

From AGING RESEARCH CENTER, DEPARTMENT
OF NEUROBIOLOGY, CARE SCIENCES AND
SOCIETY
Karolinska Institutet, Stockholm, Sweden

EMOTIONAL FACIAL PROCESSING IN YOUNGER AND OLDER ADULTS

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**Karolinska
Institutet**

Stockholm 2015

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Published by Karolinska Institutet.

Printed by Eprint AB 2015

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ISBN 978-91-7549-874-4

Emotional facial processing in younger and older adults

THESIS FOR DOCTORAL DEGREE (Ph.D.)

by

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ABSTRACT

There is evidence that older adults have difficulty processing negative but not positive facial expressions. This positivity effect among older adults is expressed in attention to as well as in memory and recognition of emotional faces. In the present thesis, effects of stimulus properties (i.e., self ratings of valence, arousal, potency), context, and visual exploration were investigated.

In **Study I**, the aim was to investigate a happy face advantage seen in younger adults' recognition and detection of facial expressions. Two recognition tasks showed that happy faces were better recognized than fearful and neutral faces. In addition, this superior effect was evident in early processing, indicating that happiness is an exceptional expression that is distinguished from other facial expressions. The objective of **Study II** was to investigate effects of age on subjective emotional impression (in terms of valence, arousal and potency) of angry and happy faces, and to examine whether any age differences were mirrored in measures of emotional behavior (attention, categorical perception, and memory). The results demonstrated that older adults perceived less arousal, potency, and valence than younger adults and that these differences were more pronounced for angry than happy faces. This was mirrored in larger age differences in attention, memory, and categorical perception for angry compared to happy faces. In **Study III** the aim was to investigate how linguistic context (i.e., written emotional labels) might reduce semantic confusability, and thereby facilitate facial expression recognition. The results showed that older adults were more reliant on linguistic context. Older and younger adults' visual exploration patterns were investigated in **Study IV**. Results showed that older adults spent proportionally more time attending to the mouth than to the eyes, which might explain their relatively lower recognition of fear, anger and sadness, but maintained happiness and disgust recognition.

In sum, subjective impression (i.e., arousal, potency), context, and visual exploration patterns interact with adult age and should be considered in research on effects of aging on facial expression processing.

LIST OF SCIENTIFIC PAPERS

- I. **Svärd, J.**, Wiens, S., Fischer, H. (2012). Superior recognition performance for happy masked and unmasked faces in both younger and older adults. *Front.Psychology*, 3:520.
- II. **Svärd, J.**, Fischer, H., Lundqvist, D. (2014). Adult age-differences in subjective impression of emotional faces are reflected in emotion-related attention and memory tasks. *Front.Psychology*, 5:423
- III. **Svärd, J.**, Lundqvist, D., Fischer, H. Linguistic contextual availability affects younger and older adults' recognition of angry, happy and neutral facial expressions. *Manuscript*.
- IV. **Svärd, J.**, Birmingham, E., Kanan, C., Fischer, H. Aging and the attentional patterns of emotional faces: new evidence using the moving window technique. *Manuscript*.

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LIST OF ABBREVIATIONS

SST	Socioemotional selectivity theory
HFA	Happy face advantage
MWT	Moving Window Technique
RT	Reaction time
ANOVA	Analysis of variance
IAPS	International Affective Picture System
MMSE	Mini Mental State Examination

1 INTRODUCTION

There is mounting evidence of a qualitative difference between older and younger adults in processing of emotional stimuli. More specifically, while attention to- and memory for- negative stimulus are negatively affected with advancing age, the processing of positive stimulus are less so. This age by valence-related difference has mainly been attributed to motivational shifts in the later stage of the lifespan. This thesis focus on one specific type of emotional stimuli namely faces and investigated stimuli properties and its effect on older and younger adults. Stimuli properties here mean the interrelationship between the different facial expressions. Rather than consider expressions as more or less nominal categories, with the assumption that all individual are equally affected by stimuli within each category, this thesis investigated how (i.e., strength, valence) and during which circumstances (i.e., in a context) the experiences of facial expressions differ and how conditions interact with age. These questions have been studied to some extent in the emotion literature on younger adults; however, have not been acknowledged in a satisfactory way in the aging and emotion field of research.

This thesis addresses stimulus properties (**study I & II**), contextual factors (**study III**) and scanning behavior (**study IV**) in relation to adult aging. In **study I** we investigated the happy face advantage (HFA). This line of research has previously been carried out in younger adults (e.g., Calvo & Nummenma, 2008; Calvo, Nummenma, & Avero, 2010) and shown that happy faces are attended to and recognized faster, and with higher accuracy, than other facial expressions. Using a backward masking paradigm with exposure times ranging from 17 to 267 milliseconds, we investigated the temporal development of the HFA and its interaction with age in younger and older adults. In **study II**, we investigated whether subjective stimulus characteristics (i.e., perceived arousal, valance, potency) differed as a function of expression and age of participants, and if this was related to attention, memory and categorical perception performance. The rationale for this study was that higher levels of perceived arousal were associated with shorter detection time of emotional faces in younger adults.

Thus, potential differences between older and younger adults in subjective impression on stimulus characteristics might underlie behavior differences between the groups. Therefore, older and younger adults ratings on the emotional dimensions arousal, valence and potency were collected, and subsequently related to attention, memory and categorical perception performance. **Study III** investigated the probability that older and younger adults differ in their use of contextual information in facial expression recognition. Again based on studies on younger adults, emerging evidence show that verbal emotional label availability facilitate facial expression recognition by placing the face in a context, and thus make the face less ambiguous (e.g., Barrett, Mesquita, & Gendron, 2011). However, age-effects on such a context dependency are uninvestigated. Finally, in **study IV**, adult age effects on intentional scanning patterns in facial expression recognition were investigated. Previous eye-tracking studies indicate that while younger adults are scanning the eyes in expression recognition, older adults are focusing more on the mouth. However, the eye-tracking method holds some caveats that make the interpretation of the results difficult. Therefore, we used a new technique, the *Moving Window Technique* (MWT) to investigate older and younger adults scanning behavior.

Before a more detailed description of the studies, I will briefly present some of the currently dominating theories in the study of emotion. Likewise, relevant findings from the aging and emotion literature, and theories based on these findings will be described. By doing so I wish to place the studies in a broader theoretical context, and thereby highlight some of the issues that this thesis is based upon.

1.1 EMOTION

“Everyone knows what an emotion is, until asked to give a definition”

This excellent quote is taken from a paper by Fehr and Russell written in 1984. Unfortunately, 31 years later it still quite strikingly describes the difficulty in defining the concept *emotion*. For example, the longstanding debate whether

emotions require appraisal of the eliciting stimuli or event can be tracked back to William James (1884) ever so accurately titled article “What is an emotion?”. Although there is still no clear-cut definition, nowadays at least a few components that researchers can agree upon are essential in the study of emotion namely: physiology, action tendencies, cognitive appraisals, motor behavior and subjective feelings.

Different weights on the components and ideas about different sequential or parallel component orders have subsequently given rise to a number of theories, of which I selectively will describe four specifically relevant for the current thesis.

1.1.1 Emotional theories

1.1.1.1 Basic emotions

The basic emotions approach to understanding emotions posits that there is a limited number of basic discrete emotions that are inherited and hardwired. Each emotion is associated with a specific corresponding physiological- and motor response (e.g. Ekman & Cordaro, 2011). It is further suggested that these basic emotions are universally recognizable. Of the emotional components mentioned previously, the basic emotion theorist’s stresses motor behavior and physiology. More specifically, these discrete emotions are mainly studied in the field of facial expression recognition.

In support for basic emotions theories, recognition rates are higher for the assumed discrete facial expressions of anger, fear, surprise, sadness, disgust, contempt, and happiness than for other non-basic expressions such as shame, embarrassment, and compassion (Widen, Christy, Hewett, & Russell, 2011). However, in the vast majority of the expression recognition studies, the expressions are accompanied with verbal emotional labels. As discussed in the Constructivism section below, such labels may act as a context and thus bias the recognition. Also, as posit by the theory, there should be separated neurological basis for each emotion. Yet there is currently a relatively high agreement in the

affective neuroscience that common areas of the brain are involved across a range of emotions (See for example Hamann, 2012, for a review).

Although these theories are sometimes questioned, all facial expression recognition studies have to relate to the basic emotions approach in one way or the other as we treat the outcome (i.e., recognition performance) as discrete (i.e., basic expressions) values.

1.1.1.2 Dimensional models

While basic emotion theorists see emotions as separated entities, another line of researchers has proposed a more dimensional approach. In this view, affective states/emotions can be organized along continuous dimensions thought to cover most aspects of emotional experience. The two most commonly used dimensions are valence (pleasantness-unpleasantness) and arousal (high-low). The original bipolar model has been modified to a *circumplex model* that allows emotions to vary between the two dimensions (Posner, Russell, & Peterson, 2005; Russell, 1980). There have also been suggestions of a third dimension or even more dimensions (Russell & Mehrabian, 1977; Fontaine, Scherer, Roesch, & Ellsworth, 2007). The third dimension that has received most attention is potency, which is related to the strength of the stimuli (i.e., weak-strong).

These dimensional models alone are no longer considered sufficient to fully describe an emotion or an emotional episode. Rather, they have to be integrated with categorical aspects of emotional processing to distinguish different emotions close in the dimensional space (Russell, 2003). That is, although being different emotions fear and anger might be undistinguished in the circumplex affective space (Russell & Feldman Barrett, 1999). Dimensional models stresses the subjective experience, and to some extent also physiology (i.e., physiological arousal) as the main emotional components. Because of lack of other emotional components than this so called *core affect* (i.e., a feeling based on hedonic and arousal values [e.g., Russell, 2003]), dimensional models are not suitable for specific differentiations between emotional situations or emotions such as fear and anger (Ekkekakis, 2013). Rather than sufficient descriptors of emotions

and/or emotional states, these models are suggested to be complemented by other emotional components such as cognitive appraisals. Nonetheless, if the purpose is to measure core affect, or the emotional impression of an emotion-eliciting stimuli, these models does a good job. In **study II**, we used the subjective emotional impression, measured with three dimensions (valence, arousal and potency), as predictor in subsequently performed memory and attention tasks.

1.1.1.3 Appraisal theories

From an appraisal theorist's perspective, emotions are the result of cognitive evaluations of experiences. This view is traceable back to the James-Lange theory of emotion (James, 1884), which proposed that the experience of emotions stems from the perception of autonomic arousal. In other words, an eliciting event activates the autonomic nervous system (ANS), and subsequently an autonomic arousal response, which is interpreted as an emotional reaction caused by the event. The notion that physiological arousal alone would be sufficient to distinguish emotions was subsequently questioned (Cannon, 1927). Instead, new theories that considered an additional cognitive aspect to the physiological aspect were developed (e.g., Schacter & Singer, 1962). Magda Arnold (1960) was the one who named the term "appraisal". She argued that a given situation is appraised on three dimensions: (1) whether the situation is beneficial or harmful; (2) if an important stimuli is present or absent; (3) if the stimuli is easy or difficult to approached or avoid. These appraisals result in specific action tendencies, which in turn are perceived as certain emotions.

Over the decades, several appraisal models have developed with a wide range of suggestions regarding both how many, and which appraisal dimensions that should be included. Despite some variances, most contemporary appraisal theories agree that novelty, valence, relevance and norms are appraisals that should be considered in the study of emotions. It is further suggested that these appraisals are processed sequentially in the order mentioned in the previous sentence (e.g., Ellsworth & Scherer, 2003). In the appraisal process, motivational and cognitive inputs lead to reappraisals. Thus, the environment is constantly evaluated for personal relevant information.

