Age differences in arousal, perception of affective pictures, and emotional memory enhancement

Appraisal, Electrodermal activity, and Imaging data

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Sous l’histoire, la mémoire et l’oubli.
Sous la mémoire et l’oubli, la vie.
Mais écrire la vie est une autre histoire.
Inachèvement.

Paul Ricoeur

Abstract in English

Research on aging indicates that cognitive and affective functions follow different trajectories across the lifespan. In general, cognitive capabilities are attenuated, whereas affective functions are more stable or may even be enhanced in older adults, for instance, emotional regulation and increased affective heterogeneity. It is unclear whether affective changes with age correspond to differences in both subjective experiences and physiological changes. Another question is the interaction of physiological activity, perception and emotional memory processing. This thesis addresses some aspects of these questions based on younger and older adults' responses to emotional pictures, carried out by measuring ratings of emotional intensity, functional magnetic resonance imaging (fMRI), skin conductance responses (SCRs); the long-term effect of emotional memory enhancement was also measured. In **Study I**, neural activity to negative and neutral facial expressions was analyzed using fMRI. Participants also rated the emotional intensity of the stimuli. Negative expressions resulted in increased neural activity in the right amygdala and hippocampus in younger adults, and increased activation in the right insular cortex in older adults. There were no age differences in subjective ratings. In **Study II**, subjective ratings of, and SCRs to, neutral and negative pictures were compared in younger and older adults. The ratings of negative pictures were higher for older adults compared to younger adults. SCRs increased in both age groups for the negative pictures, but the general magnitude of SCRs was significantly larger in younger adults. Finally, in **Study III,** participants returned after a one-year retention interval for testing of the emotional memory enhancement effect. The memory performance of both age groups was higher in response to negative pictures compared to neutral ones, although the performance was generally higher for younger adults. SCR at encoding was the better arousal predictor for memory, but only in younger adults. In conclusion, the results indicate age-related changes in affective processing that are related to previous studies. Age differences may involve a gradual shift from bottom-up (stimuli-driven) processes, to more top-down (goal-driven) processes. The results are also discussed in a wider lifespan perspective taking into consideration the accumulated life experience of older adults.
Keywords: Aging, Affective function, SCRs, FMRI, Pictures, Emotional memory enhancement, Bottom-up and Top-down processes

Sammanfattning på svenska

Äldreforskning har visat att kognitiva och affektiva funktioner följer olika utvecklingslinjer. En rad kognitiva funktioner försämras med ålder, medan vissa affektiva förmågor t o m kan förbättras med ålder, till exempel emotionell reglering och ökad affektiv heterogenitet. Det är oklart om dessa åldersrelaterade affektiva förändringar tar sig uttryck i både subjektiva upplevelser av emotionella intryck och fysiologiska förändringar. Ytterligare en fråga handlar om interaktionen mellan fysiologisk aktivitet, perception och emotionella minnesprocesser. Den här avhandlingen behandlar några av dessa aspekter i tre studier av äldres och yngres reaktioner på emotionella bilder. Studierna inkluderade subjektiva skattningar av emotionell intensitet, hjärnavbildningsteknik (fMRI), hudkonduktans och emotionell minnesförbättring efter ett långt retentionsintervall. I **Studie I** mättes neural aktivitet med fMRI för negativa och neutrala ansiktsuttryck. Deltagarna skattade också hur intensivt emotionella ansiktena upplevdes. Negativa ansiktsuttryck resulterade i en ökning av neural aktivering i höger amygdala och hippocampus hos yngre deltagare och ökad aktivering i höger insulära cortex hos de äldre deltagarna. De subjektiva skattningarna skiljde sig inte åt mellan åldersgrupperna. I **Studie II** mättes subjektiva skattningar av intensitet och hudkonduktans inför neutrala och negativa bilder. Äldre skattade de negativa bilderna högre än yngre deltagare. Reaktionerna i hudkonduktans ökade för de negativa bilderna i bägge grupperna, men yngre deltagare hade generellt kraftigare reaktioner. Slutligen, i **Studie III**, undersöktes den emotionella minnesförbättringen hos deltagarna som återkom ett år efter den initiala inkodningen. Båda gruppernas minnesprestation var bättre för negativa jämfört med neutrala bilder, men yngre mindes generellt fler bilder än äldre. Hudkonduktans vid inkodning var en bättre prediktor för minnnesprestation, men enbart hos yngre deltagare. Skattningar och hudkonduktans var inte signifikanta prediktorer av äldres minnesförmåga. I överensstämmelse med tidigare forskning visar resultaten på åldersrelaterade förändringar i affektiva processer. Åldrande kan innebära en gradvis förskjutning från stimulusdrivna (s.k. bottom-up) processer, till mer måldrivna (s.k. top-down) processer. Resultaten diskuteras utifrån flera teoretiska livsperspektiv och med hänsyn till den ackumulerande livserfarenheten som åldrande medför.

Nyckelord: Åldrande, Affektiva funktioner, SCR, FMRI, Bilder, Emotionell minnesförbättring, ”Bottom-up” och ”Top-down” processer

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List of studies

The present doctoral thesis is based on three empirical studies, hereafter referred to by their Roman numerals:

I. 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.

II. Gavazzeni, J., Wiens, S., & Fischer, H. (2008). Age effects to negative arousal differ for self-report and electrodermal activity. *Psychophysiology, 45,* 148-151.

III. Gavazzeni, J., Bäckman, L., Wiens, S., & Fischer, H. Age differences in arousal level at encoding and emotional memory enhancement after one year retention interval. (Manuscript).

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Contents

Abbreviations

ANS	Autonomic Nervous System
ACDT	Affective Complexity Development Theory
BOLD	Blood Oxygen Level Dependent
DET	Differential Emotion Theory
EDA	Electrodermal Activity
FMRI	Functional Magnetic Resonance Imaging
IAPS	International Affective Picture System
MPFC	Medial Prefrontal Cortex
MTL	Medial Temporal Lobe
PFC	Prefrontal Cortex
SAM	Self-Assessment Manikin
SCR	Skin Conductance Response
SST	Socioemotional Selectivity Theory

Prolegomenon

> "The direction in which we are heading toward the end of life is the gradual or abrupt dissolution of our physiological and psychological structure and the energy it sustains. We all ultimately experience a downward spiral of loss of function until death, regardless of the particular details and how long it takes."
>
> Lazarus (2007:25)

Many mental disorders have an affective base, ranging from the autism spectra and social phobia, to psychopathy (e.g., Blair, 2004; Davidson, 2000; Davidson, Putnam, & Larson, 2000; Tillfors, Furmark, Ekselius, & Fredrikson, 2004). Emotional dysfunction also lies at the heart of conditions traditionally not considered to be affective disorders, such as schizophrenia, Capgras syndrome and prosopagnosia (Aleman, Medford, & David, 2006; Ramachandran & Blakeslee, 1999). Many aspects of emotional well-being seem not to abate in aging, rather the opposite. In spite of age-related decrements such as physical ailments and increased prevalence of serious illnesses older adults retain or even improve their well-being and emotional stability in comparison to younger adults. There is a large amount of research describing the phenomena of *successful aging*, i.e., maintaining - or even enhancing - a sense of emotional well-being and life satisfaction in the face of age-related losses (for a review see Ouwehand, de Ridder, & Bensing, 2007). Apparently, aging may have an insulating effect against emotional turmoil's causing disruptive behavior and against at least some affective disorders. Thus, a greater understanding of affective functioning across the lifespan may be of relevance not only to successful aging, but to mental health in general.

Contemporary science is step by step coming to terms with the importance of studying phenomenological experiences and the subjective perspective. Research is showing that, for example, i) affections and subjective experiences are fundamental for personal motivation, goal-setting and decision-making (Carstensen, 2006), ii) emotional experience lies at the core of how we interpret our physical and psychological health (Cioffi, 1991), iii) our social relationships and identity are also created, sustained and shaped in the web of feelings and, iv) a sense of coherence and positive feelings can have a protective effect against the detriments of stress and traumatic life events (Antonovsky, 1987; Eriksson & Lindström, 2005; Lindfors, Lundberg, & Lundberg, 2006).

According to some eastern traditions, feelings are regarded as one of the factors (kleshas) literally creating and entertaining the self-referential subjective experience (Rapten, 2005), which places the subjective experience of affections at center stage of human life. The same holds for age. Aging forces us to adapt and deal with, often on an emotional level, the continuous changes which occur during a lifetime. Aging and affective processing involve a wide variety of physical, physiological and psychological changes; but they also relate to, and change in the light of, personal experiences and environmental adjustments. To paraphrase Nagel (1974), it feels like "something" to have an emotional experience. Aging may be a major player in changing what "something" feels like.

A major part of research on aging is focused on the detrimental consequences associated with it. In the pages to come I shall instead review some research showing aging at its best – for instance, enhanced affective regulation, greater emotional heterogeneity and social competence. This research is comforting and promising from the perspective of successful aging at a time when, at least in the west, the old are getting older and the aging population is growing. A greater understanding of the underlying mechanisms of successful aging and retained abilities may also have beneficial consequences for the emotional well-being of the general population at large. However, in spite of these promising findings it is wise to keep in mind the words of Lazarus at the beginning of this section. The inevitable loss of physical abilities and mental functions, and the final dissolution of life as we know it, place the questions of lifespan changes in perspective. All the abilities and knowledge we take pride in are just transitory and, eventually, as elusive as life itself.

Introduction

Aging is associated with many physical, physiological and psychological changes. Evidence suggests a general age-related slowing down of hormonal processes and cellular reactivity (Finch & Roth, 1999), and changes in neural structures and functioning (e.g., Raz, 2000), as well as in cognitive processing (for extensive overviews see for example, Craik & Salthouse, 2000; Cabeza, Nyberg, & Park, 2005). In particular, attention, certain memory functions (explicit memory), and executive functions have been shown to be vulnerable to aging processes (Burke & Barnes, 2006; Glisky, 2007).

However, while many cognitive functions show various rates of decline, the picture looks different for affective functioning. The long-held conviction that aging inevitably results in bluntness of emotional experience and expression is no longer tenable (see Levenson, 2000; Isaacowitz, Charles, & Carstensen, 2000). Although knowledge is still limited, the field is growing and evidence points to a more stable affective functioning over the lifespan. Theoretical and empirical studies also point to age differences in attention, and a shift in general information processing from bottom-up processes (stimulus-driven) to top-down processes (goal driven) (Adams, Smith, Nyquist, & Perlmutter, 1997; Carstensen, Mikels, & Mather, 2006; Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004; Hashtroudi, Johnson, Chrosniak, 1990; Rahhal, May, & Hasher, 2002), which should be applicable to all measures of affective functioning - including neural activation, electrodermal activity, appraisals, and memory performance. I shall elaborate on this in the theoretical and review sections that follow this introduction.

This thesis addresses the question of age-related differences in affective functioning – that is, to what extent affective functions are retained or altered with age. The three studies comprising this dissertation focus on age differences in affective functions defined in terms of functional Magnetic Resonance Imaging (fMRI), subjective arousal (appraisal), physiological arousal (measured with skin conductance response, SCR), and memory performance for emotional stimuli. In Study I, we focused on age differences in neural activation in response to negative and neutral facial expressions, using fMRI and a selection of "Ekman faces" (Ekman & Friesen, 1976). In Study II, we investigated age differences in appraisal (subjective ratings of negative arousal) and electrodermal activity in response to negative and neutral pictures chosen from the standardized International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). In the final study, Study III, we focused on age-related differences in the long-term memory of emotional stimuli. In this study, participants from Study II returned a year later and were tested for recognition of the pictures that had been presented in that study. In what follows, I shall briefly elaborate on the aims and design of each study.

In Study I, we used fMRI and appraisal (defined here as the subjective ratings of arousal in response to emotional stimuli) to assess whether younger and older adults would show different patterns of neural activation, and whether age differences in patterns of activation correspond to age differences in subjective appraisals. Prior studies showed evidence that younger and older adults recruited different neural activation patterns to emotional stimuli, from more subcortical activation in younger adults to more cortical processing in older adults (Gunning-Dixon et al., 2003; Iidaka et al., 2002), but it was not clear from these previous studies whether the differences in neural activation would relate to differences in appraisal.

