger vs. Older participants) x 2 (TARGET EMOTION: Happy versus Angry) mixed factorial design was used. For the emotional rating data, a 2 (AGE: Younger vs. Older participants) x 3 (STIMULUS EMOTION: Neutral vs. Happy vs. Angry) mixed design was used.

Correlation analysis. To also enable a correlation analysis between attention and emotion measures on an item level (for comparison to the data reported by

Lundqvist & Öhman, 2005), scores were also accumulated on a stimulus item level (for each of the 15 stimuli; 1 neutral, 7 angry and 7 happy), across participants, separately for angry and happy faces, and separately for older and younger participants.

Results

Analysis of Variance (ANOVAs)

To analyze how the Age of participants affected the discrimination between angry and happy faces, separate ANOVAs were run on the two attention measures (RTs and Accuracy) and the three emotion measures (Arousal, Valence and Potency).

Attention Measures

Reaction times (RT). There was a significant main effect from Age on RTs, $F(1,38)=16.3$, $p<.01$, $\eta^2=.29$, showing longer latencies for Older compared to Younger participants (see Figure 2). There was also a main effect of Target emotion, $F(1,38)=88.5$, $p<.01$, $\eta^2=.03$, showing shorter latencies for Angry compared to Happy stimuli (see Figure 2).

Errors. There was no significant main effect from Age on Errors. There was however a main effect of Target emotion, $F(1,38)=48.2$, $p<.01$, $\eta^2=.13$, showing fewer Errors for Angry compared to Happy stimuli (see Figure 2).

Figure 2. *Age-related Effects on Attention Measures*

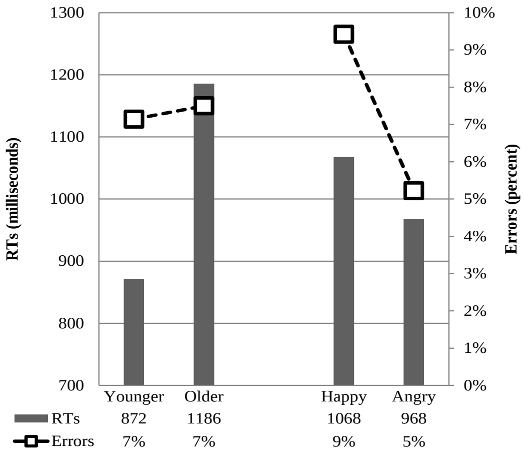

Figure 2 shows the results from the visual search task. Average RTs for the Age and Emotion factors are plotted against Error rates. The results from the Age factor show that younger participants are about 300 ms faster than older, but that there are no significant differences between these groups on error rates. The results from the Emotion factor show that Angry faces are detected about 100 ms faster than Happy faces, and with about half as many errors. Analyzes on RTs were made on logarithmized data. Figure 2 however show RTs re-transformed to milliseconds.

Emotion Measures

Arousal. There was no main effect from Age on Arousal. There was a main effect from Stimulus emotion, $F(2,76)=36.0$, $p<.01$, $\eta^2=.33$, showing the highest Arousal scores for Angry faces ($M=9.4$), followed in rank order by Happy ($M=7.3$) and the lowest scores for Neutral faces ($M=-14.1$). Furthermore, there was an interaction effect between Age and Stimulus emotion, $F(2,76)=6.8$, $p<.01$, $\eta^2=.06$. In Figure 3 (left panel), it can be seen that what drives this interaction effect is a significantly smaller range in the ratings of emotional faces from Older participants (range=15.1) compared to Younger (range=34.9).

Potency. The effects on Potency were very similar to those on Arousal. There was hence a main effect from Stimulus emotion, $F(2,76)=19.3$, $p<.01$, $\eta^2=.21$, showing the highest Potency scores for Angry faces ($M=12.9$), followed in rank order by Happy ($M=5.7$), and Neutral faces ($M=-7.5$). There was also a similar (to Arousal) interaction effect between Age and Stimulus emotion, $F(2,76)=6.2$, $p<.01$, $\eta^2=.07$. In Figure 3 (right panel), it can again be seen that what drives this interaction is a much smaller range in the ratings of emotional faces from Older participants (range=8.9) compared to Younger (range=32).