1.1.1.4 *Constructivism*

According to a constructivists' point of view, emotions are psychological events that emerge out of basic psychological operations unrelated to emotions. The fundamental perspective in all psychological constructivist models is that two operations work together to form emotions; a sensory input and a mental operation that make these inputs meaningful. Examples of sensory inputs are somatic and motor cues (James, 1884) or arousal (Schacter & Singer, 1962). The second psychological operation includes ideas (Wundt, 1897), social affiliation (Schacter & Singer, 1962) or concepts (Barrett, 2006).

One of the dominant constructivist models today is the *conceptual act model* (see e.g., Barrett, 2011; Barrett, Wilson-Mendenhall, & Barsalou, 2015). This model includes a core affect, described as a mental representation of bodily changes (Barrett, 2006). This core affect is often, but not always perceived as a sensation of pleasantness or unpleasantness (e.g., Barrett & Bliss-Moreau, 2009). Importantly, these core affects are not meaningful without being attached to an object or a situation. According to the model, the core affect becomes meaningful through *conceptualization*, a process that combines previous experience, such as memories and knowledge with the core affect (Barrett et al., 2015). An important part in the conceptualization process is context. One such context is emotional words, which is assumed to anchor for example emotional labels to facial expressions (Barrett, Lindquist, & Gendron, 2007). To put it differently, facial expressions such as anger are essentially meaningless, or at least ambiguous until anchored with the emotional label anger. Thus, input (facial expression) and context (label) are together conceptualized and categorized as anger. In **study III**, we investigated the role of such a linguistic context during perception of emotional faces in older and younger adults.

1.1.1.5 *Conclusions*

As evident from this brief introduction to the study of emotion, each theory stress different emotional components. While basic emotion theorists emphasis motor behavior and physiology, constructivism theorists, and proponents of the dimensional approach, instead emphasis subjective experience. As the name

implies cognitive appraisal theorists consider cognition and appraisal the most valuable components in emotions. Consequently, these divergences may affect the interpretation of age-related differences in emotional processing depending on the researchers theoretical position. That is, taking the basic emotions perspective, age decline in facial expression recognition might indicate neurodegeneration, affecting circuits dedicated to facial expression recognition. On the other hand, appraisal theorists might attribute this decline to a certain appraisal dimension such as valence or relevance. Further, based on the premise of constructivism, the decline may be due to insufficient conceptualization (i.e., ability to integrate core affect with knowledge of an expression). Thus, depending on the component being investigated (physiology, cognitive appraisal, subjective feelings), the interpretation might differ fundamentally.

1.1.2 Faces

In everyday life, we encounter a tremendous amount of faces. They carry information about peoples' intention, traits, and current mood etcetera. Thus, the ability to read emotions from faces is essential in order to understand and respond adequately to social interactions (e.g., Grossman & Johnson, 2007). In healthy individuals, emotional signals are detected within 100 ms, and the ability to differentiate between facial expressions has been found within 200 ms (see Eimer & Holmes, 2007 for a review). Thus, although faces might not provide the entire emotional state of others, reading faces comes quite naturally for the majority of human beings. To summarize the emotional theories described in the previous section, most people would agree on that we easily understand the *basic* intention, at least the *core affect*, by *appraisal* of the facial expression of others.

Although the emotional theoretical frameworks, which I will describe in the next section extends beyond the mere processing of faces, I have chosen to focus on facial expression processing in this thesis. The rationale for this is twofold. First, studies have shown that many modalities (facial expression, bodily posture, emotional tone) activate common affective programs in the brain (Magnée, Stekelenburg, Kemner & de Gelder, 2007). Similarly, comparisons with emotional scenes have shown that pictures of facial expressions elicit to a large

extent the same neural structures (e.g. amygdala, hippocampus, ventromedial prefrontal and occipital cortices) when they are passively viewed (Britton, Taylor, Sudheimer, & Liberzon, 2006) or remembered (Keightley, Chiew, Anderson, & Grady, 2011). Although the magnitude in neural responses may vary as a function of region of interest (ROI) and modality (i.e., faces or scenes), the neuro-spatial similarities between faces and scenes suggest that faces are good representatives for emotional information processing in general.

Second, unlike emotional objects and scenes, faces are not subjects to cohort effects. Pictures of erotic nature might for example be perceived fundamentally different by an older (e.g. 75 years) compared to a younger adult (e.g. 20 years). Such potential age-cohort confounders are minimized with the use of faces. In addition, emotional picture databases such as the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997) are based on validation scores from a younger adult sample, which makes it difficult to select pictures that are experienced as equal affective for older and younger adults. In fact, studies have also shown adult age differences in affective ratings of these IAPS pictures (e.g., Grühn & Scheibe, 2008; Keil & Freund, 2009). Thus, to facilitate the interpretation of results from the different studies in this thesis, faces were used consistently as stimuli.

1.2 EMOTION AND AGING

In this section I will describe the current view in the field of aging and emotion. I take the liberty to focus on addressing three major emotion domains – attention, memory, and expression recognition. I will start with a summary of behavior findings within these domains. At the end of this section, I will describe the current dominant aging and emotion theories, each holding a separate explanation of the findings.

1.2.1 Attention

The ability to attend to salient information in our environment is an important part of our day-to-day life. A vast majority in the visual attention research in the emotion domain has revolved around detection of potential dangerous stimulus

such as snakes and spiders (e.g., Flykt, Lindeberg, & Derakshan, 2012; Öhman, Flykt, & Esteves, 2001). However, a growing socioemotional interest has emerged in this field and thus also the use of faces as stimuli. Although the dominant interest is still on attention to threat signals (i.e., angry or fearful facial expressions), the impact of other expressions, such as happiness, on attention have also revealed interest (e.g., Calvo & Marrero, 2009).

Regarding aging and attention to emotional faces, two lines of findings emerge. Depending on whether the task is of the inspection nature or requires detection of a face, the tasks yield different results and interpretations.

When presented with pairs of faces (one emotional and one neutral) older but not younger adults responded faster to the dot if it appeared behind a neutral face in negative-neutral pairs (Knight, Seymore, Gaunt, Baker, Nesmith, & Mara, 2007; Mather & Carstensen, 2003; but see also Isaacowitz, Wadlinger, Goren, & Wilson, 2006). This indicates that older adults prefer to steer their initial attention away from negative facial expressions, an effect that is not evident in younger adults. Although not significant, older adults also showed a trend towards faster responses for positive faces in positive-neutral pairs compared to younger adults (See also Isaacowitz et al., 2006 for a similar trend). Thus, older but not younger adults seem to preferentially view positive (i.e., happy) faces when they are paired with neutral faces.

This face-pair /dot probe paradigm has also been supplemented by eye-tracking technology that measures participants eye movements while they investigate the face pairs. These studies support the positivity preferences in older adults (Isaacowitz et al., 2006; Knight et al., 2007). Importantly though, Knight et al (2007) found that older adults preferences were reversed during a dual-task condition; when distracted by a competing task, older adults spent more time viewing negative faces. They concluded that cognitive resources are required for older adults' positivity preferences to occur. However, a replication of the study demonstrated that older adults showed positivity preferences regardless of attention conditions (i.e., full or divided), indicating that the positivity preferences may be independent of cognitive resources (Knight et al., 2007).

These discrepancies in findings and interpretation of cognitive control and its functioning in older adults positivity preferences uncovers a weak point in the theoretical frameworks in the field that will be discussed later (pp. 16).

A second line of research has focused on the ability to detect certain facial expressions in arrays of other expressions. These *visual search* or *face in the crowd* paradigms have revealed that both older and younger adults detect a threatening (i.e., angry) face faster and with higher accuracy than a non-threatening (i.e., happy) face in arrays of neutral faces. This has been found mainly with schematic faces (Hahn, Carlson, Singer, & Gronlund, 2006; Mather & Knight, 2006; Lundqvist, Svärd, & Fischer, 2013; Ruffman, Ng, & Jenkin, 2009), but also with the use of real-face stimuli (Ruffman et al., 2009). Such an angry face advantage in attention has for a long time been attributed to the relevance of fast and accurate detection of threat (e.g., Hansen & Hansen, 1988; Öhman, Juth, & Lundqvist, 2010). However, this view has been questioned by a growing number of findings of a happy face advantage in search for emotional faces (e.g., Calvo & Nummenmaa, 2008). Recently, subjective impression in terms of the emotional dimension arousal has been put forward as an explanation for the diverse findings (Lundqvist, Bruce, & Öhman, 2015; Lundqvist, Juth, & Öhman, 2014). More specific, in samples of younger adults, higher arousal ratings at an individual level were associated with faster and more accurate detection of faces regardless of valence. We found the same arousal (and potency) search association for schematic faces in a sample that included also older adults (Lundqvist et al., 2013). This association was replicated with real faces and extended to other domains such as memory and categorical perception (**study II**).

To conclude the findings of age-related differences in attention to emotional faces, it seems that older but not younger adults prefer to look less on negative faces if paired with neutral faces. However, if the task requires detection of negative faces, just as their age counterparts, older adults also find those faces faster in arrays of neutral faces. However, it still remains uncertain whether these positivity preferences seen in older adults are mediated by cognitive efforts to

regulate attention, or if they are driven by stimulus properties such as arousal or a combination thereof. I will return to aging and emotion theories trying to explain these findings after a description of similar findings in memory for and recognition ability of emotional faces.

1.2.2 Memory

Memory enhancement for emotional (both negative and positive) over neutral stimulus is widely recognized (e.g., LaBar & Cabeza, 2006). However, with advancing age, there seems to emerge a qualitative difference in memory for emotional faces; while younger adults tend to have better memory for negative stimuli, older adults show better memory for positive stimuli (e.g., Charles, Mather, & Carstensen, 2003).

Studies on aging and memory for emotional information have mainly involved non-facial stimulus such as emotional scenes (e.g., Charles, Mather, & Carstensen, 2003; Denburg, Buchanan, Tranel, & Adolphs, 2003; Fernandes, Ross, Wiegand, & Schryer, 2008) and words (e.g., Fernandes et al., 2008). Only a few studies have included faces, and these show mixed findings. For example, comparisons between older and younger adults have revealed equal memory performance for positive and neutral faces, but older were worse in remembering negative faces (Leigland, Schulz, & Janowsky, 2004). In accordance with this finding, another study found the largest age differences for negative compared to positive and neutral faces (Grady, Hongwanishkul, Keightley, Lee, & Hasher, 2007). Compared to their younger counterparts, older adults have demonstrated poorer memory for fearful and neutral (Fischer, Nyberg, & Bäckman, 2010), and angry, happy and neutral faces (Ebner & Johnson, 2009). Contrasting that study, age-invariant memories for angry and happy faces has also been reported (D'Argembeau & Van der Linden, 2004).

An examination of the within-group comparisons from these studies revealed that older but not younger adults seem to have better memory for happy than angry faces (Ebner & Johnson, 2009; Mather & Carstensen, 2003). Contrary, younger but not older adults have reported to remember negative (angry, sad,

disgusted, fearful) faces more accurately than positive and neutral faces (Grady et al., 2007). A similar finding of better memory for fearful than for neutral faces were evidenced in both younger and older adults (Fischer et al., 2010). Both age groups have also demonstrated better memory for positive and neutral faces than for negative faces (Leigland et al., 2004). Also, equally memory performance for angry and happy faces has been revealed for both older and younger adults (D'Argembeau & Van der Linden, 2004).

1.2.3 Expression recognition

Opposite to the sparse amount of studies on memory for emotional faces, facial expression recognition and aging have been rigorously studied. Also, compared to aging and emotional memory studies, the findings within this research field are quite consistent.