Study II was designed to further assess age-related differences in the appraisal of affective quality, and its relationship to physiological arousal measured by skin conductance responses (SCRs). The stimuli consisted of negative and neutral pictures that varied extensively along the arousal axis. According to lifespan theories (e.g., Carstensen, 1995), aging may involve changes in the ways affective and cognitive functions interact, which influences how emotional events are appraised. However, previous empirical studies have resulted in disparate findings, demonstrating both attenuated and enhanced affective experiences with age (Carstensen, Mikels, & Mather, 2006; Levenson, Carstensen, Friesen, & Ekman, 1991; Smith, Hillman, & Duley, 2005). One explanation may be the different measures of arousal in use, as well as differences in experimental design, focusing on experience of affective states or perception of affective quality. Another factor may be the selection of emotional stimuli, even when relying on normative standards like the IAPS.

The aim of Study III was to investigate age differences in long-term (one year) memory performance in response to emotional stimuli. An event that is highly arousing is more likely to remain clear and vivid in the memory. This *emotional memory enhancement* (e.g., Hamann, 2001) is a robust effect and is found in many studies (e.g., Brown & Kulik, 1977; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002; Ochsner, 2000), in both younger and older adults (Davidson & Glisky, 2002; Kensinger, Krendl, & Corkin, 2006). It relates to an evolutionary beneficial effect of arousal on cognition and memory, in contrast to the detrimental effects of chronic or intensive stress (Lupien, Maheu, Tu, Fiocco, & Schramek, 2007; McEwen, 2007; Sapolsky, 2003). However, it was unclear whether the emotional enhancement effect would also be valid for older adults and memory after long retention intervals. Additionally, it was unclear whether physiological arousal and subjective appraisal of arousal at encoding would relate to the memory enhancement effect. Based on previous findings, we hypothesized that increased SCRs and arousal ratings would be associated with enhanced long-term memory of emotional stimuli (e.g., Denburg, Buchanan, Tranel, & Adolphs, 2003). However, given that autonomic physiological reactivity attenuates with age, the relationship between SCR at encoding and subsequent memory performance also remained an open question for investigation.

Before going into the studies in more detail, I shall present a theoretical framework and give a selective review of research on age-related changes in affective functioning. The purpose is to put the studies in a larger context, and to relate them to the history of research on aging and affective functioning, and thereby laying the ground for pointing to some issues to be addressed in future studies.

Theoretical perspectives

> "…these unconscious structures and processes, including those described as cognitive and emotional, extend throughout the body and loop through the material, social, and cultural environments in which the body is embedded; they are not limited to neural processes inside the skull."
>
> Thompson (2007:12).

Affective research has become not only an acceptable scientific subject, but a thriving field where new brain imaging methods, such as fMRI, have boosted interest in, and knowledge about, activation and structures involved in affective functioning. The field of research on affective functioning in older adults, although rapidly changing, is still lagging behind, partly because of the clash of perspectives. The previously dominant view of aging (and perhaps still looming in some quarters) is of an ever-steeper slope of deteriorating abilities and blunt emotional capacities (cf., Isaacowitz, Charles, & Carstensen, 2000; Levenson, 2000; Looft, 1972). This view is partly due to unrepresentative samples. Earlier research on aging and affect was to a large extent based on residents of nursing homes and older adults with less robust health (Levenson, 2000; Magai, 2001).

The lion's share of research in affective science has been devoted to emotional processes and their development in children or younger adults. However, there is no evident scientific reason why developmental processes of affective functions should stop at the age of 20. In fact, mounting evidence indicates that affective capabilities such as emotional regulation, self control, coping, conflict management and social judgments seem to develop continuously with age (e.g., Carstensen, Mikels, & Mather, 2006; Labouvie-Vief, 2003; Magai, 2001). The emotional challenges of life never really abate. Increasing experience and knowledge of emotional and affective functions may therefore be of adaptive value across the whole lifespan. Thus, a more reasonable hypothesis is that at least some affective functions may continue to develop over longer periods. Still, empirical findings on aging in relation to cognitive and affective functioning are many and disparate. Some cognitively taxing abilities get weaker with age and the different cognitive and affective trajectories create what has been called "the wisdom paradox"

(Goldberg, 2005). Furthermore, even if there is a general attenuation of physiological reactivity with age, it is unclear whether, and to what extent, it reflects a deterioration of affective functioning or whether it may even facilitate a growth of affective adaptive capabilities. Methodological differences between the various studies do not make it easier to disentangle the arguments for and against any particular theory. In what follows I shall set the stage for the major players in the enactment of lifespan development.

What is an emotion?

> "The question 'how do you define an emotion?' begs a question: 'What is your definition of a definition?'"
>
> (Wierbiczka, 2007:09).

Ever since William James (1884) asked: "What is an emotion?" psychology has wrestled with the question. The concept of emotion is still eluding a clear-cut definition that can be, and is, accepted by researchers in the various fields of research on affective functioning and emotional experience. Therefore, we are left with many different ways of defining emotional states and affective processes, for instance, stimulus-induced responses, action tendencies, cognitive appraisals, reflexes, passions and feelings. Nevertheless, there seems to be a consensus that at least three different systems are involved in an emotional state: i) subjective feelings, ii) physiological reactivity and iii) behavioral expressions (e.g., see Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Furthermore, for an emotional experience to arise, the subject also needs to attend to a situation relevant to personal goals. The goals may be cursory or enduring, self-focusing or peripheral, conscious or unconscious. The critical part is the situated meaning that gives rise to an affect (Gross & Thompson, 2007).

To avoid confusion, here I shall shortly elaborate on and, for the purpose of this dissertation, define the different concepts in use to describe emotional states and affective processes. *Affect*, *feeling* and *emotion* are concepts that have taken on different meanings depending on their contextual use and the theoretical framework in which they are applied. For the purpose of this dissertation I shall use the terms *affect* and *feeling* interchangeably as a description of the phenomenological experience - qualia (in a general sense that captures subjective and conscious experiences, in other words, that it feels like something to have an experience). This use will include, but will not be limited to, conscious bodily feelings. *Emotion* will be used as a description of an intentional feeling - the feeling of doing "something" (Frijda, 1986, 2007). It denotes a discrete emotional state - for example, anger, fear, happiness. I shall also use the term *emotion* when researchers have used it exclusively in studies based on discrete emotions. Furthermore, here *affective or emotional functions* will be used interchangeably as generic terms, encompassing all aspects of emotional states and processes, conscious and non conscious, feelings and moods. Finally, *affective apperceptual mass* designates the sum of emotional and affective experiences accumulated over the lifespan. *Thus, affective apperception* denotes the processes by which situated and embodied affective experiences are accumulated. These latter two concepts will be elaborated in a later section below.

Modal and dimensional descriptors

Generally speaking, affective descriptors can be categorized into two groups: *modal* (discrete) and *dimensional* (continuous) descriptors. In the discrete modal view, affective states are often regarded as an evolutionary set of universal and specific emotions, for example, happiness, sadness, anger and fear. Within this view, theories can be sorted under two major approaches - *basic emotions* and *appraisals*. They share the assumption of discrete emotions, governed mainly by automatic processes (Barrett, Ochsner, & Gross, 2007). At the heart of affective processes, basic emotion theorists posit a hard-wired set of universal emotions (e.g., Ekman, 1999) or emotion systems (Panksepp, 1998), together with specific patterns of physiological reactivity for each discrete emotion. In contrast, the fundamental assertion of appraisal theories is that evaluative judgments of an event (appraisals of a situation) will result in a discrete affective state or emotion. However, due to the cognitive component, there may be, in principle at least, an unlimited number of emotions.

In contrast to modal discrete descriptions, the dimensional and continuous descriptions stress the polarity of emotional states. Wundt (1896) organized feelings into three dimensions that would cover all aspects of feelings: pleasure-displeasure, excitement-calm, and strain-relaxation. Modern dimensional models usually map emotional states in two dimensions: arousal and valence (Lang, Greenwald, Bradley, & Hamm, 1993; Russell, 1980), or approach-avoidance (Davidson, 1992). These dimensional (bipolar) descriptors do not exclude modal aspects. In fact, a further development of the pure bipolar model resulted in the *circumplex model* that emphasized the interrelated aspects of each dimension, and allowed for translations of discrete emotions (in the sense of basic emotions as well as appraisals) into positions along arousal and valence dimensions (Russell, 1980).

The dimensional approach is the foundation of the most common bipolar/biphasic model, which is based on arousal and valence (Lang, Greenwald, Bradley, & Hamm, 1993). This model has often been used together with the Self-Assessment Manikin (SAM; Bradley & Lang, 1994; Lang, 1980). The SAM is a non-verbal pictorial self-rating measure of levels of arousal, valence and dominance (the feeling of being in control of a situation) associated with an affective experience. It consists of schematic human figures illustrating three dimensions, and each dimension is represented by a 9-point scale (Bradley & Lang, 1994). Emotional experience elicited by pictures is frequently measured by the SAM. The pictures used to elicit affective experience in an experimental design are often selected from the International Affective Picture System (IAPS). The IAPS is a picture database that was developed by Lang and colleagues (Lang, Bradley & Cuthbert, 1999) and has been validated by using the SAM. The IAPS consists of several hundred neutral and affective photographs and is widely used to elicit and study emotional processes in different laboratory settings. A selection from this database was used in Study II and Study III.

Arousal and valence are the two primary dimensions most often used to chart emotional experience in biphasic models. Valence is a measure of pleasant or unpleasant feelings, and this dimension is illustrated in the SAM by a smiling and happy face, or a frowning and unhappy face. Arousal is a measure of feeling calm or excited, represented in the SAM by a relaxed sleepy figure, or an excited wide-eyed figure. Arousal, especially, is a complex concept that can be measured in many different ways. Eysenck (1976) categorized arousal into; i) subjective arousal - the innate state of arousal at the time of measurement; ii) item arousal - the arousal that is elicited by the stimulus; and iii) background arousal - the arousal that is not directly associated with the subject or the item, for instance, white noise.

In addition to measurements of arousal that indicate different types of bodily feelings and changes in felt alertness, arousal also includes measurements of stimulus intensity properties (Barrett, Mesquita, Ochsner, & Gross, 2007). Hence, the perception of stimulus intensity – that is, affective quality (Russell, 2003) - can be measured on an arousal scale without necessarily eliciting a corresponding physical arousal state.

Appraisal theories

All three studies in this dissertation include participants' subjective ratings of arousal intensity in response to emotional stimuli. Therefore, I shall shortly elaborate on some relevant parts of appraisal theories. Appraisal theories are one among several theoretical frameworks seeking to explain the causes of emotions. Appraisal theories stress the importance of evaluation and judgment. Other theories stress other causes for emotions and emotional states: i) the James-Lange theory of bodily changes (see e.g., Cameron, 2002); ii) Cannon's theory of neural activity, (see e.g., Cameron, 2002); iii) behaviorism, excluding everything other than stimulus-response activity (Skinner, 1938); iv) facial expressive behavior approaches which stress basic emotions (e.g., Ekman, 1999); v) Damasio's somatic markers - "neo-Jamesianism" (Damasio, 1994); and vi) constructivist theories where emotions and affective functions are formed by culture independent of biological mechanisms (e.g., Averill, 1974).

At the most fundamental level, appraisal theories hold that emotions are caused by evaluations or judgments of experiences. Thus, appraisals are often conceptualized as cognitive evaluations or judgments that are conscious and deliberate. An event is cognitively evaluated and an emotion is elicited by the cognitive appraisal (Lazarus & Alfert, 1964). In a further development of the general argument, an emotion depends on how a situation is interpreted - referred to as *the law of situational meaning* (Frijda, 2007).

In Arnold's (1960) original view, she stated that appraisals are in principle unconscious processes and pre-reflective, although she also allowed for appraisals to be conscious judgments. The same pre-reflective processes have subsequently been described by other authors as *automatic* (Kappas, 2006), *elementary appraisals* (Frijda, 2007), *appraisals of intrinsic pleasantness or unpleasantness* (Ellsworth & Scherer, 2003), or as the *sensory-motor level of appraisal* (Leventhal & Scherer, 1987). All these terms relate to non-conscious appraisals of an emotional experience, outside awareness, in line with the original view of Arnold.