Valence. There was no main effect and no interaction effects from Age on Valence. There was a main effect from Stimulus emotion, $F(2,76)=165.7$, $p<.01$, $\eta^2=.71$, showing the most negative Valence scores for Angry faces ($M=-20$), the most positive Valence scores for Happy faces ($M=15.8$), with Neutral in close to zero ($M=2.9$).

Figure 3. *Age-related Effects on Emotion Measures*

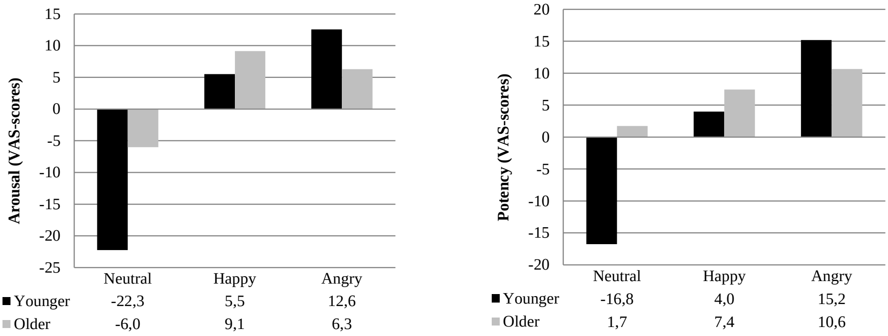

Figure 3 shows the results on Arousal and Potency measures. The results show that on Arousal (left panel), there is much smaller emotional range in the ratings of emotional faces from Older participants (range=15.1) compared to Younger (range=34.9). A similar pattern is found on Potency (right panel) where Older participants' range is 7.9 and Younger participants' range is 32.0.

Analysis of Emotion-attention Relationships

Follow-up correlation analyzes. To explore the relationships between attention and emotion measures (cf. Lundqvist & Öhman, 2005), Pearson *r* correlation coefficients were computed between attention and emotion measures. This was first done overall for stimuli of both emotions, then separately for the angry and happy stimuli. In both analyzes Neutral stimuli was left out of the computations, because they were not used as targets in the visual search task.

Overall Correlations

Reaction times. There were significant overall correlations between RTs and Arousal (N=28; r=-.44, r^2=.19, p<.05) and a very similar relationship between RTs and Potency (N=28; r=-.42, r^2=.17, p<.05). The direction of these relationships shows that both high Arousal scores and high Potency scores are associated with short response latencies (i.e. an efficient visual detection of high-arousal stimuli).

Errors. There were significant overall correlations also between the number of Errors and Arousal (N=28; r=.-46, r^2=.21, p<.05) and between Errors and Potency (N=28; r=-.44, r^2=.19, p<.05). The direction of both of these relationships shows that the high Arousal and Potency scores are associated with few Errors (again an indication of an efficient visual detection).

Correlations, Separately for Angry and Happy Faces

When correlations were computed separately for angry and happy faces, none of the relationships between attention and emotion measures were significant for happy faces. For *angry faces* on the other hand, relationships were very strong. In Figure 4, this difference in relationships is visualized by a scatterplot of RTs against Arousal, separately for angry faces (left panel) and happy faces (right panel).

Reaction times. There were significant correlations between RTs and Arousal for the angry faces (N=14; r=-.87, r^2=.76, p<.01) and a very similar relationship between RTs and Potency (N=14; r=-.83, r^2=.69, p<.01).

Errors. There were significant overall correlations between RTs and Arousal for the angry faces (N=14; r=.-74, r^2=.55, p<.01) and a very similar relationship between RTs and Potency (N=14; r=.-69, r^2=.48, p<.01).

The direction of all of these relationships shows that the high Arousal and Potency scores are associated with short response latencies and few errors (both of which indicate an efficient visual detection of high-emotional stimuli).