Several studies have showed that compared to younger adults, older adults demonstrate difficulty in recognize negative facial expressions. More specifically, age differences have been reported in recognition of fearful (Calder, Keane, Manly, Sprengelmeyer, Scott, & Nimmo-Smith, 2003; Horning, Cornwell, & Davis, 2012; McDowell, Harrison, & Demaree, 1994; Suzuki & Akiyama, 2013, but see also Phillips, MacLean, & Allen, 2002 for equal performance), angry (Calder et al., 2003; Ebner & Johnson, 2009; Isaacowitz, Löckenhoff, Lane, Wright, Sechrest, Riedel, & Costa, 2007; Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006; McDowell et al., 1994; Suzuki & Akiyama, 2013), sad (Calder et al., 2003; Horning et al., 2012; Keightley et al., 2006; Moreno, Sze, Goodkind, Gyurak, & Levenson, 2012; Suzuki & Akiyama, 2013), and surprised (Suzuki & Akiyama, 2013) facial expressions. However, recognition of happy faces have revealed equal performance for older and younger adults (Calder et al., 2003; Ebner & Johnson, 2009; McDowell et al., 1994; Phillips et al., 2002), or even better recognition in older compared to younger adults (Moreno et al., 1993; but see also Horning et al., 2012; Isaacowitz et al., 2007; Suzuki & Akiyama, 2013 for the opposite). The same pattern holds for disgusted faces with either no age differences (Moreno et al., 1993; Phillips et al., 2002), or older performing better than younger adults

(Calder et al., 2003; Horning et al., 2012; Issacowitz et al., 2007; Suzuki & Akiyama, 2013, but see also Keightley et al., 2006; Sze, Goodkind, Gyurak, & Levenson, 2012 for the opposite). With a few exceptions, these results reveal a general pattern of decreased ability to recognize negative facial expressions, but a preserved or even enhanced ability to recognize happiness and disgust with advancing adult age. These findings were also confirmed in a meta-analysis, in which they found the largest age differences in recognition of fearful, angry and sad faces, and relatively smaller age differences in recognition of happiness and surprise, and no difference for disgusted faces (Ruffman, Henry, Livingstone, & Phillips, 2008).

It should be noted however, that all these studies used static images of young posers. Recent research has start questioning the validity of this type of stimuli. First, with the exception of one study (Ebner & Johnson, 2009), all of the above mentioned studies have used faces of younger adults as stimuli. A growing number of studies have shown differences in processing older and younger faces. For example, an own-age bias in scanning patterns of emotional faces has been reported, such that older and younger adults spend longer viewing times on faces belonging to their own age group than on their counterparts' (Ebner, He, & Johnson, 2011). Importantly, they also found that longer viewing on own-age faces was associated with better recognition of facial expressions within own-age faces. Second, the use of static facial stimuli raises questions about the validity to real world situations. Emerging evidence, both from younger (e.g., de Gelder, Meeren, Righart, van den Stock, van de Riet, & Tamietto, 2006) and older samples (e.g., Lambrecht, Kreifelts, & Wildgruber, 2012) show that a multimodal approach is preferable in the study of facial expression recognition. More specific, as reviewed by de Gelder and co-workers (2006), facial expression recognition is facilitated when faces are accompanied by bodily or prosodic modalities compared to when faces are presented in isolation. Similar investigations have been done with older adults. These studies have demonstrated that when a face is accompanied by emotional bodily postures (Noh & Isaacowitz, 2013), older adults might benefit even more than younger adults.

Integrating video recorded facial expressions and voices increased the ability to recognize emotions to the same extent in older and younger adults (Lambrecht et al., 2012). Similarly, older adults were better than younger adults in emotion recognition of video-taped interactions between couples (Sze et al., 2012). Importantly, these older adults were outperformed by their younger counterparts in a standard facial recognition test. Put together, these findings emphasises the effect of contextual information on emotional recognition in general, and on facial expression recognition in particular. In **study III**, we investigate language as a context in facial expression recognition in older and younger adults. The rationale comes from several studies on younger adults showing that language may shape and influence emotional processing by serving as a context (N.B., the constructivism approach to study of emotions).

Another growing field in the study of aging and facial expression recognition is related to visual scanning patterns of emotional faces. The rationale for these studies is based on evidence showing that the most diagnostic features in negative facial expressions (i.e., anger, fear) are located in the upper part of the face (eyes and eye browse), while the most diagnostic features in other expressions (i.e., happiness and disgust) are found in the lower part of the face (mouth and surrounding areas (e.g., Calder, Young, Keane, & Dean, 2000; Smith, Cottrell, Gosselin, & Schyns, 2005). As older adults show a decrease in recognition of negative facial expression, with diagnostic features situated on the upper part of the face, and preserved recognition of expressions with diagnostic features situated in the lower parts of the face, differences in scanning patterns might be a key in facial expression recognition in adult aging. Indeed, age-related scanning patterns have been reported in facial expression recognition studies. As expected, in general, older adults seem to look longer and make more fixations to the lower part of the face than do younger adults (e.g., e.g., Circelli, Clark, & Cronin-Golomb, 2013; Sullivan, Ruffman, & Hutton, 2007; Wong, Cronin-Golomb, & Nearing, 2005). Contrary, younger adults seem to examine the eyes longer than do older adults (e.g., Circelli et al., 2013; Murphy, & Isaacowitz, 2010; Noh, & Isaacowitz, 2013; Wong et al., 2005). A few studies have also tried to link scanning patterns with recognition efficiency (i.e.,

accuracy and reaction times) for different expressions. The results from these studies have been mixed; some studies have showed the expected associations between longer viewing times on the mouth with better recognition of disgust, but only for older adults (Wong et al., 2005), while other studies did not find an association between mouth viewing and recognition (Sullivan et al., 2007). Eye-viewing on the other hand, have been more consistently associated with better recognition of fearful, angry, sad, and happy faces (Wong et al., 2005) or a combination of negative faces (i.e., angry, sad and fearful; Sullivan et al., 2007) in younger adults, and angry, fearful, and sad faces (Wong et al., 2005) in older adults. Despite some differences between studies, the general pattern is that older adults spend more time investigating the mouth; and younger adults spend more time investigating the eyes. However, all these studies have been conducted with eye-tracking technology, a method with limited control regarding the participants allocated attention. To keep it short; there is growing evidence that facial information can be attended to parafoveally (e.g., Caldara, Zhou, & Mielle, 2010) indicating that eye fixations do not necessarily mirrors the participants' allocated attention. Further, faces can be recognized within 1 or 2 fixations, which makes results from studies with long viewing times and large numbers of fixations questionable. That is, we do not really know what is measured after the second fixation and/or 1 second of viewing time. To overcome these potential caveats, in **study IV**, we introduced the *Moving Window Technique* (MWT), a novel method for measuring allocated attention in facial expression recognition.

In summary, the general pattern in facial expression processing, whether it is attention to, or memory or recognition of emotional faces show the same pattern; older adults seem to have difficulty with processing negative, but not positive facial expressions. Although not dedicated specifically to facial processing, this pattern of a valence by age interaction is often referred to as a positivity effect among older adults (Reed & Carstensen, 2012). In the next section I will describe the dominant theoretical framework in which this positivity effect is often discussed. I will also describe another conceptual model, trying to explain the underlying mechanism to this qualitative adult age difference in facial expression processing.

1.2.4 Emotion aging theories

As mentioned in the previous section, although none of the theories that will be described next are specifically dedicated to faces, their theoretical implications cover emotional processing in general, including also emotional faces. Thus, the different theories in this section will not be restricted to findings from facial expression processing studies. However, their theoretical implications will be applicable also for emotional face processing.

In this section I will describe the dominant theoretical frameworks in which the age by valence differences (i.e., positivity effect in older adults) described previously are often discussed. I will start with a socio-emotional theory, which has received tremendous attention during the last decade.

1.2.4.1 Socioemotional selectivity theory

The positivity effect and the socioemotional selectivity theory (SST) are discussed almost interchangeably in the aging and emotion field. In fact, the term positivity effect was actually coined by the research group behind SST (see Reed & Carstensen, 2012 for the close link between the two). According to SST (Carstensen, 1993, 2006; Carstensen, Isaacowitz, & Charles, 1999), with advancing age there is a shift in goals related to emotional gratification. As a consequence of a shrinkage in perceived time left in life, these goals become more oriented towards emotional meaningful information in our surroundings compared to when the future seems endless as in young age. To achieve these emotion gratification goals, older adults constrain their social network to include only the most emotional fulfilling contacts (e.g., Charles & Carstensen, 2010). In other words, older adults maximize the chances of emotional meaningful social interactions. Although younger adults also care about the quality of their social interactions, they seem to prefer a mix of close friends and making new contacts that might be beneficial in the longer term, for example for a future career (Charles & Carstensen, 2010). It should be noted that this shift in motivational priorities towards emotional goals is not driven by chronological age per se. According to SST, a perceived shrinkage of time is essential. Support for this comes from a study that shows that when time horizons are equated between

older and younger adults, as in younger adults suffering from severe diseases these younger adults show the same positivity effect as older adults (Carstensen & Fredrickson, 1998).

More relevant for this thesis, this age-related positivity effect, or shift in emotional gratification, is extended from the social engagement to also attention and memory for emotional information. As mentioned in previous sections, older adults seem to pay more attention to positive, and neglecting negative stimuli (e.g., Isaacowitz et al., 2006), and also have better memory for positive than negative IAPS images (e.g., Charles et al., 2003) and faces (e.g., Mather & Carstensen, 2003). According to SST, this age-related positivity effect would reflect chronically activated goals that influence cognitive processing in favor of positive over negative information (Reed & Carstensen, 2012). In other words, these goals guide attention and memory resources towards emotional satisfying stimuli, and thereby enhance positive mood and/or regulate the emotional state (Carstensen & Mikels, 2005; Carstensen, Mikels, & Mather, 2006).

Despite an impressive body of findings of a positivity effect among older adults, there are still quite a number of studies that did not find such an effect. In response to such criticism, proponents of SST assemble a series of predictions for when the effect is most likely to appear and when we should not expect such an effect (Reed & Carstensen, 2012). As the positivity effect reflects motivated cognition, and is driven by chronically activated goals, the effect should be mostly pronounced in conditions where participants have cognitive resources available to direct their attention towards emotional satisfying stimuli, when the situation allows conscious processing that do not interfere with goals, and when the regulation of emotions contributes to the individuals' well-being. Thus, the effect is not to be expected in conditions of low cognitive control, in automatic processing conditions, when the task demands/situations conflicts with the goals, or when positive preferential processing is associated with risks.

The major criticism of the SST is the lack of causal relationship between emotional selectivity and well-being (e.g., Isaacowitz & Blanchard-Fields, 2012). That is, although there is evidence that older adults report less negative

affect (e.g., Mroczek & Kolarz, 1998; Charles, Reynolds, & Gatz, 2001) and avoid processing negative stimuli (e.g., Carstensen & Mikels, 2005), there is little evidence that actively avoiding negative stimuli would lead to enhanced well-being. In a recent study (Isaacowitz, Livingstone, Harris, & Marcotte, 2015) older and younger adults were equipped with mobile eye-tracking and spent 15 minutes in a room with various valenced stimuli to interact with, such as computer screens showing videos and websites, emotional pictures on the walls etcetera. Self-reported mood ratings as well as eye-recordings were continuously measured as the participants attended to the stimuli. Results showed similar effects of attention selection (i.e., towards positive and negative stimulus) on mood for older and younger adults. In addition, both groups spent equal amount of time viewing positive and negative stimuli. Thus, this study did not support the notion that older adults use attention selection (i.e., neglecting negative and favoring positive stimulus) as an emotion regulation tool. However, another study demonstrated that older adults with high executive (i.e., cognitive) control, preferentially looked at positive and away from negative faces, and also maintained positive mood (Isaacowitz, Toner, & Neupert, 2009).