Leventhal and Scherer (1987) suggested three different types of appraisal processing: i) sensory-motor processing based on biologically dependent perceptual processing, ii) schematic processing that automatically compares new information patterns with previously learned patterns, and iii) conceptual and conscious processing in which knowledge refines emotional responses. With experience, accumulated knowledge and practice, this conceptual processing becomes less effortful (less ruled by conscious control). Scherer (1999) further refined the model and proposed four types: i) the intrinsic properties of the stimulus (novelty and pleasantness), ii) the meaning of the event for the individual (his/her motivations and goals), iii) the individual's ability to cope with the consequences of an event, and iv) the compatibility of the event with social and personal norms and values.

In addition, it has been suggested that emotional appraisals depend on the spatiotemporal context and the source of the experience (Frijda, 2007). Thus, in this view, appraisals are *situated embodiments*. In conclusion, following Arnold's view, appraisal mechanisms are here conceptualized primarily in terms of non-reflective and immediate experiences, although the experiences may be based on conscious and reflective processes.

Phylogenetic and ontogenetic development

In the terminology of Frijda (2007), we need to make a distinction between the *state of feeling* and the *feeling of doing* something. The latter is the emotion arising from so-called intentional *action tendencies or action readiness* (Frijda, 1986; 2007; Lazarus, 1991). This agrees with evolutionary theory where the primary function of feelings and emotions is to guide actions and social interactions. In order for this function to operate, a system needs to organize and evaluate the available information. In Levenson's affective model (1988, 1994), the core of this system contains a biologically hard-wired mechanism evaluating all types of input, external and internal. Part of this perceptual vigilance mechanism is a number of *evolutionary programs* that activate when a situation is encountered that resembles previously encountered situations. These programs represent prototypical situations and trigger pre-wired adaptive affective responses. Age-related biological changes of the nervous system influence these pre-wired programs by means of alterations in emotion activation thresholds.

Encompassing these evolutionary basic and automatic mechanisms regulating behavior is an overarching control system formed by learning. The control system modulates perception and thus the core mechanism, by means of appraisals. It also regulates the output behaviors and actions through cultural and emotional rules. Experience changes the way events are appraised and aging may impact both the input and output side of this suprastructure.

> "With age, things are appraised against a much deeper store of pertinent experiences, which can lend different perspectives on emotionally relevant matters involving such considerations as losses and gains. Also as we age, our inclinations to exert control over our emotional response tendencies may change in significant ways, as may our abilities to impose these controls effectively" (Levenson, 2000: 128).

As mentioned in the introduction, limited research exists on age changes in affective functioning. In the following, I shall briefly describe three theories of relevance: i) *the affective complexity development theory* (ACDT; Labouvie-Vief, 2003; Labouvie-Vief, De Voe, & Bulka, 1989; Labouvie-Vief & González, 2004), ii) *the differential emotional theory* (DET; e.g., Izard, 1991; Magai, Consedine, Krivoshekova, Kudadjie-Gyamfi, & McPherson, 2006), and iii) *the socioemotional selectivity theory* (SST; e.g., Carstensen, 1995; Carstensen, Fung, & Charles, 2003).

The affective complexity development theory

In a series of studies, Labouvie-Vief and her colleagues (Labouvie-Vief, 2003; Labouvie-Vief, De Voe, & Bulka, 1989; Labouvie-Vief & González, 2004) showed a continuous growth of cognitive-affective complexity also in older adults (at least until the participants reached their sixties). I have labeled this line of research *the affective complexity development theory* (ACDT). The age-related changes that were found involved increased affective differentiation and complexity. Affective differentiation is a measure of how well an individual integrates both positive and negative emotions. A distinction is made between optimization and differentiation. Optimization is a question of emotional regulation that minimizes negative feelings and reinforces positive feelings. In contrast, differentiation implies emotional refinement and regulation in terms of greater tolerance of emotional ambiguity (Labouvie-Vief, 2003).

In their research, Labouvie-Vief and colleagues found that after the age of 60 the affect complexity declined. Although older adults reported feeling higher levels of positive emotions, such as joy and interest, they also showed lower levels of negative emotions, such as sadness and anger (Labouvie-Vief & González, 2004). These general findings of more accentuated positive experiences and reduced negative affects in older adults are also supported by a large amount of empirical findings, which will be reviewed below, and which are not limited to research within the ACDT. In the terminology of affective complexity, decreased complexity goes with increased optimization. It has been suggested by theorists of the ACDT that negative experiences may be more cognitively taxing than positive experiences. Thus, the increase in positive feeling may be regarded as compensation for declines in cognitive-affective complexity (Labouvie-Vief, De Voe, & Bulka, 1989; Labouvie-Vief, 2003).

The differential emotional theory

DET (Izard, 1991; Magai et al., 2006) is a theory of basic and discrete emotions. The basic emotions are regarded as pre-wired and remain stable across the lifespan, although experience can change parts of the system. The emotions are biological adaptations and form a system that has developed to meet evolutionary challenges and to benefit survival and fitness (Consedine, Magai & Bonanno, 2002). Lifespan development results in more elaborated cognitive networks that influence the affective functions, as well as in different emotion regulation abilities (Consedine, Magai & King, 2004; Magai et al., 2006). Emotion regulation ability is retained even in older adults. Within this framework, emotion regulation is explained as a protective measure for age-related physiological decline. Physiological decline brings with it decrements in flexibility as the somatic system becomes more rigid and less capable of handling emotional changes, especially negative affective states that may be more taxing on the system (Magai et al., 2006). This is also in line with research on stress and cognition. Experience of detrimental stress may result in increased sensitivity and avoidance of stressful events and stimuli (Lupien et al, 2007; McEwen, 2007; Sapolsky, 2003). Thus, the focus on positive emotional experiences in older adults has a protective function (Consedine, Magai, & King, 2004), which resembles the arguments of the affective complexity theory.

The socioemotional selectivity theory

According to the SST (e.g., Carstensen, 1992, 1995; Carstensen, Fung, & Charles, 2003), aging involves changing goals and motivation: a shift from knowledge-seeking goals in youth, when time seems unlimited, to the emphasis on emotionally gratifying goals in late adulthood when time is experienced as limited. Within this time perspective, late adulthood is associated with motivational goals enhancing emotionally satisfying social relationship, and thereby with personally relevant and positive emotional meaning. With age, cognitive resources and attention are allocated to affective resources because of a motivational shift towards more emotionally gratifying processing, and not as a consequence of decrements in affective functioning (Carstensen, Mikels, & Mather, 2006). Whereas many so-called effortful cognitive capabilities deteriorate with age, some affective processes - for instance, emotional regulation (Gross et al., 1997) - remain more stable or even show improvements,

In contrast to the other theories, viewing age-related changes in affective experiences as compensations, SST allows for an explicit enhancement of emotional regulation ability with age (Carsentsen, Fung, & Charles, 2003). Empirical findings are also amassing showing that emotional regulation abilities may become more pronounced as an individual ages (Gross & John, 2002; Charles & Carstensen, 2007). Furthermore, in contrast to ACDT and DET, theorists within the field of SST have defined emotional regulation in more general terms: that is, as age-related changes in goals and motivations (Charles & Carstensen, 2007). Emotional regulation has been further divided into *antecedent-focused*, that is, regulation occurring prior to the actual emotional response, or *response-focused*, that is, regulation of an emotional response after it has occurred (Gross & Thompson, 2007). Within this SST framework, growing life experience in older adults - which may develop into the concept of wisdom - may also influence the development and use of different forms of emotional regulation, both antecedent-focused and response-focused.

Automatic (bottom-up) and controlled (top-down) processing

The distinction between automatic and controlled processes is applied by psychologists to two quite different, but related psychological phenomena: on the one hand awareness, and on the other hand attention. At the origin of this distinction is the question of consciousness. Automatic processes were originally used for any experiences lying outside the conscious control of the subject – unintentional, but efficient at the level of information processing. In contrast, controlled processes involved conscious experience of the subject – intentional, but with limited attention span. In the light of contemporary cognitive science, this dichotomy between automatic and controlled processes is hardly tenable (Bargh, 1994). Human thinking, feeling, and behavior involve a mixture of automatic and controlled processing and any given action at any given time exists on a continuum between the opposites in the original use of the terms (Pashler, Johnston, & Ruthruff, 2001). From this perspective, the distinction between automatic and controlled processing has taken on a second meaning that may be of greater relevance for the question of aging and affective functioning.

In this context of human attention and information processing, automatic processing refers to stimuli-driven attention, whereas controlled processing refers to goal-driven attention (Barrett, Ochsner & Gross, 2007). In other words, automatic processing is more reactive to the situation at hand, whereas controlled processing is more detached from the environmental demands. From this perspective, the distinction between automatic and controlled processing is then parallel to bottom-up versus top-down processing. Whereas bottom-up, automatic processing to a larger extent is subject to stimuli priming of affective functions, controlled top-down processing may modulate perception prior to the subsequent subjective experience (Luck & Hillyard, 2000; Posner & DiGirolamo, 2000). Importantly, the distinction between top-down and bottom-up processes made here has a parallel in - but cannot be reduced to - a strict neurobiological differentiation between the functions of brain regions processing incoming stimuli and regions associated with higher cognitive functions, such as the reactivity of primary visual cortices and a conscious control function of the PFC. Considering that goal-driven behavior develops with experience, controlled processing may also be subject to quantitative and qualitative growth with age. Automatic and stimuli-driven attention may dominate information-processing during youth, whereas controlled and goal-driven attention may become more important with age.

In this dissertation, I shall use the distinction between automatic and controlled processing in the latter sense of different forces (bottom-up versus top-down), underlying the human attention-span. In fact, emotional reactions differ greatly between individuals, in terms of both quality and intensity of reaction to similar experiences. This diverse range of affective reactivity has been defined as *affective style* (Davidson, 1992) and is also related to temperament and other personality factors. One important aspect of affective style concerns emotional regulation - a multidimensional concept that may include amplification, attenuation, and/or maintenance of an emotional reaction. Emotional regulation is intrinsic to an emotional experience, and much of emotional maturation is associated with learning to handle emotional experiences. With practice, this regulation becomes less effortful (Davidson, 1998) and subject to controlled processing in its present sense, but automatic in its original sense. Consequently, aging, the accumulation of life experiences of emotional challenges, may imply a gradual shift from bottom-up reactivity to top-down affective regulation (Charles & Carstensen, 2007).

Successful aging

Aging involves both gains and losses. Older adults' resilience in the face of losses, and their ability to sustain a positive and satisfying life approach, are two key concepts of *successful aging* (Baltes & Baltes, 1990). In this view, successful aging is not only a matter of coping with decrements but an active process of maintaining a positive balance in life.

In spite of decrements in physical and cognitive functions, as well as increases in the prevalence of age-related illnesses, research on successful aging (using questionnaires) has shown that the subjective experience on items such as emotional well-being, social life and independent living, provides a psychological framework that may be a better measurement for successful aging than measures based on pure physiological status. Although successful aging is a complex concept lacking a coherent framework, studies focusing on clinical definitions of successful aging, for example, prevalence of chronic medical illness or physical disability, differ from the results based on criteria used by the elderly themselves (Glatt, Chayavichitsilp, Depp, Schork, & Jeste, 2007).

The presence of a condition regarded as detrimental for successful aging in a clinical setting may not influence the actual subjective feelings of successful aging in the elderly (Montross et al., 2006). Subjective, internal goals become more important for wellbeing, health and life-satisfaction with age. Studies of general well-being in older adults have shown that they feel at least as content as younger adults (Ingelhart, 1990). In a longitudinal study spanning 22 years, in which 1.927 healthy men (aged 40-85) participated, it was shown that life satisfaction reached a maximum at 65-70 years and then declined (Mroczek & Spiro, 2005). The inverted U shape showed an equal level of life satisfaction, both for men aged 40 and for those aged 85. In self-reports, older adults score higher on contentment than younger adults (Lawton, Kleban, & Dean, 1993). Furthermore, both longitudinal and cross-sectional studies have reported an age-related increase in psychological well-being (Ouwehand, de Ridder, & Bensing, 2007). In addition, several studies showed that negative affects decreased with age, while positive affects remained stable (Carstensen et al., 2000; Charles, Reynolds, & Gatz, 2001; Mroczek, 2001). Other studies have also shown that older adults are less depressed, less anxious and less aggressive than younger adults (Lawton et al., 1993). Older adults also scored higher on emotional control, mood stability, and emotional maturity (Lawton et al., 1992). Increments in explicit social affective functioning have been found in observational studies, where older adults are better at balancing conflicts and opposing affects (Charles, 2005; Levenson, Carstensen, & Gottman, 1994). These increments are also manifested in better memory performance for the emotional content of a situation. Carstensen and Turk-Charles (1994) showed in a memory test (with participants aged 20 to 83 years), that recollection of emotional content increased gradually according to the participant's age.