Figure 4. *The Relationship between Attention and Emotion Measures*

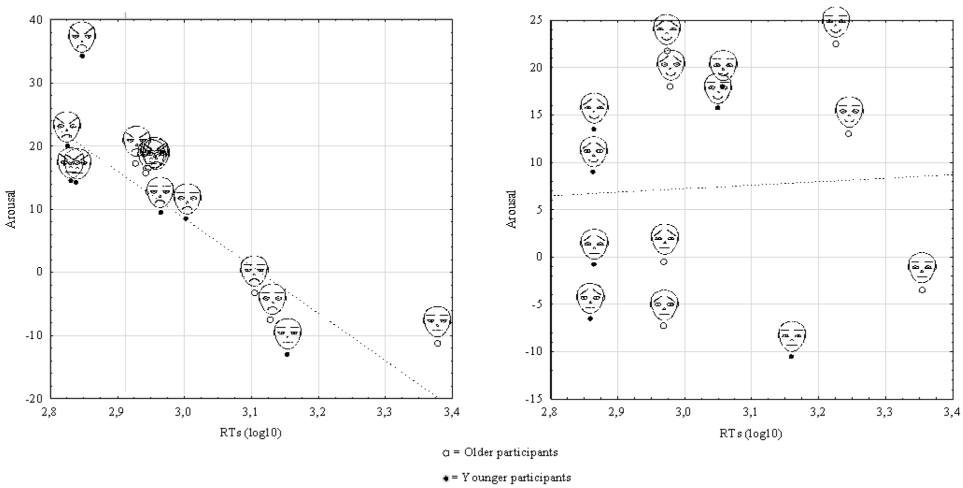

Figure 3 shows the relationship between emotional Arousal scores and RTs separately for *angry faces* (left panel) and *happy faces* (right panel) in younger and older participants. *Regarding angry faces.* For younger participants, most stimuli are centered in the top left area, denoting high arousal scores and short RTs. For older participants, most stimuli are centered in the middle to bottom right area, denoting comparatively lower arousal scores and longer RTs. *Regarding happy faces.* For younger participants, faces are centered on the left side of the plot, denoting shorter RTs. For older participants, the opposite pattern is found. The distribution of faces along the arousal dimension is however about the same for both groups.

Discussion

Summary of Results

Attention. The ANOVAs on attention measures showed a main effect of Age on RTs but no corresponding main effect on Error rates. These results thus show that while older participants are slower in responding, they perform with the same low number of errors as younger participants. The main effects of Target emotion found on both of these attention measures jointly show that the angry faces were detected more efficiently (faster and with fewer errors) compared to the happy faces. These results replicate the general pattern of results often found when using schematic facial emotional stimuli in visual search experiments (see in particular Lundqvist & Öhman, 2005; for an overview of such results, see Lundqvist, Juth, et al., 2013; Öhman et al., 2010). The results are also in accordance with previous studies showing a preserved threat-detecting ability among older adults (Mather & Knight, 2006; Ruffman et al., 2009).

Emotion. While the ANOVAs on emotion measures showed no main effects of Age, there were significant interaction effects between Age and Stimulus emotion on both Arousal and Potency measures. In both cases, the results showed a significantly declined range in emotional ratings of the schematic facial stimuli in Older compared to Younger participants. On both measured, the pattern of results showed that ratings in Older participants had moved towards zero (mid-point) on the rating scale, showing a decrease in discrimination, and indicating a comparatively flatter affect on both of these emotional key dimensions compared to younger participants.

There was however no such decline in the emotional valence dimension, suggesting that an age-related decline in emotional sensitivity develops in different degrees for different dimensions. These results hence join the literature which shows that emotional valence is largely intact across increased age (Leclerc & Kensinger, 2008, 2010; Ruffman et al., 2009). It also extends previously reported age-related differences in ratings of emotional pictorial stimulus (IAPS), to also include such differences in ratings of emotional faces (c.f. Kensinger, 2008). As mentioned in the introduction, older adults seem to rate positive pictures as less arousing than younger adults (Grühn & Scheibe, 2008; Keil & Freund, 2009), and negative pictures equally arousing (Keil & Freund, 2009), or even more arousing (Grühn & Scheibe, 2008) than did younger adults. Our results showed opposite patterns for emotional faces, namely that older adults rated happy faces as more arousing than did younger adults. In addition, older adults rated angry faces as less arousing than younger adults. The same pattern was evident also for the rating of emotional potency. These findings indicate an overall decrease in emotional sensitivity to facial expressions in older adults, and a positivity effect only for relatively low arousal stimuli such as emotional faces (where faces can be considered low in arousal compared to emotional IAPS pictures).