Although SST is by far the most dominant theory in the aging and emotion field, there are also few other theories trying to explain emotional behavior in the later adulthood. For example, *Selective Optimization with Compensation Theory* (Baltes & Baltes, 1990) posits that as people age, they become more aware of their weaknesses and strengths. Accordingly, older adults allocate their resources (socially and cognitively) to achieve goals that are important to them, and can realistically be obtained. In order to optimize the chances to achieve their goals, older adults sacrifice other goal-irrelevant resources. If the goals cannot be achieved through allocating of resources, older adults use compensatory actions instead. These actions include for example seek of support from others.

Thus, although the SST provides a tempting and theoretically logical framework for the positivity effect often reported in aging and emotion field, empirical evidence of a link between positive preferential process and outcome (i.e., well-being) is lacking. Until such a link have been firmly established, other

explanations most be considered. One such explanation is related to neurodegeneration in brain areas involved in emotional processing.

1.2.4.2 Aging-brain perspectives

In addition to the motivational account proposed by SST, neurodegenerative, physiology and cognitive-related explanations have been suggested.

Age-related volume loss is evident in various parts of the brain such as frontal and temporal regions, which in turn are involved also in processing of some, but not all facial expressions. Interestingly, the orbitofrontal cortex (OFC) is one of the regions that express the most rapidly and severe atrophy (e.g., Lamar & Resnick, 2004), a region also known to play a key roll in processing angry faces (e.g., Fischer, Sandblom, Gavazzeni, Fransson, Wright, & Bäckman, 2005). Thus, age-related deficits in processing angry faces might be due to structural and/or functional changes in OFC with advancing age (Ruffman et al., 2008). Similar co-occurrence of volumetric loss and involvement in emotional processing are found for the amygdala (fear and sadness) and anterior cingulate cortex (sadness). Contrary, less volume loss in some parts of the basal ganglia have been associated with a maintained ability to read disgust from faces (Calder et al., 2003). Also, a more widespread network for processing positive than negative information could explain why processing of positive information is less vulnerable to age-related atrophy.

Reduced amygdala activity among older adults has been proposed to contribute to older adults proportionally less efficient processing of negative stimuli (Cacioppo, Berntson, Bechara, Tranel, & Hawkey, 2011). More specifically, amygdala is thought to have an essential role in processing, and responding to negative stimuli (e.g., Whalen et al., 1998; Wright et al., 2001). Consequently, less amygdala activation might dampen the emotional reaction (i.e., via a dampened arousal response) to negative stimuli particularly. This would thus explain why older adults exhibit more difficulty processing negative stimuli more than positive. However, older adults' lower amygdala activity is often accompanied by increased prefrontal cortex (PFC) activation (Tessitore et al.,

2005). Since PFC is assumed to be involved in emotion regulation (e.g., Ochsner, Silvers, & Buhle, 2012) this subcortical-cortical shift with advancing age has been argued to reflect emotion regulation in older adults rather than a decrease in amygdala functioning (e.g., Dolcos et al., 2014; Mather, 2012).

Older adults have also been reported to show less awareness of visceral sensations, such as heartbeats (Khalsa, Rudrauf, & Tranel, 2009) and gastric distension (Rayner, MacIntosh, Chapman, & Horowitz, 2000). Given that such physiological cues play an essential part in creating emotions (e.g., Garfinkel et al., 2014), a reduction in interoception might underlie age-related differences in affective responsiveness and/or emotional experience (Mather, 2012). Support for the idea of a decline in interoception with advancing age comes from studies showing a decrease in perceptual ability accompanied by alterations in somatosensory cortex (Kalisch, Ragert, Schwenkreis, Dinse, & Tegenthoff, 2009). Although this seems like a plausible explanation to a dampened processing of negative stimuli, there is yet a lack of research on effects of age-related differences in interoception on emotion perception.

In addition to the imaging studies just described, several behavior studies have included various cognitive measures as mediators in emotional processing in older and younger adults. For example, it has been found that older adults low on executive functioning were less accurate in recognition of angry faces (Krendl & Ambady, 2010). Correlation analysis also revealed that higher executive functioning was associated with better angry face recognition. Similarly, a study showed that adding a dual task affected older, but not younger, adults' ability to encode emotional facial expressions (García-Rodríguez et al., 2011). The authors concluded that older adults' difficulty in recognition of emotional facial expressions might partially be attributed to cognitive decline. At a more conceptual and theoretical level, Labouvie-Vief (2003) suggests that regulate, and integrate positive and negative affects become more complex with advancing age. As a consequence, due to decreased cognition, older adults prefer processing of only positive information because it is less demanding compared to integrating both positive and negative information.

Proposers of the SST reject this cognitive decline approach by referring to studies showing that older adults with the highest cognitive control are the one that show the largest positivity effect (Knight et al., 2007). If cognition had been accountable for decline in emotional processing, less cognitive control would have been associated with increased positivity effect. Yet other studies that have used cognitive measures such as fluid abilities as covariates concluded that cognition do not account for age differences in facial expression recognition (Murphy & Isaacowitz, 2010; Sullivan & Ruffman, 2004).

In summary, in addition to the motivational account proposed by the SST, degeneration of brain areas associated with emotional processing, less interoceptive awareness, and cognitive decline among older adults have been put forward to explain age differences in emotional processing. However, as with the motivational explanation, all these alternative approaches lacks direct empirical links between the predictors (neural loss, interoceptive cues, cognition) and behavior (positivity effect). Further, these explanations are studied to a far less extent compared to the SST. This highlights the impact of the SST in the aging and emotion field, which is demonstrated in a quote by Reed & Carstensen (2012, p.2), “Although the majority of empirical findings have been interpreted through the lens of SST, [...]”. Such a dominant position and the consequently priority as a theoretical framework that comes with this dominance is troublesome for two reasons. First, as just mentioned, the theory has become so dominate that its explanation is almost taken for granted. Due to this dominance, almost all research on aging and emotional processing relates to the theory, which in turn leaves little space left for other accounts to grow. Second, it is harder to disprove a theory than to prove its existents. That is, null-findings (i.e., age similarities) are more likely to be rejected than findings of age differences in emotional processing.

1.3 SUMMARY AND STUDY OBJECTIVES

First, there is convincing evidence that older adults have difficulty in processing negative, but not positive facial expressions. This positivity effect among older adults is expressed in attention, memory and recognition of emotional faces. The

effect is mainly explained in the framework of the SST, which posits that with advancing age, there is a motivational shift in goals from knowledge oriented to more emotion oriented goals. Under influence of cognitive control systems, these chronically activated goals motivate older adults to attend to positive, and neglect negative information, with the purpose to maintain emotion gratification. Alternative explanations concern neurodegenerative, physiological, and cognitive accounts, and all affecting older adults processing of negative stimuli.

Second, depending on the emotion related theoretical standpoint, the findings and interpretation of the results might differ fundamentally. For example, while basic emotion theorists posit that there are a limited number of basic emotions that have separate neural -and motor signals, proposers of the constructivism approach mean that subjective experience and conceptual knowledge is essential for the interpretation of core affect, which in turn might lead to generation of emotions.

As the lack of a causal link between behavior (i.e., positivity effect) and outcome (enhanced well-being) indicators, there might be separate effects co-occurring, which are both related to emotional processing. Put it differently, behavior A (older adults processes proportionally more positive than negative faces) and finding B (older adults show more positive affect) is due to C (older adults' motivation to seek for emotional gratifying stimuli). Alternatively, behavior A (older adults processes proportionally more positive than negative faces) is a result of D (neuraldegeneration in emotion specific areas). In both cases, the behavior is driven by external factors (i.e., motivation or neural loss) rather than by the stimuli itself. A third alternative might be that E (positive faces are easier to process) leads to A (older adults processes proportionally more positive than negative faces). In other words, do stimulus properties affect behavior over and above mere valence? For example, do facial expressions differ in activity (i.e., arousal), in the way they are scanned for emotional cues, or whether they are presented in a context or not? These kinds of questions may vary as a function of both emotional expression and age.

Thus, there are inconsistency in both emotion, and aging and emotion theories regarding the interpretation of facial expression recognition. This thesis is aimed to highlight an overlooked aspect in facial expression processing, namely stimuli properties. Perhaps needless to say, I do not aim at resolve the ambiguity in facial expression processing; rather I want to highlight the importance of consider differences between facial expressions in terms of experience/subjective impression beyond valence (i.e., positive-negative). Studies on emotional pictures and scenes indicate that there are age differences in the perception of those pictures (e.g., Backs, da Silva, & Han, 2005). Thus, using emotional stimuli with the assumption that they are equally emotional to both older and younger adults may complicate the interpretation of the results if they are not. To date, as far as I know, no study has addressed these kinds of questions in depth in either processing of emotional pictures or scenes, or emotional faces.

2 AIMS

The thesis aimed to investigate how (**study I, II, IV**) and during which circumstances (**study III**) do processing of facial expressions differ and how does these conditions interact with age. The specific research questions were:

1. **Study I:** Is there a happy face advantage, such as happy faces are detected earlier than fearful and neutral faces, and how does such an advantage change as a function of age of participant, and increasement in visibility?
2. **Study II:** Does the subjective emotional impression (arousal, valence, potency) of faces differ as a function of age of participants, and expression, and if so; are such differences reflected in attention, memory, and categorical perception performance?
3. **Study III:** Does written emotional labels provide a linguistic context, which facilitate facial expression recognition, and does this effect vary as a function of age of participant, and facial expression?
4. **Study IV:** Do older and younger adults differ in the way they explore faces in facial expression recognition settings, and are such differences associated with recognition efficiency?

3 METHODS AND RESULTS

3.1 STUDY I

The objective of this study was to investigate a happy face advantage seen in younger adults in recognition and detection of facial expressions. The temporal development of such an advantage was also investigated with the use of a backward masking paradigm with stimuli durations ranging from 17 to 267 ms.

3.1.1 Participants

This study included 20 younger (50% women, $M_{age} = 26.4$, $SD_{age} = 2.6$), and 19 older (10 women, $M_{age} = 73.7$, $SD_{age} = 2.5$) adults. There were no age differences in years of education, Mini Mental State Examination (MMSE), neuroticism, or vocabulary performance.

3.1.2 Materials and procedure

Older and younger adults were presented with fearful, neutral, and happy faces in two separated tasks; an unmasked recognition and intensity-rating task, and a masked recognition task. In the unmasked recognition and intensity-rating task, the participants rated the intensity of the face on a nine-point scale, and chose one of seven emotional written labels that best described the emotional expression of the face. In the masked recognition task, the same target faces as used in the unmasked task were presented for 17, 33, 50, 67, 83, 117 and 267 ms followed by a scrambled picture. Thus, recognition could be investigated in conditions of low to high visibility.

3.1.3 Results

In both recognition tasks, happy faces were better recognized than fearful and neutral faces. This happy face advantage was evident in both older and younger adults, indicating an age-independent effect rather than positivity effect among older adults. The analyses of the different target durations revealed that happy faces were better recognized than fearful and neutral faces already at 67 ms

durations. The intensity rating results showed that older adults rated both fearful and neutral, but not happy faces as more intense than did younger adults.

Conclusions. Together, two recognition tasks showed that happy faces are better recognized than fearful and neutral faces. In addition, this superior effect starts within 67 ms of exposure, indicating that happy faces are an exceptional expression that is distinguished from other facial expressions. This finding had implication for the understanding of the positivity effect, and should be considered in studies on facial expression recognition in older and younger adults.

3.2 STUDY II

The objective of this study was to investigate effects of age on the subjective emotional impression of angry and happy faces and to examine whether any age differences were mirrored in measures of emotional behavior (attention, categorical perception, and memory).

3.2.1 Participants

In this study, 39 older (24 women, $M_{age} = 70.5$, $SD_{age} = 2.8$), and 40 younger (21 women, $M_{age} = 25.2$, $SD_{age} = 10.5$) adults were included. The groups did not differ in years of education, MMSE, and self-reported depression. Although younger adults reported more anxiety on one test (HAD), they did not differ from older adults on two other scales (STAI-S and STAI-T).