Taken together, these studies indicate that physiological decrements do not necessarily result in attenuated affective experiences or reduced life-satisfaction. The giving of meaningful interpretations to physiological changes may even be an important factor in the subjective experience of successful aging and well-being. That is why somatic interpretations play a fundamental role in physical and psychological health (Cioffi, 1991).

Affective apperceptual mass

Apperception is commonly considered as the processing of new information in the light of an individual's accumulative experiences (cf., Paivio, 2007). New information is reflected and appraised against this referential framework. An affective experience is appraised by the situated and embodied conceptual knowledge associated with the experience. Previous experiences associated with the affective state change or modulate a new emotional experience, thereby adding to the concept of affective apperception. Thus, *affective apperceptions* are the processes by which situated and embodied affective experiences are accumulated over the lifespan. The accumulated sum of affective experiences will be referred to as the *affective apperceptual mass*.

The notion of embodied experience is used here in a slightly different sense from the one used by Niedenthal and colleagues (Niedenthal, Barsalou, Ric, & Krauth-Gruber, 2005). They restrict the term to "bodily states that arise (e.g., postures, facial expressions, and uses of the voice [i.e., prosody]) during the perception of an emotional stimulus and the later use of emotional information (in the absence of the emotional stimulus)." The wider conceptualization used here involves affordances, i.e., what constraints and options the physical and physiological system of an organism offer in terms of behavior and actions in relation to its environment.

Affective functioning – a selective review

In this part of the thesis, I shall present a selective review of findings relevant to the issue of age-related changes in affective functioning. In general, affective functioning has been characterized in terms of stability or decrements in processing efficiency and sometimes, although more rarely, in terms of increased efficiency. However, in this field of research there are many discrepant findings that may depend on various methodological issues, on experimental designs and on measures of affective functioning. This point will also be touched upon in this review. The order of presentation in this section mirrors the order of the measures of affective functioning used in the three studies (i.e., appraisal, fMRI, SCR, and memory performance).

Appraisals of affect intensity and frequency

A large body of research based on self-reported retrospective accounts of emotional experiences (frequency and intensity of emotions) lends support to the notion of sustained affective functioning in aging (Levenson, Carstensen, Friesen, & Ekman, 1991; Magai et al., 2006; Malatesta, Izard, Culver, & Nicolich, 1987; Tsai, Levenson, & Carstensen, 2000). For example, in one of the studies, participants were asked to recall personal emotional events in relation to a set of antecedent emotional situations. The personal experiences were as intensively experienced by older as by younger adults and the affects were accompanied by spontaneous facial expressions equally often in the two age groups (Levenson, Carstensen, Friesen, & Ekman, 1991). Still, there are empirical studies supporting the idea of a shift in motivational goals and attention in older adults, involving less negative and increasingly positive emotional experiences compared to younger adults (Carstensen & Charles, 1998; Charles, Reynolds, & Gatz, 2001, Mather et al., 2004).

In one study, participants (184 persons aged 18-94) were asked to record their emotional experiences randomly several times a day during one week. No differences in subjective intensity between ages were discerned, but the frequency of negative affects gradually decreased until the age of around 60 years (Carstensen, Pasupathi, & Mayr 2000). In another study on marital interactions, older couples showed more positive affect compared to middle-aged couples (Levenson, Carstensen, & Gottman, 1994). Furthermore, in a series of four studies, questionnaires about emotional expressivity and control were administered to participants aged 19 to 101 years (Gross, Carstensen, Tsai, Götestam Skorpen, & Hsu, 1997). Taken together, the studies showed that older adults reported fewer negative experiences than younger adults, as well as lower impulse strength (i.e., fewer intense emotional impulses that the participant found difficult to control), less positive and negative expressivity, and greater emotional control. However, in one of the studies in which Catholic nuns participated, older nuns reported feeling more happiness compared to the younger nuns.

There are also findings of quantitative changes in the intensity of emotional experiences. As reported above, in the study by Levenson and colleagues (1991), when instructed to relive a personal emotional event, younger and older adults reported experiencing equally strong emotional intensity, but emotions elicited artificially by a directed facial task resulted in older adults' reporting fewer emotional experiences, as well as producing less frequent facial expressions corresponding to the target expressions (Levenson et al., 1991). Participants were required to make facial configurations which, unbeknown to the participants, morphologically would be equivalent to six target emotions (anger, disgust, fear, happiness, sadness, and surprise). Compared to younger adults, older participants were less accurate on the task and reported feeling the target emotions less often.

Studies on subjective ratings of pictorial information using the IAPS have yielded inconclusive results, with findings of both lower and higher emotional ratings in older compared to younger participants (Smith, Hillman, & Duley, 2005). Whereas some studies have not found any difference in subjective ratings between older and younger adults (Backs, da Silva, & Han, 2005; Denburg, Buchanan, Tranel, & Adolphs, 2003), there is at least one study where older adults demonstrated lower arousal ratings of negative pictures compared to younger participants (Mather et al., 2004). The participants (18-29 and 70-90 years respectively) were asked to rate how excited or calm they felt viewing each picture. The age differences in arousal ratings were found only for negative pictures, and not for positive or neutral pictures. In contrast, Smith, Hillman & Duley (2005) reported that older adults (60-71 years) generally rated pictures higher on both valence and arousal in comparison to younger adults (18-32 years). Importantly, the selection of IAPS pictures in this study included age-related themes: negative, positive and neutral scenes involving older and younger adults.

Age differences in affective appraisal of pictorial information have also been tested with film-clips. In the first study, participants were presented with scenes of injustice to younger and older participants. Older adults reported a greater mix of affects – greater emotion heterogeneity (Charles, 2005). In the second experiment, Kunzman and Grühn (2005) showed age-related films, and the older participants reported feeling greater sadness compared to younger adults. To summarize, the appraisal of the arousal intensity of emotional pictures may be at least equally intense for older as for younger adults, but the relevance of the material seems to become more important for older adults' emotional involvement.

Mapping affective neural activity with fMRI

Brain imaging techniques have become increasingly important tools in affective research, with fMRI being one of the most widely used methods. Thus, knowledge is increasing about structural and functional changes related to both healthy and pathological aging. There are indications of a general age difference in cortical activity (Hedden, 2007). For a particular task, older adults may activate larger areas of neural activity than younger adults. There are also indications of reduced hemispheric and asymmetric processing and increased bilateral activation, that is, older adults recruit the same region in the contra-lateral hemisphere. Therefore, bilateral activation has been interpreted as a compensatory function, and older adults showing the largest bilateral activation of the prefrontal cortex (PFC) usually perform better than their cohorts with less bilateral activation. In principle, the greater variability in older adults' neural activity and performance may be an indication of plasticity and neural changes due to life experience, but, on the other hand, it may also reflect pathological changes (Hedden, 2007). These aspects of age-related changes in neural activation may also be important for emotional processing and affective style. In addition, not only cortical areas are affected by aging and changes in different emotional functioning.

Both sub-cortical and cortical brain regions are implicated in affective functioning, such as brainstem structures, amygdala, PFC, insular cortex and anterior cingulate cortex (Knight & Mather, 2006; Wager et al., in press). Noteworthy is that regions traditionally associated with cognitive processing also play an important role in affective functioning, and a strict dichotomization between structures involved in cognitive respectively affective processing is not tenable (Davidson & Irwin, 1999). One example is executive functions (such as planning, self regulation and strategic memory processes) associated with activity in the ventrolateral and dorsolateral PFC, regions that also interact with affective processes (Knight & Mather, 2006).

In brain imaging studies, the prefrontal cortex (PFC) and amygdala are two regions of the brain that have consistently been implicated in affective processes related to, for example, perception, experience and memory function (e.g., Knight & Mather, 2006; Davidson & Irwin, 1999; LeDoux 1996; Kilpatrick & Cahill, 2003). These regions' involvement in affective functioning is further supported by lesion studies showing that damage in these regions results in decrements in emotional functioning. For example, damage to the left dorsolateral PFC has been associated with depressive symptoms, and there seems to be a general division between the left and right PFC for positive and negative feelings (Davidson, 1992; Davidson & Irwin, 1999).

Although no general differences between the cerebral hemispheres in emotional functioning were found in a recent meta-review (Wager, Phan, Liberzon, & Taylor, 2003).

The other main structure involved in affective functioning, the amygdala, is important for both the perception and the production of at least some negative emotions (Davidson & Irwin, 1999), and has been associated with the recognition of fearful faces (Adolphs, Tranel, Damasio, & Damasio, 1995). In a meta-analysis by Phan and colleagues, the medial prefrontal cortex (MPFC) was associated with a range of different affective studies and it was suggested that the MPFC plays an important general role in affective processing (e.g., appraisals, emotion regulation and emotional decision-making) that would be similar in different affective settings (Phan, Wager, Taylor, & Liberzon, 2002). The MPFC may be especially important for emotional self-regulation (Davidson, 2000) and emotional decision makings (Damasio, 1996).

Importantly, evidence indicates that aging involves altered functional processing in brain regions engaged in emotional behavior. A recent fMRI study showed that aging was associated with increased emotional stability and control, and also with increased activity in the MPFC (Williams et al., 2006). Another study, presenting fearful and threatening stimuli to younger (under 30 years) and older (over 60 years) adults, Tessitore and colleagues (2005) found reduced activity in the right amygdala and posterior fusiform gyri in the elderly participants, compared to younger participants. In contrast, older showed increased activity in neocortical areas, including Broca's area and the left MPFC. This neural activation pattern was interpreted as an adaptive network functioning in older adults (Tessitore, et al., 2005). This conclusion is in line with the theory of a more controlled, top-down development as people age, and is supported by earlier imaging studies showing enhanced cortical activation in older adults in the processing of negative emotional expressions and attenuated activity in sub-cortical regions (Gunning-Dixon et al., 2003; Iidaka et al., 2002).

Differentiated emotional functioning of the PFC and the amygdala was also found in a study separating perceptual and intellectual tasks (Hariri, Bookheimer, & Mazziotta, 2000). Young participants had to either match a facial expression (angry or fearful) by choosing one of two simultaneously presented expressions, or choose the appropriate linguistic/semantic label for a facial expression presented to them. An inverse relationship was found between the PFC and the amygdala. Matching a negative facial expression increased activity bilaterally in the amygdala. In contrast, labeling an affective facial expression increased activation in the PFC, whilst activity bilaterally decreased in the amygdala (Hariri et al., 2000).

Besides the PFC and the amygdala, also other regions in the medial temporal lobe (MTL), including the hippocampus and the perirhinal cortex, are critical structures for affections and memory. These regions are associated with different aspects of memory function. For example, there is mounting evidence of separate structures processing recollection and recognition (familiarity) within subregions of the MTL. The hippocampus was demonstrated to have a crucial role for recollection, whereas the perirhinal cortex was necessary for recognition (Eichenbaum, Yonelinas, & Ranganath, 2007). Furthermore, long-term memory performance for emotional stimuli was associated with increased activation in the amygdala of younger adults (Dolcos, LaBar, and Cabeza, 2005). A differential age-related memory effect, with a more intact amygdala but a more vulnerable hippocampus, has been suggested as an explanation for memory decrements with regard to perceptual details and specificity in older adults, but not with the memory for gist of stimuli (Denburg, Buchanan, Tranel, & Adolphs, 2003).

The insular cortex is an evolutionary old cortical region that has been implicated in cognitively engaging affective processes, such as, control, evaluation and experiential aspects (Phan, Wager, Taylor, & Liberzon, 2002; Wager & Barrett, 2004). More specifically, its function seems to integrate interoceptive and sensory information (Craig, 2002, 2003), incorporating self-referential information with external input. Recent findings have also shown that the anterior insula can be divided into functionally different subregions (e.g., the ventral anterior insula was shown to be associated with the basic affective experience that resulted from self-relevant events ("core affect"), while the dorsal anterior insula was suggested to be more closely related to goal oriented development and control), bridging affective and cognitive processing (Wager & Barrett, 2004).