Emotion-attention relationships. The general correlation relationships results show that the higher a stimulus is in arousal and potency, the more efficiently it is detected during visual search. These results confirm earlier results using the exact same stimuli (e.g. Lundqvist & Öhman, 2005) and other facial emotional stimuli (Lundqvist, Bruce, et al., 2013; Lundqvist, Juth, et al., 2013), and add to the literature by showing that this emotion-attention relationship extends also to older adults. While the direction of the attention-valence relationship is also in the same direction as in Lundqvist and Öhman (2005; using the same stimuli), it is in the opposite direction of results from using *photographed stimuli*. For a discussion of the direction of relationships between Valence, Arousal, Potency and attention measures see Lundqvist, Bruce, et al. (2013), and Lundqvist, Juth, et al. (2013).

Different relationships for angry and happy stimuli. The correlation analyzes run separately per emotion indicated that the attention-emotion relationship was tied mainly to the angry stimuli. This indicate that while there were no age-related effects from the Valence measure itself, age-related differences on other dimensions (Arousal and Potency) still appear located primarily to stimuli on one side of the Valence dimension (the negative side). This could be interpreted as indicating that an underlying age-related change is primarily located to negatively valenced stimuli. However, it may also reflect the fact that these particular schematic stimuli were designed with a particular concern. When exploring the role of facial geometry on emotional impression, the historical focus was on locating maximally angry/negative features (see Aronoff et al., 1988; Lundqvist et al., 1999, 2004) whereas the happy faces were designed mainly by reversing the features used for angry/negative faces (e.g. reversing negative eyebrows, negative mouth, negative eyes) rather than maximizing the ability to convey a happy impression. It may hence be that the angry faces simply are better at conveying anger than the happy faces are at conveying happiness and that the angry faces therefore are better emotional stimuli, providing more sensitive means to pick up age-related differences. Whatever the reason to the fact that the schematic happy and angry faces show very different emotion-attention relationships, this is an issue that needs to be explored further in future research.

Conclusions

The present results indicate that there is a flattening of affect (i.e. a decreased differentiation) in older compared to younger participants. This flattening is found in the emotional key dimensions of Arousal and Potency, but not in the Valence dimension. This pattern of results indicates that the older participants can still accurately determine the degree of pleasantness/unpleasantness in faces, while the Arousal and Potency reactions to these stimuli (and thereby the overall size of the emotional space) is declined in older compared to younger participants.

The present results also indicate a maintained guidance of visual attention from emotion, despite the decline in differentiation on emotion measures in older adults. Interestingly, the correlation between emotion and attention for angry faces indicate that although arousal scores are lower and RTs are longer for older participants, the direction of the relationship is about the same for younger and older participants. As can be seen in Figure 4, for younger participants most stimuli are centered in the top left area, denoting high arousal scores and short RTs; whereas for older participants, most stimuli are centered in the middle to bottom right area, denoting comparatively lower arousal scores and longer RTs. This is in accordance with the notion of perceptual speed as a key mechanism in older adults cognitive processing (e.g., Salthouse, 1996; Small, Dixon, & McArdle, 2011). Although older adults are generally slower in their processes, they manage to solve most cognitive demands as good as younger adults. Our results indicate that even though older adults showed longer RTs, their efficiency (search performance) appeared to rely on the same underlying emotional factor (Arousal) as younger adults, although at a lower level.

Concluding Remarks

The results in this article show a significantly reduced range in responses to emotional stimuli in the older compared to the younger group of participants. The results in this article also indicate a maintained relationship between the emotional arousal response to stimuli and RTs during visual search. The generalizability of these findings may potentially be limited to these particular stimuli (for a background to these stimuli, see Lundqvist et al., 1999, 2004; Lundqvist & Öhman, 2005) or to this class of stimuli (facial emotional stimuli). It would therefore be of interest to explore these findings further with additional facial emotional stimuli, and also with real faces or non-facial emotional stimuli.

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