3.2.2 Materials and procedure

Older and younger adults rated their subjective impression of angry, happy, and neutral faces. The rating was conducted with the use of a visual analog scale that ranged from -1 to 1 on the three emotional dimensions arousal (active- inactive), valence (pleasant-unpleasant), and potency (weak- strong). These measures were then used as predictors in regression analysis on visual search, short-term memory, and categorical perception performance.

3.2.3 Results

The emotional rating task showed that older adults perceived less arousal, potency, and valence than younger adults and that the difference was more pronounced for angry than happy faces. Similarly, although older adults performed worse than younger adults on measures of attention, memory, and categorical perception, the age differences were most pronounced for angry compared to happy faces. The regression analysis confirmed an age-independent association between the emotional dimension potency (and marginally also arousal) and attention, and memory for angry faces, such that higher ratings were correlated with faster detection and better memory (i.e., less errors).

Conclusions. The results point to the importance of stimulus selection in studies of emotional behavior in younger and older adults. As shown in the current study, emotional faces elicit different emotional impressions in younger and older adults, and this in turn affects attention and memory processing. Thus, a decrease in emotional impression seems to dampen the effect of emotion on memory performance and attention processing. By assuming that younger and older adults perceive emotional material equally in terms of the key dimensions of emotional impression, we risk misattributing age effects in emotional behavior. In addition, the results also strengthen our findings from **study I**, showing that across age, happy faces are processed more efficiently (i.e., faster and better accuracy in detection, less error in short-term memory, more distinct categorical perception) than angry faces. Also, this study revealed a potential stimuli property underlying this difference; the emotional dimension potency.

3.3 STUDY III

The objectives of this study were to investigate how linguistic context (i.e., written emotional labels) might reduce semantic confusability, and thereby facilitate facial expression recognition in older and younger adults. The rationale for this study is based on previous studies on younger adults that have showed that without emotional labels (i.e., free-labeling conditions) the expression recognition dropped dramatically. Thus, words may serve as a context that reduces the confusability. Another line of research has found that older adults are

more dependent on contextual information than younger adults in facial expression recognition. Thus, linguistic context and age might interact on expression recognition.

3.3.1 Participants

The study sample consisted of 42 older (20 women, $M_{age} = 69.1$, $SD_{age} = 3.1$), and 42 younger (22 women, $M_{age} = 23.9$, $SD_{age} = 2.8$) women. There were no age differences in years of education or MMSE. Older adults reported lower anxiety, and depression scores, but higher positive affect than their younger counterparts. Although younger adults showed better letter- and category fluency performance, older adults were better on a vocabulary test. Two composite scores (one with the mood variables and one with the verbal ability measures) were created, and subsequently used in the analysis.

3.3.2 Materials and procedure

Participants were presented with angry, neutral, and happy facial expressions, accompanied by three, six or no expression labels. We analyzed whether facial recognition rates were influenced by word label availability, and whether there was an interaction with number of negative versus positive expressions.

3.3.3 Results

As expected, across age, recognition performance decreased from the 3 to 6 to free labeling, indicating an increase in semantic confusability as a function of increased response alternatives. Happy face recognition was less affected than angry and neutral recognition, indicating less semantic confusability for the former. Furthermore, the decrease in recognition was most pronounced for older adults recognition of neutral faces in the free-labeling condition.

Conclusions. The results showed that older adults were more dependent on word related contextual information compared to younger adults, and particularly for recognition of neutral faces. A lower recognition rate was found for angry compared to happy faces across both age groups. We suggest that this may stem from an increased number of negative response alternatives.

The results from this study also indicate that in addition to the findings from **study I** and **II**, that demonstrated that happy faces seem to be more powerful stimuli in terms of stimuli properties, they are also less likely to be confused with other expressions.

3.4 STUDY IV

The objectives of this study were to investigate older and younger adults' viewing patterns in recognition of facial expressions. Previous studies has showed that while younger adults search for emotional cues from the eyes, and surrounding areas, older adults focus more on the mouth. This viewing behavior might be disadvantageous, especially for recognition of negative expressions, in which the most diagnostic cues are positioned in the eye regions. However, these previous findings were conducted with eye-tracking technology, a technique with distinct methodological concerns. Therefore, a new technique, the Moving Window Technique, was used to overcome these issues.

3.4.1 Participants

Participants were the same as in Study III.

3.4.2 Materials and procedure

Ten faces of each of the emotional expressions anger, fear, happy, and disgust were used in the study. The faces were blurred with a Gaussian filter that prevented recognition of the expression. A 100 x 100-pixel window was initially positioned in the center of the face at the beginning of each trial. Within this movable window, there was a clear view (i.e., the Gaussian filter was gone). The participants were told that they were free to move around the window as they preferred to reveal the expression of the blurred face.

3.4.3 Statistical analyses

Each face was divided into six regions of interest (ROI): left eye, right eye, nose, mouth, face (face minus internal features) and head (head minus face). From this data we analyzed (1) recognition accuracy (percentage of correct

responses), (2) reaction times (latency between onset of image and pressing of the space bar to end the trial) for correctly recognized faces, (3) percentage of exploration time spent on each of the 6 ROIs, normalized by ROI size to correct for the fact that bigger ROIs would, by definition, have greater overlap with the window than smaller ROIs, (4) correlations between a difference score (eyes-mouth) and recognition performance (accuracy and RT). Eyes-mouth difference scores were created at an individual level by subtracting percentage of time spent on the mouth from the percentage of time spent on both of the eyes (combined). Thus, a positive difference score reflects that the eyes were explored proportionally more than the mouth; a negative score reflect that the mouth was explored more than the eyes.

3.4.4 Results

The results confirmed previous eye-tracking findings showing that older adults spent proportionally more time viewing the mouth than the eyes. Younger adults on the other hand spent more time viewing the eyes than the mouth. Importantly, for older but not younger adults more time spent on the mouth was associated with faster recognition of happy and disgusted faces. Across age, more eye viewing was associated with faster recognition of fearful faces.

Conclusions. Our results and previous findings clearly demonstrate that older and younger adults pay attention to different parts of the face in searching for emotional cues. It also suggests that older adults' proportional longer viewing time at the mouth could partly explain their relatively lower recognition of fear, anger, and sadness, but maintained recognition of happiness and disgust.

As the correlational analyses revealed, older adults that spent time viewing the mouth were the ones that were fastest in recognition of happy and disgusted faces. Thus, recognition of happy and disgust seems to come at a cost of recognition of fear and anger in older adults.

4 DISCUSSION

The thesis aimed to investigate how (i.e., strength, valence, potency) and during which circumstances (i.e., in a context) do facial expressions differ and how do these conditions interact with age. I will now discuss the findings in relation to the specific research questions (p. 24). When it is appropriate to do so, I will also discuss the findings in the light of emotion, as well as aging and emotion theoretical frameworks.

4.1 HAPPY FACES ARE SPECIAL

In four studies including 7 experimental tasks, we have shown that happy faces are special: not only older adults but also younger adults showed superior processing of happy faces. Based on results from this thesis, I will specify three different areas in which happy faces clearly differ from other expressions.

4.1.1 In early visual processing

The results from **study I** and **study II** (experiment II) demonstrated that happy faces are recognized (**study I**) and detected (**study II**, experiment II) faster, and with higher accuracy than fearful (**study I**), angry (**study II**, experiment II), and neutral faces (both **study I and II**). These findings of facilitation in early processes are in line with a growing body of research from younger study populations, showing a happy face advantage both in attention (e.g., Calvo & Marrero, 2009; Calvo & Nummenmaa, 2008) and recognition speed (Calvo & Lundqvist, 2008). Such priority in early visual processing might affect subsequent memory. The impact of this advantage in recognition and detection on for example memory functioning is however beyond the scope of this dissertation. So rather than speculate in the consequences of this effect, it can be concluded that happy faces are detected and recognized more efficiently than other facial expressions. By integrating current results from older adults with a growing body of research on HFA in younger adult samples we get a more nuanced view on facial expression processing; happy faces are not special only for older adults. It is rather surprising that the aging and emotion literature seem to ignore these kinds of findings from the younger age sample. Although the

present results may not be ground breaking, it highlights an important issue in the aging and emotion field that is a partial lack of insight in studies from other research areas.

4.1.2 Stimuli properties

In **study II**, we investigated whether emotional expressions differed in how they were perceived in terms of the key emotional dimensions arousal, valence, and potency, and if these impressions interacted with age and with emotional face task performance.

The results showed that across age, happy faces received higher ratings on all three emotional dimensions. That is, happy faces were better in conveying their expected valence (i.e., happy faces were more happier than angry faces were angry). They were also seen as more active (arousal) and stronger (potency) than angry faces. These findings could be considered in relation to neutral faces, which at least theoretically should be expected to be associated with low ratings on valence (neither pleasant or unpleasant), arousal (calm), and potency (weak). Low ratings for a certain expression would thus indicate less distinction from a neutral expression. On the contrary, high ratings would indicate more distinction from neutral, and other low-rating expressions.

As mentioned in the Emotional theories section (1.2.4.), emotional dimensions alone might not be sufficient to discriminate between expressions (e.g., fear and anger might both receive similar negative valence and high arousal). Importantly though, the task in **study II** did not include discrimination or labeling of the expressions at hand. The purpose was to investigate how different expressions were perceived, and how such impression was associated with emotion-cognition behavior. The answer to that question is quite clear; happy faces are strong, vivid emotional stimuli, which are reflected in relatively more efficient attention and memory performance compared to angry faces. Age differences in subjective impression and implications of such differences will be discussed separately in a forthcoming section.

For now, it can be concluded that a happy face is perceived as a pleasant, active, and strong expression, distinct from other expressions. This distinction from other expressions will be even clearer in the next section in which I will discuss the finding that happy faces are less likely to be confused with other expressions.

4.1.3 Less confused with other expressions

In **study III** it was revealed that across age recognition of angry and neutral but not happy faces decreased in conditions where six possible response labels were offered compared to when only three were offered. This indicates that angry and neutral facial expressions are confused with other expression. At the same time, this also indicates that happiness is not confused with other expressions to the same extent, again highlighting the distinction from other expressions (Ekman & Friesen, 1971). This effect was even more pronounced in the free-labeling condition, in which the recognition performance decreased dramatically for angry and neutral, but only marginally for happy faces. A more detailed discussion regarding labels as a word context and its role in mediating semantic confusability will follow in a later section. In this section, the purpose was to briefly highlight the fact that happy faces are special in that sense that they are less likely to be confused with other expressions, unlike angry and neutral facial expressions.

A last note on this topic, several studies have demonstrated that recognition of happy facial expressions are less affected by a variety of neurological and psychiatric conditions (Heberlein, Padon, Gillihan, Farah, & Fellows, 2008; Pelfrey et al., 2002; Tsuchida & Fellows, 2012). I find it very unlikely that the majority of the patients from these studies share the motivational goals proposed by SST.

4.2 SUBJECTIVE IMPRESSIONS DIFFER WITH ADVANCING AGE

As mentioned in a previous section, in **study II**, happy faces were rated higher than angry faces on all three key emotional dimensions (valence, arousal and potency). However, this pattern was even more pronounced in older compared to younger adults. Thus, older adults perceived angry faces as less unpleasant, less

arousing, and weaker than did younger adults. In addition, the differences in perceived arousal and potency did affect attention and memory functioning. This is not surprising because it is well known that arousal is closely related to both attention and memory functioning (eg., Mather & Sutherland, 2011; Ponzio & Mather, 2014; Steinmetz, Schmidt, Zucker, & Kensinger, 2012). What is novel though is that the results from **study II** reveal that group differences on these emotional scales are reflected in group differences also in emotional attention and memory performance.