Imaging studies in younger adults have also shown that the amygdala plays an important role in emotional discrimination and emotional memory (Legiland, Schulz, & Janowsky, 2004). The fact that aging seems to affect the neural activation to emotional discrimination and memory was demonstrated in an fMRI study by Mather and colleagues (2004). Younger (18-29 years) and older (70-90 years) participants were shown neutral, negative and positive pictures selected from the IAPS and asked to rate how calm or excited they felt when viewing the pictures. The imaging data showed attenuated amygdala activation in older participants for negative pictures, but there were no significant age differences for positive pictures. In line with this, no age difference in arousal ratings was found for neutral and positive pictures, but older adults did rate negative pictures as less arousing.

To summarize, fMRI studies on affective functioning indicate that older adults show greater activation in cortical areas - for instance in the PFC, but less activity in sub-cortical areas, for instance in the amygdala - compared to younger adults. This age-related difference in the neural activation pattern suggests that aging involves altered functional processing in brain regions engaged in emotional behavior. It has been suggested that older adults engage in more cognitive elaborations and become more dependent on conscious and effortful aspects for processing information. It has also been shown that conscious cognitive tasks, such as semantic categorization, increase the activity within the PFC and attenuate activation in the amygdala. It has also been suggested that the amygdala is less affected by age-related changes than the hippocampus, leading to better emotional memory performance for gist than for context (details). In addition, the insular cortex has been found to integrate affective and cognitive processes.

Before closing the discussion on fMRI, it is important to keep in mind methodological issues, i.e., the problem with comparing results from different studies due to variations in experimental designs, stimulus material and population samples. To illustrate, Gunning-Dixon et al. (2003) used a fixation cross as a baseline reference when estimating the neural activity for emotional faces. Consequently, it is not possible to tell whether neural activation is a reaction to facial stimuli in general or to the emotional quality of the stimuli. Furthermore, the participants were also asked to determine the valence of the faces presented. Even simple cognitive tasks involved in affective perception can modulate the effect on the "limbic system" (Hariri, Bookheimer, & Mazziotta, 2000). Still, the fMRI studies include a variety of tasks which make it difficult to assess the effects. Iidaka and colleagues (2003) provide another example. They studied age-related differences, but only asked their participants to identify the gender of the faces, not to rate the affective quality of the stimuli. Thus, these types of differences in experimental designs are important to keep in mind when the results form different studies are compared.

Electrodermal Activity: Skin Conductance Response

The findings of general age-related decrements in physiological reactivity are robust (Cacioppo, Berntson, Klein, & Poehlman, 1997; Ferrer, Ramos, Pérez-Sales, Pérez-Jiménez, & Alvarez, 1995; Frolkis, 1977; Furchtgott & Busemeyer, 1979; Low et al., 1997; Zelinski, Walsh, & Thompson, 1978). Given the close association between psychophysiological arousal and emotional experiences (e.g., Cacioppo et al., 1997), this has probably contributed to the view that associates aging with a period of emotional bluntness. As for physiological reactivity to emotionally engaging stimuli, earlier studies have also shown that the magnitude of autonomic activity is generally attenuated, especially in the cardiovascular system (Burriss, Powell, & White, 2007; Smith, Hillman, & Duley, 2005; Tsai, Levenson, & Carstensen, 2000).

Electrodermal activity (EDA) is under the control of the sympathetic nervous system and reflects the activity of the eccrine sweat glands and release of the neurotransmitter acetylcholine (Cacioppo et al., 1997; Dawson, Schell, & Filion, 2000). EDA can be measured by skin conductance responses (phasic activity) or skin conductance level (tonic activity). The skin conductance response (SCR) reflects rapid and transient reactions to internal or external affective events, while the skin conductance level (SCL) reflects sustained attention or baseline activity at rest (Dawson et al., 2000; Hugdahl, 1995). Studies that have targeted this automatic affective reactivity add evidence to the attenuation of autonomic processing with age (Cacioppo et al., 1997; Levenson, 2000), even though the attenuation for EDA may be less than the reduction found in other systems, for example, cardiovascular activity (Levenson, 2000). Most studies measuring physiological activity to affective stimuli have used relatively short emotional presentations, but also studies using measures of long-lasting affective and emotional functioning show physiological attenuation. For example, in a study with married couples engaged in discussions about emotionally engaging topics, older couples demonstrated attenuated physiological arousal, but expressed more positive affects compared to younger couples (Levenson, Carstensen, & Gottman, 1994).

A few studies have not found any age differences in EDA (e.g., Denburg et al., 2003) and compared to younger adults, even a larger startle-blink was found in older adults for unpleasant pictures (Smith, Hillman, & Duley, 2005). Further, Kunzman and Grühn (2005) included several measures of autonomic activity - namely heartbeat interval, finger pulse amplitude, pulse transmission time to the finger, respiratory intercycle interval, finger temperature, body movement and skin conductance level. These measures showed no age differences in response to film clips with age-related, and sadness-eliciting content. For these film clips with age-related content, for example, Alzheimer's disease, they also found enhanced subjective appraisal in older adults (60-70 years) compared to younger adults (20-30 years). To sum up, aging is associated with a general attenuation of autonomic affective systems, although there may be some exceptions. For example, by presenting age-related stimuli of emotional relevance to older adults, the level of autonomic reactivity may be as high as in younger adults.

Importantly, even if general autonomic activity is attenuated in magnitude in older adults, the reactivity-pattern for emotional stimuli has been shown to be similar across ages (Lawton, 2001; Levenson, 2000; Levenson, Carstensen, Friesen, & Ekman, 1991; Tsai et al, 2000). In other words, even if autonomic reactivity (at least that measured by heart rate and skin conductance) decreases in magnitude, the qualitative functioning may remain more or less intact. A recent study using event-related potential (ERP) also showed age-related attenuation of physiological reactivity in older compared to younger adults; but this was not reflected in any decrements of subjective affective appraisal (Kisley, Wood, & Burrows, 2007).

There are also studies targeting gender differences in younger and older adults. Bradley et al. (2001) found no gender differences in SCR magnitude between younger adults, although they did find a tendency of increased magnitude towards erotic pictures in men. In the same study, women rated unpleasant pictures as being more arousing than did men. The same increased arousal experience was reported by women for film-clips eliciting sadness (Kunzman & Grühn, 2005). Denburg and colleagues (2003) also found negative pictures to be rated more unpleasant by both younger and older women than by men, which points to the importance of also taking gender into account when studying age differences in affective processing.

Aging and memory performance

> "Memorizing is the process of making an immediate experience effective so that it may be utilized at some future time. Recalling is making use at the present time of what was memorized in the past. Retaining is the process of keeping intact what was memorized so that it can be recalled."
>
> (Morgan, 1941:272).

Memory systems and processes

Memory is not a single construct (Schacter & Tulving, 1994). One distinction that has been made, at least since the time of William James ([1890], 1950), is the difference between memories that are retained for a long time and memories that are more cursory. This distinction has become known as a distinction between working memory (or short-term memory) and long-term memory (Broadbent, 1958). The latter is further divided into explicit and implicit memory (Graf & Schachter, 1985). These are analogous to declarative and non-declarative memories respectively (Cohen & Squire, 1980). Explicit memories are intentionally recollections of events. They involve active and conscious memory of past events, for instance - what you had for lunch today. In contrast, implicit memories are non-conscious and non-intentional forms of experience - for instance, routine skills such as riding a bike and word-fragment completion. Older adults generally show impoverished performance on explicit memory tests, but perform relatively on a par with younger adults on implicit memory tests (Hedden & Gabrieli, 2004).

Another classification of long-term memory distinguishes between i) semantic memory (explicit analytical knowledge), ii) episodic memory (explicit knowledge about personally experienced events) and iii) procedural memory (skills and habits that do not normally require any conscious or executive monitoring; Tulving, 1972, 1987; Tulving & Schachter, 1990). Comparing these, aging negatively affects episodic memory to a greater degree than it does semantic or procedural memory (Craik & McDowd, 1987; Rugg & Morcom, 2005; Zacks, Hasher, & Li, 2000). There is a general decline in memory performance with age (Park & Gutchess, 2005), and episodic memory is more vulnerable to aging processes, and its impairment is also associated with the onset of Alzheimer's disease (Bäckman, Hill, Herlitz, Fratiglioni, & Winblad, 1994; Bäckman & Larsson, 1992).

Dual-process models account for the two main ways in which an event may be remembered, that is, recollection, which is the conscious retrieval of specifics and the contextual information about a previous event (the where and when) and familiarity (recognition), a more automatic and generalized process of identifying the general contours of a previous event; a feeling of knowing that a previous event was encountered (Jacoby, 1991; Yonelinas, 2002). With age, memories become less vivid and detailed, as well as showing reduced contextual associations (Craik & McDowd, 1987; Rugg & Morcom, 2005). This agrees with findings on memory performance which show that older adults rely more on feelings of familiarity compared to younger adults who rely more on recollection processing (Naveh-Benjamin, 2000; Yonelinas, 2002). Other memory processes that rely on automatic processing - for example, autobiographical and implicit memory - appear to be more stable across the age range (Hedden & Gabrieli, 2004). Memory processing in aging becomes more focused on interpretation rather than the veridical reproduction of events (Adams, 1991).

Eidetic memory, sometimes misleadingly called photographic memory, has been studied in both children and adults. It used to be a vibrant research field – at least until the 1970's, when it went out of fashion (Rose, 2003). In some early studies, this type of memory was associated with psychopathology (Luria, [1968] 1987); but in its wider sense, eidetic memory is an enhanced general memory capacity for visual details (Gray & Gummerman, 1975). Even if there are mixed findings on specifics, children generally outperform adults on this type of memory (Gray & Gummerman, 1975). Anyone who has played Memory with a 10-year old child knows how this specialization works and the difference age makes. It is likely that this enhanced visual memory for details in children may show a continuous and dramatic decrement during aging (Rose, 2003). In fact, Haber (1979) concluded that the eidetic ability found in young children only seldom remained after the age of ten, and was not found in adults at all. This memory function is also indicative of a general age-related change in memory processing relating to memories of affective events.

There are several theories about the underlying causes for age-related memory declines - for example, i) reduced processing resources (Craik & Byrd, 1982), including working memory capacity (Park et al., 1996), ii) lack of inhibition (Zacks & Hasher, 1997), iii) recollection impairment (Jennings & Jacoby, 1993). In general, the greatest loss of memory occurs soon after learning, both for younger and older adults, with the rate of loss flattening out after a few days (Morgan, 1941). In a series of memory tests with different retention intervals, reported by Morgan (1941), the greatest memory loss for words occurred within 48 hours of initial encoding. After six and 30 days respectively, there was little further memory deterioration.

Emotional memory enhancement

Generally speaking, older adults are less apt than younger adults to access detailed information on an item (Kensinger & Schacter, 1999; Koutstaal, 2003). This is manifested in studies of recognition where older adults, more than younger adults, fail to identify old information and to reject new information (Gutchess, Kensinger, Yoon, & Schachter, 2007). Older adults attend more to the content and gist of an event and its personal relevance, and they often have more difficulty remembering specifics (Adams, Smith, Nyquist, & Perlmutter, 1997; Comblain, D'Argembeau, Van der Linden, & Aldenhoff, 2004; Craik & McDowed, 1987; Fredrickson & Carstensen, 1990; Hashtroudi, Johnson, & Chrosniak, 1990; Rugg & Morcom, 2005; Spencer & Raz, 1995;). Younger adults attend more to the details of a situation (Rahhal, May, & Hasher, 2002). It has been suggested that this age-shift in encoding processing may reflect or result in decreasing memory performance in older adults (Glisky, Rubin, & Davidson; 2001; May, Rahhal, Berry & Leighton, 2005); but it also interacts with another phenomenon: *emotional memory enhancement*.