Equating perceived arousal between older and younger adults have resulted in age-invariant behavior responses (accuracy and RT) to negatively valenced pictures (Leclerc & Kensinger, 2008). In other words, the positivity effect among older adults disappeared when both age groups perceived the pictures as equally arousing. Together with results from **study II**, this indicates that the positivity effect is tightly linked to perceived arousal and/or potency. It further implicates that arousal rather than valence may underlay the positivity effect. That is, angry faces are perceived as less arousing than happy faces. Such ideas have been proposed to explain inconsistent findings in the visual search literature (Lundqvist et al., 2014). They found that regardless of valence (anger or happiness), the expression that received the highest arousal ratings was the one that was detected the fastest and with the highest accuracy. Thus, in some circumstances, arousal may override valence. The results from **study II**, and also from another study from our lab (Lundqvist et al., 2013) indicate that this might be evident also in the aging and emotion field. Although this is a tempting assumption, it needs to be more systematically investigated. In the section on future studies, I will elaborate more on how this can be done.

4.3 CONTEXT SUPPORT FACIAL EXPRESSION RECOGNITION

In **study III**, it was revealed that older adults were more dependent on contextual word information than younger adults, especially for neutral facial expressions. This finding is in line with a growing body of research showing the same pattern with bodily contexts (Isaacowitz & Stanley, 2011; Noh & Isaacowitz, 2013). These kinds of concerns have been acknowledged to a greater extent in studies

on facial expressions processing in younger samples (e.g., de Gelder et al., 2006). In the aging and emotion field on the other hand, this type of research is still in its infancy.

These findings may have implications both on how facial expressions are used in research settings, but also for the understanding of older adults' social interactions in their everyday life. The use of single static faces might not be the most optimal approach to fully appreciate emotion recognition. Although the underlying causes of this increase in context dependency remains unclear, it seems that older adults are more reliant on additional cues (i.e., bodily postures, linguistic information) than are younger adults when reading emotions from faces. Thus, despite difficulty in facial expression recognition, older adults may still be as good as younger adults in recognizing emotion at a conceptual level. For a clearer view of emotional processing in older and younger adults, research on this topic might benefit from considering these findings. Whether older adults use contextual information as cognitive support, or if it reflects a more elaborative approach, aiming to gain a deeper understanding of the facial emotion remains to be solved. Regardless, context dependency might also have an impact outside research settings. A decrease in reading emotions from faces in combination with an increase in context dependency might make older adults more vulnerable to fraud. For example, a fake smile accompanied with convincing gestures might be difficult for older adults to interpret. On the other hand, overly explicit gesticulations might also improve older adults' readings of emotional social situations.

In the introduction of this thesis, I argued that faces are good candidates as emotional stimulus. Despite the somewhat critical tone in this section, I still think they are. However, to fully understand facial expressions processes, we need to consider all aspects, such as for example influences of contextual information.

4.4 EXPLORATION PATTERNS MAY CONTRIBUTE TO RECOGNITION DIFFERENCES

Study IV showed that while older adults spent proportionally longer time

exploring the mouth, younger adults preferred exploring the eyes in recognition of facial expressions. This is in accordance with a general pattern of results from previous eye-tracking studies (e.g., Circelli et al., 2013; Wong et al., 2005). Importantly, the results from **study IV** also revealed those older adults that spent most time exploring the mouth were the ones that detected happy and disgusted faces fastest. Thus, older adults exploration patterns seem to facilitate, and possibly partly explain the commonly reported maintenance in recognition of happy and disgust faces (e.g., Ruffman et al., 2008). However, this facilitation in recognition of happiness and disgust seems to come at the expense of recognition of fear and anger. That is, the eyes are the most informative regions in these negative facial expressions (Kohler et al., 2004; Schurgin et al., 2014; Smith et al., 2005; Vaidya et al., 2014), and thus mouth exploration might increase the risk of missing diagnostic information from the eyes. This line of thoughts is in accordance with findings from studies on the role of the eyes in facial expression recognition in adults with Aspergers' syndrome. Several studies within this field have showed that less fixation on the eyes are associated with reduced ability to recognize fear and anger from faces (e.g., Corden, Chilvers, & Skuse, 2008). Together with the results from **study IV**, this emphasizes the importance of adequate exploration patterns in facial expression recognition. To fully understand the impact of such patterns on emotional aging, a systematic alteration or manipulation of search strategies, and/or training studies are needed. Such studies would increase the understanding of the underlying mechanisms behind the observed age differences in exploration patterns. It is also important to establish whether the differences are due to a motivation to avoid threat signals from the eyes, or as a consequence of decreased perceptual abilities.

5 LIMITATIONS

One obvious limitation of this thesis concerns the fact that all studies used a cross-sectional approach. Even though the majority of studies on aging and emotional processing share this issue, nevertheless, it is a troublesome fact that cause doubts on the reliability of the results. Especially given that both SST and theories of the aging brain shares the assumption that the underlying mechanisms to the positivity effect (i.e., motivation and neurodegeneration) is successively changing over time. Thus, a longitudinal approach would minimize between subject effects, cohort effects, and other unpredictable effects that may be incorporated in cross-sectional designs. Thus, longitudinal studies may yield more reliable results regarding these research questions. This issue is acknowledged in the cognitive aging literature to a greater extent than in emotional aging (e.g. Rönnlund, Nyberg, Bäckman, & Nilsson, 2005). Hopefully, this reflects the fact that the aging and emotion field is a relatively new topic compared to the cognitive aging research, and that experience from the cognitive field will generate new understanding in the study of aging and emotion.

Another limitation of this thesis is that it does not provide a complete solution to the criticized weak parts of the SST. That is, as in the case with SST, the alternative provided in this thesis also lacks a causal relationship between the predictor (i.e., subjective impression, exploration behavior, context dependency) and positivity effect. Although it is evident that there are age differences already at the level of stimuli properties (compared to at the level of behavior), it cannot be concluded that these differences in emotional ratings are a reflection of a down-regulation of negative stimuli among older adults rather than “pure” measure of their subjective impression. Likewise, the findings in **study IV**, that older adults prefer viewing the mouth rather than the eyes, might be due to a deliberate strategy of avoiding threatening cues from the eyes. This kinds of causality related issues were not targeted in the present thesis. Nor have they been in previous studies on aging and emotional processing. Although this thesis advocate a greater emphasis on stimulus properties, scanning patterns, and

context dependency than what have previous been the case, it still has to be consider exploratory rather than explanatory in nature. Nevertheless, it provides an alternative to the current view on emotional aging.

One possible avenue to overcome this issue of non-causality would be to integrate emotional components. As mentioned in the introduction of the thesis, results, and interpretation of results may differ depending on which component is investigated. Accordingly, investigations of facial expression alone might reveal only a fraction of the complete concept of emotional processing. Integrating facial processing with underlying neural processes, physiology and subjective measures would provide a richer understanding of age differences in emotional processing.

6 FUTURE STUDIES

As mentioned at several occasions in this thesis, it is necessary to consider age differences in subjective impressions of emotional stimuli. If the goal is to study age differences in valence processing, there must be no differences in other emotional dimensions, such as arousal or potency. If these variables are not controlled, any behavior differences (e.g., attention, memory) might be equally attributed to these dimensions as to valence. Thus, a systematical manipulation of stimulus properties (i.e., arousal and potency measures) by means of morphed facial expressions of the kinds used in **study II**, experiment 3 & 4, might be one way to match older and younger adults on these properties. This approach would also provide an opportunity to experimentally reverse the age differences in subjective impression revealed in **study II**. That is, present younger adults with less intense expressions while keep the intensity high in expressions displayed to older adults, would result in less subjective impressions in younger than older adults. Studies on emotional behavior (i.e., attention and memory) using such manipulated faces might provide new insights in emotional aging. A reversed effect on behavior due to this stimuli manipulation for example would speak for the importance of subjective impression (arousal and potency) and against a motivational account proposed by SST. In other words, a reduction in emotional response (i.e., subjective impression) in younger adults would in that case most likely be independent of their motivational goals. Thus, a decrease in emotional attention and memory would be due to a decrease in subjective impression rather than a sudden change in motivation (i.e., positivity effect). These manipulations would provide a new venue of research on cognitive control and motivation in facial expression processing.

Another interesting approach that would foster understanding of emotional processing in late adulthood is the use of pharmacological interventions. This idea is acknowledged in the Ruffman et al., (2008) meta-analysis. There, the authors discussed findings that younger adults that had been administrated a dopamine antagonist (i.e., sulpride) showed a decrease in recognition of anger.

Similar effects on recognition of anger have also been found for drugs that increase GABAergic activation (i.e., an inhibitor in central nervous system). In both cases, younger adults have pharmacologically been altered to resemble older adults both neurotransmitter and arousal wise. As concluded in the article, depleted levels of neurotransmitters might explain older adults' lower amygdala activation and decreased recognition of some negative expressions sensitive to changes in neurotransmitter levels. Though these ideas were introduced in 2008, to my knowledge, there is yet not a single study addressing this line of research. Equating older and younger adults physiologically might help clarifying the underlying mechanisms behind the positivity preferences among older adults. That is, making younger adults "older" pharmacologically would most likely only affect their current, task-related behavior, and not their long-term motivational goals (as posits in SST).

Rather than assuming that all facial expressions are equally emotional to all individuals, or groups of individuals, I think it would be fruitful to challenge that view. Presenting static emotional faces to older and younger adults and subsequently measure accuracy and reaction times to those might be to simplify a complex process. As this thesis indicate, our impression (i.e., arousal, potency), whether presented in a context or not, and how we explore faces all contribute to our understanding of facial expressions.

7 ACKNOWLEDGEMENTS

I would like to thank the following individuals for various reasons:

First of all, thank you **Håkan Fischer** for being a true source of inspiration and optimism. I've left every single meeting with you excited, enlightened, and with new energy. During these years, you have kept me in a state of positive affect. In addition to always lifting my spirits, you have always provided me with adequate research tools when it comes to materialistic things as well as a scientific freedom. In fact, I honestly don't think that I've ever heard you say no to any suggestion I've ever brought up. Thank you!!

Daniel Lundqvist, a never-ceasing source of wisdom! I've never met someone that has such a deep urge to understand even the tiniest aspect of an observed effect. This obsession reaches from molecular level to implications for the human society. The way you twist and turn things around made me not only dizzy, but also and smarter! I wish we can work together in the future.

This thesis steered away from personality and cognition into a full-scale emotion thesis. Consequently, I've not worked as closely with **Lars Bäckman** and **Hui-Xin Wang** as I would have liked. Nonetheless, both of you have contributed to making my time at **Aging Research Center (ARC)** enjoyable and enriching.

A special salute is warranted for all the office roomies I've terrorized during these years. For many years, I bribed **Beata Ferencz** with good coffee and croissants. If it weren't for **Arthur**, we would still enjoy bicycle stories over a big cup of coffee. One day, he will be a champion! **Alex Pantzar**, I really don't know how you survived with me around. Perhaps our shared interest in difference scores? Put your gloves on and start boxing again; you are next to defend... **Johanna Lovén**, your laughter still echoes in my head. **Jonas Wastesson** (and **Beata**), if you ever scotch tape my chair again, I'll hunt you down to Denmark!

I would also like to thank all other colleagues at ARC for providing an interesting environment during these years, in particular past, and present

members of the Psychology group, **Agneta, Alireza, Anna, Benjamin, Claudio, Erika, Goran, Greg, Jonas, Jonna, Lars-Göran, Marc, Martin & Martin, Nina, Rasmus, Sari, Urban, Ylva, Yvonne, Åke**, and all new members of the group that I didn't have had the pleasure to meet yet.

Other people at ARC that deserves to be mentioned are **Pär**, the hipster that gave the epic walk a face, and **Almira, Ingemar, Kristina J., Rui, Sara HJ.**, all enriching my time at ARC. Last, but not at al least, the whole administrative crew, working behind the scenes for us to be able to do research: **Cecilia, Christian, Hélène, Johanna, Kimberly, Maria & Maria, Zoltan, Vanessa.**

Finally, **Anna Lång**, I hate to say this because it's fits so well in the gender stereotype, but I'm deeply thankful that you have been taking such great care of **Gösta** and **Maj**, as well as me during this time period. Truly, without you, this thesis would not have been finalized. Now when it's over, let us spend some time in the garden!

Mam, you didn't live to see. I miss you.

This research was supported by grants from Riksbankens Jubileumsfond (P10-0732:1) and Jochnick Foundation.

8 REFERENCES

- Arnold, M. B. (1960). *Emotion and Personality*. New York: Columbia University Press.
- Backs, R. W., & da Silva, S. P., & Han, K. (2005). A comparison of younger and older adults' self-assessment manikin ratings of affective pictures. *Experimental Aging Research, 31*, 421-440.
- Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: The model of selective optimization with compensation. In P. B. Baltes & M. M. Baltes (Eds.), *Successful aging: Perspectives from the behavioral sciences* (pp. 1-34). New York: Cambridge University Press.
- Barrett, L. F. (2006). Are emotions natural kinds? *Perspectives on Psychological Science, 1*, 28-58.
- Barrett, L. F. (2011). Constructing emotion. *Psychological Topics, 20*, 359-380.
- Barrett, L. F., & Bliss-Moreau, E. (2009). Affect as a psychological primitive. *Advances in Experimental Social Psychology, 41*, 167-218.
- Barrett, L. F., Lindquist, K. A., & Gendron, M. (2007). Language as context for the perception of emotion. *Trends in Cognitive Sciences, 11*, 327-332.
- Barrett, L. F., Mesquita, B., & Gendron, M. (2011). Context in emotion perception. *Current Directions in Psychological Science, 20*, 286-290.
- Barrett, L. F., Wilson-Mendenhall, C. D., & Barsalou, L. W. (2015). The conceptual act theory: a roadmap. In L. F. Barrett and J. A. Russell (Eds.) *The psychological construction of emotion* (p. 83-110). New York: Guilford.
- Britton, J. C., Taylor, S. F., Sudheimer, K. D., Liberzon, I. (2006). Facial expressions and complex IAPS pictures: Common and differential networks. *NeuroImage, 31*, 906-919.

- Cacioppo, J. T., Berntson, G. G., Bechara, A., Tranel, D., & Hawkley, L. C. (2011). Could an aging brain contribute to subjective well being?: The value added by a social neuroscience perspective. In A. Todorov, S. T. Fiske, & D. Prentice (Eds), *Social Neuroscience: Toward Understanding the Underpinnings of the Social Mind* (pp. 249-262). New York: Oxford University Press.
- Caldara, R., Zhou, X., & Miellat, S. (2010). Putting culture under 'the spotlight' reveals universal information use for face recognition. *PLoS ONE*, 5, e9708.
- Calder, A. J., Keane, J., Manly, T., Sprengelmeyer, R., Scott, S., & Nimmo-Smith, I. (2003). Facial expression recognition across the adult life span. *Neuropsychologia*, 41, 195-202.
- Calder, A. J., Young, A. W., Keane, J., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 527-551.
- Calvo, M. G., & Lundqvist, D. (2008). Facial expressions of emotion (KDEF): Identification under different display-duration conditions. *Behavior Research Methods*, 40, 109–115.
- Calvo, M. G., & Marrero, H. (2009). Visual search of emotional faces: The role of affective content and featural distinctiveness. *Cognition and Emotion*, 23, 782–806.
- Calvo, M. G., & Nummenmaa, L. (2008). Detection of emotional faces: Salient physical features guide effective visual search. *Journal of Experimental Psychology: General*, 137, 471-494.
- Calvo, M. G., Nummenmaa, L., & Avero, P. (2010). Recognition advantage of happy faces in extrafoveal vision: Featural and affective processing. *Visual Cognition*, 18, 1274-1297.

- Cannon, W., B. (1927). The James-Lange theory of emotion: A critical examination and an alternative theory, *American Journal of Psychology*, 39, 10-124.
- Carstensen, L. L. (1993). Motivation for social contact across the life span: A theory of socioemotional selectivity. In J. E. Jacobs (Ed.), Nebraska symposium on motivation: 1992, *Developmental perspectives on motivation (Vol. 40, pp. 209-254)*. Lincoln: University of Nebraska Press
- Carstensen, L. L. (2006). The influence of a sense of time on human development. *Science*, 312, 1913-1915.
- Carstensen, L. L., & Fredrickson, B. F. (1998). Socioemotional selectivity in healthy older people and younger people living with the human immunodeficiency virus: The centrality of emotion when the future is constrained. *Health Psychology*, 17, 1-10.
- Carstensen, L. L., Isaacowitz, D. M., & Charles, S. T. (1999). Taking time seriously: A theory of socioemotional selectivity. *American Psychologist*, 54, 165-181.
- Carstensen, L. L., & Mikels, J. A. (2005). At the intersection of emotion and cognition. *Current Directions in Psychological Science*, 14, 117-121.
- Carstensen LL, Mikels JA, Mather M. 2006. Aging and the intersection of cognition, motivation and emotion. In *Handbook of the Psychology of Aging*, ed. JE Birren, KW Schaie, pp. 343–62. San Diego, CA: Academic. 6th ed
- Charles, S. T., & Carstensen, L. L. (2010). Social and emotional aging. *Annual Review of Psychology*, 61, 383-409.
- Charles, S. T., Mather, M., & Carstensen, L. L. (2003). Aging and emotional memory: The forgettable nature of negative images for older adults. *Journal of Experimental Psychology: General*, 132, 310-324.

- Charles, S. T., Reynolds, C. A., & Gatz, M. (2001). Age-related differences and change in positive and negative affect over 23 years. *Journal of Personality and Social Psychology, 80*, 136-151.
- Circelli, K. S., Clark, U. S., Cronin-Golomb, A. (2013). Visual scanning patterns and executive function in relation to facial emotion recognition in aging. *Aging, Neuropsychology, and Cognition, 20*, 148-173.
- Corden B, Chilvers R, Skuse D (2008) Avoidance of emotionally arousing stimuli predicts social-perceptual impairment in Asperger's syndrome. *Neuropsychologia 46*, 137–147.
- D'Argembeau, A., & Van der Linden, M. (2004). Identity but not expression memory for unfamiliar faces is affected by ageing. *Memory, 12*, 644-654.
- de Gelder, B., Meeren, H. K. M., Righart, R., van den Stock, J., van den Riet, W. A. C., & Tamietto, M. (2006). Beyond the face: exploring rapid influences of context on face processing. *Progress in Brain Research, 155*, 37-48.
- Denburg, N. L., Buchanan, T. W., Tranel, D., Adolphs, R. (2003). Evidence for preserved emotional memory in normal older persons. *Emotion, 3*, 239-253.
- Dolcos, S., Katsumi, Y., & Dixon, R. A. (2014). The role of arousal in the spontaneous regulation of emotions in healthy aging: a fMRI investigation. *Frontiers in Psychology, 5*:681.
- Ebner, N.C., He, Y., & Johnson, M.K. (2011). Age and emotion affect how we look at a face: Visual scan patterns differ for own-age versus other-age emotional faces. *Cognition & Emotion, 25*, 260-269.
- Ebner, N. C., & Johnson, M. K. (2009). Younger and older emotional faces: Are there age-group differences in expression identification and memory? *Emotion, 9*, 329-339.

- Eimer, M., & Holmes, A. (2007). Event-related brain potential correlates of emotional face processing. *Neuropsychologia*, *45*, 15-31.
- Ekkekakis, P. (2013). Should affective states be considered as distinct entities or as positioned along dimensions? In P. Ekkekakis (Ed), *The measurement of affect, mood, and emotion : a guide for health-behavioral research*, Cambridge: Cambridge Press.
- Ekman, P., & Cordaro, D. (2011). What is meant by calling emotions basic? *Emotion Review*, *3*, 364-370.
- Ekman, P., & Friesen, W. V. (1971). Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology*, *17*(2), 124–129.
- Ellsworth, P. C., & Scherer, K. R. (2003). Appraisal processes in emotion. In R. J. Davidson, K. Scherer. & H. H. Goldsmith (eds), *Handbook of Affective Sciences*. New York: Oxford University Press.
- Fehr, B., & Russell, J. A. (1984). Concept of emotion viewed from a prototype perspective. *Journal of Experimental Psychology: General*, *113*, 464-486.
- Fernandes, M., Ross, M., Wiegand, M., & Schryer, E. (2008). Are memories of older adults positively biased? *Psychology and Aging*, *23*, 297-306.
- Fischer, H., Nyberg, L., & Bäckman, L. (2010). Age-related differences in brain regions supporting successful encoding of emotional faces. *Cortex*, *46*, 490-497.
- Fischer, H., Sandblom, J., Gavazzeni, J., Fransson, P., Wright, C. I., & Bäckman, L. (2005). Age-differential patterns of brain activation during perception of angry faces. *Neuroscience Letters*, *386*, 99-104.
- Flykt, A., Lindeberg, S., & Derakshan, N. (2012). Fear makes you stronger: Responding to feared animal targets in visual search. *Attention, Perception, & Psychophysics*, *74*, 1437-1445.

- Fontaine, J. R. J., Scherer, K. R., Roesch, E. B., & Ellsworth, P. C. (2007). The world of emotions is not two-dimensional. *Psychological Science, 18*, 1050-1057.
- Garfinkel, S. N., Minati, L., Gray, M. A., Seth, A. K., Dolan, R. J., & Critchley, H. D. (2014). Fear from the heart: Sensitivity to fear stimuli depends on individual heartbeats. *Journal of Neuroscience, 34*, 6573-6582.
- Grady, C. L., Hongwanishkul, D., Keightley, M., Lee, W., & Hasher, L. (2007). The effect of age on memory for emotional faces. *Neuropsychology, 21*, 371-380.
- Grossman, T., & Johnson, M. H. (2007). The development of the social brain in human infancy. *European Journal of Neuroscience, 25*, 909-919.
- Grühn, D., & Scheibe, S. (2008). Age-related differences in valence and arousal ratings of pictures from the International Affective Picture System (IAPS): Do ratings become more extreme with age? *Behavior Research Methods, 40*, 512-521.
- Hahn, S., Carlson, C., Singer, S., & Gronlund, S. D. (2006). Aging and visual search: Automatic and controlled attentional bias to threat faces. *Acta Psychologica, 123*, 312-336.
- Hamann, S. (2012). Mapping discrete and dimensional emotions onto the brain: controversies and consensus. *Trends in Cognitive Sciences, 16*, 458-466.
- Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology, 54*, 917-924.
- Heberlein, A. S., Padon, A. A., Gillihan, S. J., Farah, M. J., & Fellows, L. K. (2008). Ventromedial frontal lobe plays a critical role in facial emotion recognition. *Journal of Cognitive Neuroscience, 20*(4), 721-733.
<http://dx.doi.org/10.1162/jocn.2008.20049>.