Emotional information is usually remembered better than neutral information. This is also called emotional memory enhancement (e.g., Hamann, 2001). Flashbulb memory is an extreme example (Brown & Kulik, 1977), where a strongly arousing event, for instance, the personal experience of a highly violent event, leaves a vivid emotional memory imprint in both young and older adults (Brown & Kulik, 1977; Davidson & Glisky, 2002). The same effect also comes in less dramatic forms. Any experience of personal affective relevance may enhance memory (Kensinger, 2006; Kensinger, Garoff-Eaton, & Schacter, 2007; Kunzmann & Grühn, 2005). It relates to the constructive effect which the transient heightening of arousal levels has on memory by enhancing processes of attention and encoding, in contrast to the detrimental effects of highly stressful (especially continuously stressfully experienced) events on the same processes (Lupien et al., 2007; McEwen, 2007; Sapolsky, 2003). Given the historically close association between autonomic arousal and emotional experiences (Cacioppo et al., 1997), it is not surprising that stress and affect are concepts often linked together, given the physiological properties of stress (Lupien et al., 2007). Whereas stress often relates to the long-term effects of enduring arousing events, emotional enhancement relates additionally to memory effects in situations involving the subjective appraisal of stimuli, and their arousal intensity and valence (affective quality).

The emotional memory enhancement effect is also found in experimental settings with affective pictures (Charles, Mather, & Carstensen, 2003; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002; Ochsner, 2000), both for older and for younger adults, even though older adults remember these events less vividly (Kensinger, Krendl, & Corkin, 2006). In one study, the memory enhancing effect of content, at the expense of memory for detail, was found in both younger and older adults after a long retention interval of 8 months (Denburg, Buchanan, Tranel, & Adolphs, 2003). In another study involving memory for words, there was no age difference for emotional memory enhancement after one minute, but there was after 30 minutes (Leigland, Schulz, & Janowsky, 2004). In addition, highly arousing negative stimuli activated processes that were more stimulus-driven than low arousal stimuli which activated more goal-driven processes and the PFC to a greater extent (Knight & Mather, 2006). Arousal may enhance memory for central and vivid information, but it results in decrements for peripheral information (Christianson & Loftus, 1991).

Kensinger and colleagues (2005) found that emotional enhancement matters for both older and younger adults, but that task instructions influence younger adults to a greater extent. Both younger and older adults show better memory for the central elements of emotional scenes and poorer memory for peripheral information during implicit encoding. By changing instructions to intentional encoding, younger adults remembered peripheral details regardless of the affective quality of the scene. Older adults' memory performance did not change with instructions. They continued to show a positive bias for emotional information at the expense of peripheral detail.

Concluding comments

This review shows that physiological attenuation and physical impairments in older adults are not, by and large, a question of emotional bluntness or blindness. The changes that have been reported are, first and foremost related to a reduction in negative affective processing and experiences, with less stereotyped expressions of emotions and greater affective heterogeneity. These changes have also been related to changing goals and motivations; to successive shifts from bottom-up, stimulus-driven processing, to more top-down, goal-driven processing. This involves qualitative as well as quantitative changes and could also explain the age-related shift in the neural underpinnings of emotional processing from subcortical to more cortical activation which has been demonstrated in several studies. Even though there is a general attenuation of physiological reactivity with age, autonomic reactivity, as well as appraisal, can actually be enhanced in older adults by presenting age-related stimuli of personal relevance. Again, however, the pattern of physiological reactivity is similar across ages, albeit the magnitude is lesser for older adults. Finally, emotional memory processes also seem to be affected by aging, for example, there is a greater focus on emotional meaning and an attenuated ability for contextual memory. Hence, aging might be associated with both qualitative and quantitative changes in emotional processing. This involves activity in the central and peripheral nervous systems as well as in subjective appraisal mechanisms.

Overview of the studies

The general subject of study was age-related differences in affective functioning – both qualitative and quantitative differences – and the relationships between different affective functions. Here affective functions were operationally defined in terms of four measures: (1) ratings of arousal intensity; i.e., appraisals of negative arousal, (2) fMRI using the blood oxygenation level dependent signal (BOLD), (3) SCR, and (4) long-term emotional memory enhancement of pictures. As picture recognition appears to be less affected by age than other effortful cognitive tasks are (e.g., Park, Puglisi, & Smith, 1986) and pictures are often used in studies to elicit emotional reactions, we used pictorial stimuli appraisals in all studies.

To summarize the programmatic focus of the studies: i) age differences in, and relationships between, the appraisal of arousal intensity and neural activation, ii) age differences in, and relationships between, SCRs and the appraisal of arousal intensity, and iii) age differences in, and relationships between, long-term memory performance and arousal intensity at encoding (appraisal and SCR).

Study I

Aim and background

In Study I, we assessed age differences in, and relationships between, fMRI and ratings of facial expressions: firstly, whether younger and older adults would differ in their neural activation patterns in response to angry and neutral faces; and secondly, how these patterns of activity would relate to subjective ratings.

Earlier brain-imaging studies on neural activity in response to facial expressions almost exclusively included only younger participants. These studies have shown that perception of facial affections activates the amygdala, the basal forebrain, and the insular cortex (Davis, & Whalen, 2001; Haxby, Hoffman, & Gobbini, 2002). Two previous fMRI studies which also included older adults, point to age-related differences in neural activation associated with emotional processing. Iidaka and colleagues (Iidaka et al., 2002) presented neutral, positive and negative facial expressions to younger and older healthy adults, while the participants identified the gender of the facial representations. There was a significant age difference in the left amygdala for negative faces; the younger participants showed increased activation, in contrast to attenuated activity in older participants. The results were interpreted as an age-related vulnerability of the medial temporal lobe, including the amygdala and the hippocampus. In the other fMRI study (Gunning-Dixon et al., 2003), healthy participants viewed happy, sad, angry and fearful faces. During the processing of emotional faces, the older adults showed more extensive activation in the prefrontal regions (including the anterior cingulate), while younger showed greater activation in the right amygdala and the surrounding medial temporal lobe. Structural and functional age-related changes were put forward as possible explanations.

Normal aging may be associated with attenuated "limbic" activity and increased reliance on frontal activation. However, it was still uncertain whether these differences also related to age differences in the subjective experiencing of affective stimuli. The aim in Study I was to investigate possible age differences in negative emotional face perception, controlling for systematic cognitive elaborations that might moderate regional neural activity, and thus to explore emotional perception with minimal cognitive elaborations during the viewing task.

Materials and methods

Forty-six healthy, right-handed participants were recruited from respondents to an advertisement placed in a Stockholm newspaper. They were divided into two age groups of 24 younger adults (aged 20-30 years, mean age 25 years) and 22 older adults (aged 70-80 years, mean age 74 years), with an equal number of men and women. Health issues and vision were assessed through interviews, using as exclusion criteria, a relevant set of medical, neurological and psychiatric disorders as well as psychotropic medication and substance abuse.

At study, participants passively viewed angry and neutral "Ekman-faces" (Ekman & Friesen, 1976). We used a blocked fMRI design set up with the facial pictures presented in a semi-randomized order (the same face never occurred twice in a row), to decrease habituation effects. After the scanning the participants were asked to rate the faces on emotionality. Whole-brain imaging data was acquired using a 1.5 Tesla GE Signa Echospeed MR scanner.

Results and conclusions

Previous research points to age-related changes in neural activation patterns when perceiving emotional stimuli, from subcortical to more cortical processing. It was not clear from previous studies (Gunning-Dixon et al., 2003; Iidaka et al., 2002; Tessitore et al., 2005) whether this difference would also correspond to different subjective appraisals of stimuli. We assessed the subjective ratings in relation to neural activation in order to establish whether a differential neural pattern in younger and older adults in response to angry facial expressions might be explained by an age difference in subjective appraisal also.

Results showed no group differences in the subjective emotionality ratings of the faces. Moreover, the BOLD fMRI signal was stronger in younger adults in the right amygdala for angry versus neutral faces, whereas the same face contrast in older adults evidenced a greater activation in the right insular and the ventrolateral prefrontal cortices. A comparison of the BOLD signal in the two age groups showed a greater right medial temporal lobe activity in younger adults for angry faces versus neutral faces in comparison to the older participants. The older adults demonstrated greater activity in the right anterior-ventral insular cortex for the same face contrast.

Although we did not find a significantly enhanced PFC activation in older adults, lesser amygdala activity and the integrative function of the insular cortex (Damasio, 2003; Wager & Barrett, 2004) may be indicative of changing affective functioning in older adults. The current study supports the general conclusion of differential neural activation patterns between age groups reported in previous studies. Younger adults showed greater subcortical activation compared to older adults, who activated more cortical areas. The results also showed that the different activation patterns seen in the two age groups were not based on differences in the perceived emotionality of the experimental faces. Normal aging may be associated with attenuated subcortical activation and greater activity in cortical areas for negative (angry) faces. This may represent a functional compensation in the older adults as temporal lobe areas become less efficient with age, or an age-related functional change involved in the task processing.

Study II

Aim and background

The aim of Study II was to assess age differences and the relationship between physiological (sympathetic) arousal, indexed by SCRs, and phenomenological arousal, measured by subjective ratings of affective quality (i.e. whether potential age effects of negative arousal differ for appraisals and for EDA).

Changes in cognitive and affective functions have been found to be somewhat differently related to aging. Whereas many effortful cognitive processes become less efficient, some emotional abilities become more stable or even enhanced, with advancing age (Carstensen, Mikels, & Mather, 2006). Reports on physiological measures and subjective ratings of emotional stimuli are mixed (Smith, Hillman, & Duley, 2005). Studies have reported lesser (Mather et al., 2004), greater (Smith el al., 2005), as well as equal (Backs, da Silva, & Han, 2005; Denburg, Buchanan, Tranel, & Adolphs, 2003) emotional responses in older compared to younger adults. In general, aging is associated with attenuated physiological activity. However, the response pattern has been shown to be similar in younger and older adults for neutral versus emotional stimuli - i.e., increased physiological reactivity (Levenson et al., 1991; Tsai, Levenson, & Carstensen, 2000).

Materials and methods

The participants in Study II were recruited through an advertisement in a local newspaper in Stockholm and consisted of 38 younger adults (20-30 years, mean age 26) and 40 older adults (70-80 years, mean age 74), healthy, right-handed adults, with men and women equally represented. Through telephone interviews vision and health status were assessed using the same criteria as in Study I.

A selection of 110 pictures, from neutral to negative valence and varying greatly in arousal, were chosen from the IAPS. Each picture was shown for 6 seconds and SCRs were collected during the first 1-4 seconds. Participants were also asked to rate the negative intensity of the picture after each presentation on a scale of 1 to 9, with 1 being least and 9 being the most negative.. The pictures were semi-randomized (no more than two neutral or negative pictures in a row) and were organized into ten different sequences, counterbalanced over the participants in the two age groups. The pictures were shown on a computer screen approximately 1 meter from the participants.

SCR was recorded from the hypothenar eminence on the left hand at 100 Hz with Psylab SC5 instruments, and log-transformed to reduce skewness.

Results and conclusions

Older compared to younger adults rated the pictures as being more negative ($mean_{older}$ = 4.28, SD = .97; $mean_{younger}$ = 3.79, SD = .88). In addition, women also rated pictures as being more negative than men ($mean_{women}$ = 4.24, SD .82; $mean_{men}$ = 3.84, SD 1.04). In contrast, SCRs were larger in younger compared to older adults ($mean_{younger}$ = 0.21, SD = 0.21; $mean_{older}$ = 0.12, SD = 0.12). The correlations in Study II also showed opposite patterns of arousal reactivity for older and younger adults. Whereas the older compared to the younger adults showed a higher increase in subjective arousal with normative arousal values ($r = .51$, $p < .001$), the younger, compared to the older adults, demonstrated higher increase of SCR ($r = .39$, $p < .001$).

The higher subjective ratings by older adults may be attributable to several reasons, for instance, it may be the effect of highly arousing pictures used in this study. At least some of the previous studies that did not find affective enhancement in older adults used less arousing pictures (or included pictures with less emotional scenes); or they presented fewer pictures, including both positive and negative pictures (Charles, Mather, & Carstensen, 2003). Perhaps more importantly, arousal is a multidimensional measure and subjective ratings may focus on stimulus intensity or bodily feelings, and this may reflect age-related differences in the affective processing of subjective experiences. In this study the focus was placed on the perception of stimulus intensity, rather than the experience of bodily felt arousal, which may positively bias older adults' affective apperception in contrast to younger adults' more stimulus-driven processing (Mather et al., 2004). Another methodological issue is habituation that may affect subjective ratings. Repeated exposure to the same pictorial stimuli prior to assessment may attenuate the subjectively experienced emotionality and may level out potential age-related differences in subjective ratings (Backs, da Silva, Han, 2005; Denburg, Buchanan, Tranel, & Adolphs, 2003). Age-related differences in rating may also be due to habituation to stimuli over time. However, a post-hoc analysis of the data in Study II did not confirm any age differences in this regard, either for SCRs, or for ratings. I shall come back to this issue later on in the final discussion.