- Horning, S. M., Cornwell, R. E., & Davis, H. P. (2012). The recognition of facial expressions: An investigation of the influence of age and cognition. *Neuropsychol. Dev. Cogn. B Aging Neuropsychol. Cogn.* 19, 657-676.
- Isaacowitz D.M., Blanchard-Fields, F. (2012). Linking process and outcome in the study of emotion and aging. *Perspectives on Psychological Science*, 7, 3–16.
- Isaacowitz, D. M., Livingstone, K. M., Harris, J. A., & Marcotte, S. L. (2015). Mobile eye tracking reveals little evidence for age differences in attentional selection for mood regulation. *Emotion*, 15, 151-161.
- Isaacowitz, D. M., Löckenhoff, C. E., Lane, R. D., Wright, R., Sechrest, L., Riedel, R., & Costa, P. T. (2007). Age differences in recognition of emotion in lexical stimuli and facial expressions. *Psychology and Aging*, 22, 147-159.
- Isaacowitz, D. M., & Stanley, J. T. (2011). Bringing an ecological perspective to the study of aging and emotion recognition: Past, current, and future methods. *Journal of Nonverbal Behavior*, 35, 261-278
- Isaacowitz, D. M., Toner, K., & Neupert, S. D. (2009). Use of gaze for real-time mood regulation: Effects of age and attentional functioning. *Psychology and Aging*, 24, 989-994.
- Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006). Is there an age-related positivity effect in visual attention? A comparison of two methodologies. *Emotion*, 6, 511-516.
- James, W. (1884). What is an emotion? *Mind*, 9, 188-205.
- Kalisch, T., Ragert, P., Schwenkreis, P., Dinse, H. R., & Tegenthoff, M. (2009). Impaired tactile acuity in old age is accompanied by enlarged hand representations in somatosensory cortex. *Cerebral Cortex*, 19, 1530-1538.

- Keightley, M.L., Chiew, K.S., Anderson, J.A.E., Grady, C.L. (2011). Neural correlates of recognition memory for emotional faces and scenes. *Social, Cognitive, and Affective Neuroscience*, 6, 24-37.
- Keightley, M. L., Winocur, G., Burianova, H., Hongwanishkul, D., & Grady, C. (2006). Age effects on social cognition: Faces tell a different story. *Psychology and Aging*, 21, 558-572.
- Keil, A., & Freund, A.M. (2009). Changes in the sensitivity to appetitive and aversive arousal across adulthood. *Psychology and Aging*, 24, 668-680.
- Khalsa, S. S., Rudrauf, D., & Tranel, D. (2009). Interoceptive awareness declines with age. *Psychophysiology*, 46, 1130-1136.
- Knight, M. Seymore, T. L., Gaunt, J. T., Baker, C., Nesmith, K., & Mather, M. (2007). Aging and goal-directed emotional attention: Distraction reverses emotional biases. *Emotion*, 7, 705-714.
- Kohler, C. G., Turner, T., Stolar, N. M., Bilker, W. B., Brensinger, C. M., Gur, R. E., et al. (2004). Differences in facial expressions of four universal emotions. *Psychiatry Research*, 128, 235–244.
- Krendl, A. C., & Ambady, N. (2010). Older adults' decoding of emotions: Role of dynamic versus static cues and age-related cognitive decline. *Psychology and Aging*, 25, 788-793.
- LaBar, K. S., & Cabeza, R. (2006). Cognitive neuroscience of emotional memory. *Nature Reviews Neuroscience*, 7, 54-64
- Labouvie-Vief, G. (2003). Dynamic integration: Affect, cognition, and the self in adulthood. *Current Directions in Psychological Science*, 12, 201-206.
- Lamar, M., & Resnick, S. M. (2004). Aging and prefrontal functions: Dissociating orbitofrontal and dorsolateral abilities. *Neurobiology of Aging*, 25, 553-558.

- Lambrech, L., Kreifelts, B., & Wildgruber, D. (2012). Age-related decrease in recognition of emotional facial and prosodic expressions. *Emotion, 12*, 529-539.
- Lang, P.J., Bradley, M.M., Cuthbert, B.N. (1997). International Affective Picture System (IAPS): Technical Manual and Affective Ratings. Gainesville, FL: NIMH Center for the Study of Emotion and Attention, University of Florida.
- Leclerc, C. M., & Kensinger, E. A. (2008). Effects of age on detection of emotional information. *Psychology and Aging, 23*, 209-215.
- Leigland, L. A., Schulz, L. E., & Janowsky, J. S. (2004). Age related changes in emotional memory. *Neurobiology of Aging, 25*, 1117-1124.
- Lundqvist, D., Bruce, N., & Öhman, A. (2015). Finding an emotional face in a crowd: Emotional and perceptual stimulus factors influence visual search efficiency. *Cognition and Emotion, 29*, 621-633.
- Lundqvist, D., Juth, P., & Öhman, A. (2014). Using facial emotional stimuli in visual search experiments: The arousal factor explains contradictory results. *Cognition and Emotion, 28*, 1012-1029.
- Lundqvist, D., Svärd, J., & Fischer, H. (2013). Age-related differences in sensitivity to emotional facial stimuli but age-independent association between arousal ratings and visual search efficiency. *Psychological Topics, 22*, 271-286.
- Magnée, M. J. C. M., Stekelenburg, J. J., Kemner, C., & de Gelder, B. (2007). Similar facial EMG responses to faces, voices, and body expressions. *NeuroReport, 18*, 369-372.
- Mather, M. (2012). The emotion paradox in the aging brain. *Annals of the New York Academy of Sciences, 1251*, 33-49.

- Mather, M., & Carstensen, L. L. (2003). Aging and attention biases for emotional faces. *Psychological Sciences, 14*, 409-415.
- Mather, M., & Knight, M. R. (2006). Angry faces get noticed quickly: Threat detection is not impaired among older adults. *Journal of Gerontology, Series B: Psychological Sciences, 61B*, 54-57.
- Mather, M., & Sutherland, M. R. (2011). Arousal-biased competition in perception and memory. *Perspective on Psychological Science, 6*, 114-133.
- McDowell, C. L., Harrison, D. W., & Demaree, H. A. (1994). Is right hemisphere decline in the perception of emotion a function of aging? *Intern. J. Neuroscience, 79*, 1-11.
- Moreno, C., Borod, J., Welcowitz, J., & Alpert, M. (1993). The perception of facial expressions across the adult life span. *Developmental Neuropsychology, 9*, 305-314.
- Mroczek, D. K., & Kolarz, C. M. (1998). The effect of age on positive and negative affect: A developmental perspective on happiness. *Journal of Personality and Social Psychology, 75*, 1333-1349.
- Murphy, N. A., & Isaacowitz, D. M. (2010). Age effects and gaze patterns in recognizing emotional expressions: An in-depth look at gaze measures and covariates. *Cognition and Emotion, 24*, 436-452.
- Noh, S. R., & Isaacowitz, D. M. (2013). Emotional faces in context: Age differences in recognition accuracy and scanning patterns. *Emotion, 13*, 238-249.
- Ochsner, K. N., Silvers, J. A., & Buhle, J. T. (2012). Functional imaging studies of emotion regulation: a synthetic review and evolving model of the cognitive control of emotion. *Ann N Y Acad Sci, 1251*, E1-E24.

- Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders*, 32(4), 249–261.
- Phillips, L.H., MacLean, R.D.J., & Allen, R. (2002). Aging and the understanding of emotions: neuropsychological and sociocognitive perspectives. *Journal of Gerontology: Psychological Sciences and Social Sciences*, 57, 526-530.
- Ponzio, A., & Mather, M. (2014). Hearing something emotional influences memory of what was just seen: How arousal amplifies effects of competition in memory consolidation. *Emotion*, 14, 1137-1142.
- Posner, J., Russell, J. A., & Peterson, B. S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. *Developmental Psychopathology*, 17, 715-734.
- Rayner, C. K., MacIntosh, C. G., Chapman, I. M., & Horowitz, M. (2000). Effects of age on proximal gastric motor and sensory functioning. *Scandinavian Journal of Gastroenterology*, 35, 1041-1047.
- Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology*, 3.339. doi: 10.3389/fpsyg.2012.00339
- Ruffman, T., Henry, J. D., Livingstone, V., & Phillips, L. H. (2008). A meta-analytic review of emotion recognition and aging: Implications for neuropsychological models of aging. *Neuroscience and Biobehavioral Reviews*, 32, 863-881.
- Ruffman, T., Ng, M., & Jenkin, T. (2009). Older adults respond quickly to angry faces despite labeling difficulty. *Journal of Gerontology, Series B: Psychological Sciences*, 64B, 171-179.

- Russell, J., A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, 39, 1161-1178.
- Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, 110, 145-172.
- Russell, J., A., & Feldman Barrett, L. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology*, 76, 805-819.
- Russell, J. A., & Mehrabian, A. (1977). Evidence for a three-factor theory of emotions. *Journal of Research in Personality*, 11, 273–294.
- Rönnlund M1, Nyberg L, Bäckman L, Nilsson LG. (2005). Stability, growth, and decline in adult life span development of declarative memory: cross-sectional and longitudinal data from a population-based study. *Psychol Aging*. Mar;20(1):3-18.
- Schachter, S., & Singer, J. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review*, 69, 379-399.
- Schurgin, M. W., Nelson, J., Lida, S., Ohira, H., Chiao, J. Y., & Franconeri, S. L. (2014). Eye movements during emotion recognition in faces. *Journal of Vision*, 14, 1-16.
- Smith, M. L., Cottrell, C. W., Gosselin, F., & Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychological Science*, 16, 184-189.
- Steinmetz, K. R. M., Schmidt, K., Zucker, H. R., & Kensinger, E. A. (2012). The effect of emotional arousal and retention delay on subsequent-memory effects. *Cognitive Neuroscience*, 3, 150-159.
- Sullivan, S., & Ruffman, T. (2004). Emotion recognition deficits in the elderly. *International Journal of Neuroscience*, 114, 403-432.

- Sullivan, S., Ruffman, T., & Hutton, S. B. (2007). Age differences in emotion recognition skills and the visual scanning of emotion faces. *Journal of Gerontology: Psychological Sciences, 62B*, 53-60.
- Sze, J. A., Goodkind, M. S., Gyurak, A., & Levenson, R. W. (2012). Aging and emotion recognition: Not just a losing matter. *Psychology and Aging, 27*, 940-950.
- Suzuki, A., & Akiyama, H. (2013). Cognitive aging explains age-related differences in face-based recognition of basic emotions except for anger and disgust. *Neuropsychol. Dev. Cogn. B Aging Neuropsychol. Cogn. 20*, 253-270.
- Tessitore, A., Hariri, A. R., Fera, F., Smith, W. G., Das, S., Weinberger, D. R., & Mattay, V. S. (2005). Functional changes in the activity of brain regions underlying emotion processing in the elderly. *Psychiatry Research: Neuroimaging, 139*, 9-18.
- Tsuchida, A., & Fellows, L. K. (2012). Are you upset? Distinct roles for orbitofrontal and lateral prefrontal cortex in detecting and distinguishing facial expressions of emotion. *Cerebral Cortex, 22*(12), 2904–2912.
- Vaidya, A. R., Jin, C., & Fellows, L. K. (2014). Eye spy: The predictive value of fixation patterns in detecting subtle and extreme emotions from faces. *Cognition, 133*, 443-456.
- Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M., & Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *Journal of Neuroscience, 18*, 411-418.
- Widen, S. C., Christy, A. M., Hewett, K., & Russell, J. A. (2011). Do proposed facial expressions of contempt, shame, embarrassment, and compassion communicate the predicted emotion? *Cognition and Emotion, 25*, 898-906.

- Wong, B., Cronin-Golomb, A., & Nearing, S. (2005). Patterns of visual scanning as predictors of emotion identification in normal aging. *Neuropsychology, 19*, 739-749.
- Wright, C. I., Fischer, H., Whalen, P. J., McInerney, S. C., Shin, L. M., & Rauch, S. L. (2001). Differential prefrontal cortex and amygdala habituation to repeatedly presented emotional facial stimuli. *NeuroReport, 12*, 379-383.
- Wundt, W. (1897). *Outlines of psychology* (C. H. Judd, Trans.) Oxford, England: Engelman.
- Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*, 466-478.
- Öhman, A., Juth, P., & Lundqvist, D. (2010). Finding the face in a crowd: Relationships between distractor redundancy, target emotion, and target gender. *Cognition and Emotion, 24*, 1216-1228.