Study III

Aim and background

In Study III, we investigated age differences in, and relationship between, arousal measures at encoding (ratings of arousal intensity and SCR) and subsequent long-term memory performance for emotional stimuli, i.e., the emotional memory enhancement effect. It remains unclear whether the emotional memory enhancement effect is present after long retention intervals in older adults, as has been shown to be the case in younger adults (Dolcos, LaBar, & Cabeza, 2005). Additionally, it is not clear how arousal measures at encoding relate to subsequent emotional memory performance in younger and older subjects after very long retention intervals. Considering that the autonomic system is attenuated in older persons, it remains to be seen if and to what extent, the emotional memory enhancement effect applies to both the appraisal and the physiological processing of emotional stimuli at encoding.

Emotional events have a tendency to remain in memory much better than neutral events, and this emotional enhancement has been found in both younger and older adults. Long-term memory is better for high arousing pictures than for those eliciting low arousal (Bradley, Greenwald, Petry, & Lang, 1992). A few studies have established a relationship between electrodermal activity and memory performance, thus confirming that stimuli which are remembered correspond to larger electrodermal response at encoding in younger adults (Kleinsmith & Kaplan, 1964; Plouffe & Stelmack, 1984; Stelmack, Plouffe, & Winogron, 1983). For example, in the picture study by Plouffe and Stelmack (1984) the pattern of SCRs was the same in two groups of women, even though in comparison to younger, older women responded with lower SCRs and they recalled fewer pictures. However, the retention intervals in these studies did not extend to more than a few weeks. It remains unclear how long-term memory for affective stimuli over longer retention intervals differs in younger and older adults, and how it is related to arousal measures at encoding.

Materials and methods

In Study III we asked the participants from Study II to return to the lab a year later (the participants who returned were tested within 11-13 months) for an incidental memory test (the participants had not previously been informed that they would be performing a memory test at the return visit). At retrieval, 34 younger (19 females) and 38 older (19 females) adults were presented with 220 pictures (the original 110 target pictures and an additional 110 lures, with equal numbers of neutral and negative pictures) in the same room as during encoding, and using the same technical equipment. As in Study II, the pictures were semi-randomized (a maximum of two consecutive neutral or negative pictures). The target and lures were matched on normative valence and arousal ratings. In a forced-choice design, participants were instructed to decide whether they recognized each picture or not. No time constraint was used during this recognition procedure. The rate of hits and false alarms was computed, and signal detection theory was applied to calculate bias and criterion for the two age groups.

Results and concluding remarks

In Study III, we focused on age differences in, and relationship between, emotional memory - i.e., the recognition of emotional pictures - and arousal measures at encoding after a year’s retention. Arousing events enhances memorability for at least the central parts of an event, but in view of a physiological attenuation with age, the effect for older adults is not clear. Thus, we wanted to assess age differences in the relationship between emotional memory enhancement and arousal at encoding, i.e., intensity ratings of pictures and SCRs.

Results demonstrated higher memory performance for negative pictures than for neutral pictures, both for older and for younger adults. Performance was generally lower for older compared to younger adults. More specifically, older adults’ lower performance was reflected in fewer hits for negative pictures and more misses for neutral pictures compared to younger participants. The criterion demonstrated a generally less conservative attitude for negative than for neutral pictures, for both older and younger participants. The criteria for neutral and negative pictures were less polarized for older compared to younger adults; that is, the older participants were less conservative for neutral pictures, but more conservative for negative pictures. In addition, we tested the measures of arousal at encoding (intensity ratings and

SCRs) as predictors of memory performance for negative pictures. SCR was a significantly better predictor of memory than rating, but only for younger participants. Neither rating, nor SCR, predicted the memory of negative pictures for older participants. Considering this, arousal at encoding may explain the memory performance of younger, but not of older adults. The polarized criteria used by younger adults for negative and neutral pictures lend further support to the emotional reactivity of younger participants. Study III indicates that separate processes may underlie the cognitive appraisal of pictures and the memorability of events in older adults in relation to arousal.

Given the link between physiological arousal (often measured by SCR) and memory performance, older adults may rely more on cognitive and top-down processes and less so on bottom-up processing for memory consolidation. In line with this reasoning, memory performance - especially for categorically similar stimuli and for stimuli not specifically age-related - would be more vulnerable in older adults. The large categorical aggregation made it difficult for both age groups to distinguish the true target pictures from lures. Both younger and older adults remembered negative pictures better than neutral, but younger managed to discriminate better between targets and lures, that is, they had a better memory for details separating the pictures (eidetic memory capacity). Older adults, on the other hand, made more categorical mistakes, confirming previous literature showing reduced memory ability in older adults to remember details (context), compared to memory performance for gist or content (Spencer & Raz, 1995).

General discussion

> "The manner in which the typical laboratory study of memory and aging is constructed, however, is consistent with the implicit assumptions that task-relevant goals do not vary with age, that personal goals will not systematically influence performance on the task at hand, and that task characteristics (e.g., instructions, materials) will activate the same goals in individuals across adulthood. An increasing number of research findings question the validity of these assumptions"
>
> (Hess 2005: 387).

To reiterate the rationales for the dissertational studies, previous evidence suggested a general age-related attenuation of affective physiological activity. However, it was unclear how this change would relate to other measures of affective functioning, such as self-reported appraisals of arousal, SCRs, the fMRI BOLD signal, and emotional memory. Previous studies have generated mixed findings and the different conclusions go with different measures of affective functioning. Few studies have tried to unite and integrate these various measures. The overall aim with this dissertation was to disentangle these age-related differences in affective functioning.

Summarizing the results of the three studies, older adults showed; i) reduced subcortical activity and increased activity in the cortical areas in response to emotional facial expressions, compared to younger adults, but they did not differ from younger adults in appraisal; ii) higher negative arousal ratings, but lower SCRs for pictures with increasingly negative arousal levels; iii) along with younger adults, better memory performance for negative pictures compared to neutral pictures - thus confirming an emotional memory enhancement - but a generally weaker memory performance of older adults. Older adults were also less differentiating in their criterion (their memory performance was less polarized compared to younger adults). Furthermore, tests of relationships between arousal measures at encoding and subsequent memory performance only showed a significant effect of SCR on memory of negative pictures for younger adults. Arousal measures at encoding could not explain the emotional memory enhancement of older adults.
Overall, the results are in line with, and extend, previous research. No gender differences were found for SCR, but subjective ratings differed in Study

II. Younger and older women rated the pictures as more negatively arousing than men This finding is in line with previous studies (Bradley et al., 2001; Denburg, Buchanan, Tranel, & Adolphs, 2003; Kunzman & Grühn, 2005).

Age differences in neural activity

The point of departure for our first study was previous fMRI studies regarding age-related differences in neural activation during different facial evaluation tasks (Gunning-Dixon et al., 2003; Iidaka et al., 2002). In Study I participants rated the intensity of the facial expressions and fMRI BOLD signal was used to analyze neural activation to emotional faces. To enable comparisons of neural activation patterns to be made, neutral facial expressions were contrasted with negative facial expressions. This latter measure was included in order to eliminate the possibility that differences in neural activation might occur for facial processing per se, rather than for the actual emotional faces. The former measure of subjective arousal intensity served to assess potential age-related differences in the perception of affective quality for the selected facial expressions.

Study I showed that older adults had attenuated activity in the amygdala region and increased activity for emotional stimuli in the cortical regions, particularly in the insular cortex. This is in line with previous imaging studies (Gunning-Dixon et al., 2003; Iidaka et al., 2002; Mather et al., 2004). The interpretation of these results was not clear. It could reflect a functional compensation in the older adults, where cortical networks support a more dysfunctional amygdala network. However, Mather et al. (2004) demonstrated increased activity in the amygdala for positive stimuli, making it unlikely that the reduced amygdala activation was due to general functional or structural decrements. The results could also reflect a qualitative difference in the way younger and older adults approach the task at hand. Mather et al (2004) interpreted their findings as a shift in processing style, i.e., an age shift in the pattern of activation in the amygdala, with retained activity for positive stimuli in older adults, but reduced activity for negative stimuli. In line with this reasoning, the attenuated amygdala function found in our study could potentially also reflect this shift in processing style. Another explanation is that more top-down cognitive processing of the emotional faces could result in a down-regulation of amygdala activity, in line with the study by Hariri, Bookheimer, and Mazziotta (2000). Their research has shown that cortical activation can have attenuating effects on sub-cortical structures.

Our findings are also in line with recent research indicating a higher activation in the frontal region in older adults, hypothesized to correspond to adaptive cortical networks for emotional faces (Tessitore et al., 2005). The fMRI studies lend further empirical support to the aspect in the SST in which aging involves increased cognitive-affective interaction with greater reliance on controlled, top-down processing (Carstensen, Mikels, & Mather, 2006).

Age differences in arousal

In contrast to Study II, in Study I we found no age differences in subjective ratings, and there are several reasons why these studies are not comparable, for example: i) we used different stimuli in the studies, and facial expressions may be a special case in affective processing; ii) participants had already seen the facial expressions in Study I before making the subjective ratings; and iii) in Study II, 110 different pictures were used, compared to the 12 different identities of the facial expressions (angry and neutral) in Study I.

The appraisal procedure used in Study II focused on age differences in the perception of the intensity of affective stimuli (i.e., the evaluation of affective quality) and physiological arousal measured with SCRs. It differs from measures focusing on perceived bodily feelings - for example, the SAM - which may positively bias affective experiences associated with somatic changes. Instead, stressing the perception of affective quality, as was done in Study II, may bias older adults' greater affective apperceptual mass. The pictures varied considerably in arousal level, allowing us to test age differences over gradual increases in negative arousal.

The higher ratings of negative arousal in older compared to younger adults in Study II indicate that older adults have a perceptual sensitivity to negative experiences that is not attenuated by age, even if their physiological response in general is attenuated. These results did not support what would have been expected from an affective lifespan theory (Labouvie-Vief, 2003). In this framework negative affects are believed to be more cognitively demanding than positive affects, for which reason it is suggested that older adults (60 years and older) compensate for declines in cognitive-affective complexity by enhancing positive experiences (optimization in the affective lifespan/affective development theory). Again, in this view, aging involves decrements in processing of negative affects (contrasting with the positivity-bias hypothesis in SST). However, in Study II, the appraisal ratings were actually higher for older adults and the age difference increased as the normative (negative) arousal increased.

A majority of previous studies show that older and younger adults make similar arousal ratings of standardized IAPS pictures (Backs, da Silva, & Han, 2005; Charles, Mather, & Carstensen, 2003; Denburg, Buchanan, Tranel, & Adolphs, 2003). However, there are also findings of older adults giving higher ratings of arousal than younger adults (e.g., Kunzmann & Grühn, 2005; Smith, Hillman, & Duley, 2005). Still other self-reports of the perception of affective quality using standardized stimuli have resulted in mixed results. Mather and colleagues (2004) for example, in line with the hypotheses of SST, provided support for attenuated appraisals of negative arousal compared to positive stimuli in older adults.

Several methodological differences may contribute to the mixed results, even in studies based on picture selections from the IAPS. For example, in Study II, we specifically instructed the participants to make appraisals based on the perception of affective intensity of pictures, which may be different from self-reports focusing on the experience of bodily feelings (e.g., Backs, da Silva, Han, 2005). Furthermore, studies may differ in the number of pictures used and the selection criteria, based on the normative arousal or valence ratings. In addition, the degree of age-relevant stimuli may also be an important factor. For example, Smith and colleagues (2005) selected pictures containing age relevant scenes (for instance, showing elderly persons in different neutral and negative contexts). This may explain higher ratings, as well as increased physiological reactivity in older participants. In contrast, mildly negatively arousing pictures may not result in age-related differences. Other factors that may influence arousal ratings are repeated exposure to pictures (resulting in greater habituation) prior to ratings and different selections of age distributions among participants (Denburg, Buchanan, Tranel, & Adolphs, 2003).

Age differences in long-term emotional memory

Previous studies have shown a general emotional memory enhancement – better memory for high arousing stimuli – for both younger and older adults (Bradley et al., 1992; Denburg, Buchanan, & Tranel, 2003; Dolcos, LaBar, & Cabeza, 2005). However, very little research has been carried out on long-term emotional memory and aging, except for studies on flashbulb memories (Kensinger, 2006). Findings relating different arousal measures at encoding - appraisals as well as EDA - to subsequent memory performance after long retention intervals are even sparser. To the best of our knowledge, the only previous attempt to relate arousal measures at encoding to later memory performance in older adults was a memory study with younger and older women (Plouffe and Stelmack, 1984). This study demonstrated that pictures recalled after 30 minutes were related to higher SCRs elicited at encoding for both groups, although younger participants remembered more pictures and had larger SCR magnitude than older women.

In study III, we wanted to know how both arousal ratings and SCRs at encoding would relate to memory performance after a long retention interval in older and younger adults. Participants returned to the lab for an incidental memory test of the pictures they had viewed in Study II one year earlier. The results demonstrated that picture memory was above chance level for both age groups, and that both older and younger adults showed an emotional memory enhancement. However, the relationship between arousal measures at encoding and subsequent memory performance confirmed only one significant relationship in younger adults between SCR and memory for negative pictures. No relationship between arousal at encoding and memory could be confirmed for older adults. Furthermore, older adults demonstrated a higher, more conservative, criterion for negative pictures in comparison to younger adults; - but they demonstrated a lower, more liberal, criterion for neutral pictures. Older adults were more likely to give positive answers for neutral pictures, but less likely to do so for negative pictures, compared to younger adults. This is indicative of attenuated reactivity during the recognition situation, that is, pictures of different affective quality (normative ratings) were less likely to trigger differential responses in older adults.

In Study III, the emotional memory enhancement effect found in older adults could not be related to arousal measures at encoding. This indicates affective factors in memory encoding and consolidation in older adults, other than physiological reactivity (SCR) and perception of affective quality. Although there is evidence that older adults may show equally reactive physiological responses as younger adults when presented with age-related stimuli (Kunzmann & Grühn, 2005). Hence, a more age-related stimulus selection than the one used in our study could have yielded a more age-homogenous relationship between SCR at encoding and memory performance. It is possible that the general decrements in long-term memory in older adults, found in Study III and others studies, may depend on a lower level of physiological arousal at encoding. This was also suggested by Allen et al. (2005), who argued that that fewer somatic markers may lead to decrements in episodic memory - contrasting semantic memory, which remains relatively stable across aging. They based their arguments on the hypothesis that there are different neural structures involved in long-term episodic memory, including emotional regulation, and semantic memory. The generally attenuated autonomic activity would result in decrements of memory performance. Allen and colleagues also argued that physiological attenuation equals lower emotional experience. However, the results of our own and other researchers' studies which are reviewed in the dissertation makes a strong case that the experience, or at least the perception, of emotional information is retained in older adults, and may be relatively independent from a dampened physiological reactivity (at least measured by SCR) to emotional stimuli. Lupien and colleagues (2007) even argued that age-related memory impairments may, to some extent at least, be an artifact of the experimental setting, because it induces higher levels of detrimental stress in older adults than in younger adults. Older adults may have an increased sensitivity to stress that may be detrimental for the encoding process. In fact, in the differential emotional theory, emotional regulation may develop as a means of handling the effects of an increasingly less flexible and more rigid somatic system that is less able to sustain physiological fluctuations (Magai et al., 2006). Thus, greater focus on positive affects can have an insulating effect in older adults (Consedine, Magai, & King, 2004). This would imply that physiological response (EDA), arousal, and stress are different factors in affective memory, each playing a decisive role in aging. Furthermore, in contrast to the emotional enhancement effects of temporarily increased arousal levels, long-term stress has detrimental effects on cognition and memory. With age, long-term stress may lead to deterioration in MTL regions of the brain, such as the hippocampus (Lupien et al., 2007; McEwen, 2002; 2007; Sapolsky, 2003). The MTL, with its structural and functional subregions, plays an important role in affective functioning and memory, and its functions have been shown to be sensitive to the effects of aging (e.g., Eichenbaum et al., 2007; Raz, 2000, 2005).

General methodological concerns

The cross-sectional designs used in the present thesis are limited by; i) cohort effects; ii) convenience samples; and iii) the fact that affective functioning is studied in an artificial laboratory setting. Several methodological issues can be raised with regard to the cross-sectional design. One specific issue concerns the use of pictures and possible age differences in habituation of arousal measures. Compared to the older generations, young adults are probably more exposed to, and used to, graphic emotional content through the use of modern electronic media and games. This may result in a greater habituation effect (or a lesser one, as younger adults may be more used to interacting emotionally with graphic content) in younger compared to older adults. On the other hand, it could be argued that older adults would be more reactive, and show less habituation, as they probably have greater real-life experience of the consequences of some of the negative scenes in the pictures.

To control for potential age differences in habituation, two mixed 2x2x2 (order x age x gender) ANOVAs for ratings and SCRs respectively were carried out after the completion of study II. Order refers to the mean values of two sets of pictures, that is, the first 55 and the last 55 pictures viewed by the participants. The ANOVA of ratings confirmed a main effect of order, $F(1, 74) = 7.72$, $p = .007$ ($rating_{first55} = 4.10$, $SD = 0.93$, $rating_{last55} = 3.97$, $SD = 1.03$), but no main effect, either of age or of gender. The results of the ANOVA of SCR were similar, but with a stronger main effect of order, $F(1, 74) = 66.13$, $p < .001$ ($SCR_{first55} = 0.20$, $SD = 0.20$, $SCR_{last55} = 0.12$, $SD = 0.16$). The ANOVAs did not show any interaction effect between either order and age, or order and gender.

Besides habituation, age differences to task instructions may be another uncontrolled factor in our studies. For example, given the general physiological attenuation in aging, instructions requiring participants to focus on bodily feelings may result in attenuated levels of self-reported emotional experiences in older compared to younger adults. However, this issue cannot be controlled for by means of statistical analysis, and must be left for future research. The attenuated physiological reactivity associated with age which was found in previous studies (e.g., Levenson, 2000) was supported by the attenuated magnitude of SCR found in Study II. In light of the argument of there being age-related changes in affective functions, it is important to stress that no causal conclusions can be drawn from this. That is, age-related attenuation of the autonomic system in itself is not taken as evidence of affective changes; and affective abilities are as likely to mediate/moderate physiological activity as decrements in physiological reactivity are to facilitate some affective functions. EDA and affective functioning may not generalize to other measures of autonomic activity, as different measures of physiological reactivity to affective stimuli are only weakly correlated (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005).

Another potential drawback may be the long retention interval in Study III, resulting in overall low memory performance. Although a year is a long retention interval in an experimental setting, it is more in accordance with real-life factual events and memories. Although Study III did not assess this, previous research has shown that younger and older adults differ in memory performance for context (details) and content (gist); that is to say, older adults are generally less impaired in memory for content than for context in comparison to younger adults (e.g., Yonelinas, 2002). In the original set-up of Study III, we used a remember-know paradigm (Gardiner, Ramponi, & Richardson-Klavehn, 2002). Although a difference in memory for negative pictures that had previously been shown to the participants was present in favor of younger adults' performance (*Remember:* Neutral pictures, $mean_{older} = 1.6$, $SD = 4.4$; $mean_{younger} = 1.8$, $SD = 2.9$; Negative pictures, $mean_{older} = 3.6$, $SD = 5.9$; $mean_{younger} = 6.1$, $SD = 7.2$; *Know:* Neutral pictures, $mean_{older} = 8.8$, $SD = 6.6$; $mean_{younger} = 8.8$, $SD = 7.6$; Negative pictures, $mean_{older} = 15.4$, $SD = 8.6$; $mean_{younger} = 18.7$, $SD = 7.9$), due to floor effects, no further effects were performed and the separate remember-know answers were aggregated to one measure of memory.

A question can be raised regarding picture selection. The studies exclusively made use of neutral and negative pictures. Therefore, it remains unclear whether positive pictures would result in age related patterns similar to those found for neutral versus negative pictures. In addition, many of the negative pictures used in Studies II and III - for instance, serious injuries - could also be described as evoking a great amount of disgust, which may be a special category among negative emotional experiences. Previous research has also shown that older adults may be particularly sensitive to pictures eliciting disgust (Calder, Lawrence & Young, 2001). From an evolutionary perspective, negative events may have been more important for survival success, and thus more closely tied to physiological reactivity than would have positive events. Positive pictures may also be more dependent on individual preferences and in a categorical sense they are less coherent than negative pictures. In addition, although electrodermal activity is a sensitive measure of stimulus intensity, it has been found to be less susceptible to valence differences (Cacioppo et al., 1997).

Despite these and other potential drawbacks, the present experiments, taken together with previous research, suggest that aging involves both quantitative and qualitative changes in affective functioning. On the one hand, aging involves an attenuation of physiological reactivity; but the autonomic changes must be interpreted in the light of other changes in affective functioning, i.e. the ways in which emotional experiences are processed. Aging does not necessarily seem to have a negative effect on affective functioning. Emotional intensity and emotional heterogeneity in general remain stable or continue to develop across the lifespan (e.g., Malatesta, Izard, Culver, & Nicolich, 1987; Tsai, Levenson, & Carstensen, 2000), although there are age-related changes in the specifics of affective functioning. For example, both cross-sectional (e.g., Lawton, Kleban, & Dean, 1993) and longitudinal (Charles, Reynolds, & Gatz, 2001) studies of self-reported affective experiences suggest fewer negative emotional experiences with age, but no general affective attenuation. There is also evidence for an enhanced focus on positive affects (Carstensen, Mikels, & Mather, 2006). This change - going from negative affective processing to the successive allocation of attention and affective functioning to positive information - may be interpreted as a lifespan shift in goals and motivations, as well as increased emotional regulation (Carstensen, 1995; Isaacowitz, Charles, & Carstensen, 2000), or possibly optimization processing (Labouvie-Vief, 2003) with aging. In either case, we may speak of a shift in affective experience with age that may go together with other changes in affective functioning.

The lifespan theories, described in the theoretical framework above, differ in the specifics of affective age-related changes - goal and motivational shifts (SST; e.g., Carstensen, 1995), increased controlled regulation (DET; e.g., Magai, Consedine, Krivoshekova, Kudadjie-Gyamfi, & McPherson, 2006) and optimization/differentiation (ACDT; e.g., Labouvie-Vieg, 2003) - but they all stress the importance of emotional experience for processing information in older adults. There is an increased role of top-down (goal-driven) processes, and a reduced effect of bottom-up (stimuli-driven) processes. In other words, older adults are more influenced and guided by their increasing affective apperceptual mass. Increasing life experience results in an expanding affective apperception that filters all new perceptions and changes the way a situation is appraised. For example, an event that seemed very threatening the first time it was encountered may have lost some of its intimidating quality the fifth time that it, or a similar event, occurs. This would seem to imply a gradually increased dissociation between physiological and appraisal processes in affective functioning. This theory of the increasing importance of affective apperception lends support from and builds on the model by Levenson (1994). Conclusions similar to those drawn from our own studies of an age-related shift in affective functioning were also reached by Burriss and colleagues (2007):

> "young people respond with greater peripheral feedback and less cognitive appraisal, perhaps due to less associative cognitive experience, i.e., meaning, whereas older people who have greater experience in cognitive associations with emotion-producing stimuli, rely more on cognition and need less peripheral feedback to appraise the meaning of stimuli" (Burriss et al., 2007:204).

There is also empirical research showing that older adults experience and express greater emotional heterogeneity and complexity, compared to younger adults (Charles, 2005; Labouvie-Vief, 2003). One line of research has shown that older adults experience positive affects at least as often as younger adults, while negative affects are less frequent (Carstensen & Charles, 1998). There is also evidence for greater emotional control (Charles & Carstensen, 2007; Gross & John, 2002), more empathic affects and less hostility (Charles, 2005; Levenson, Carstensen, & Gottman, 1994). However, when older participants are instructed to perform directed facial tasks (Levenson, Carstensen, Friesen, & Ekman, 1991) or are presented with artificial emotional stimuli - i.e., ones that are not personally relevant or have not been experienced - their emotional experiences may be less frequent or less intense in comparison to those of younger adults.

There is no doubt that the age-related attenuation of physiological reactivity is well established, both in our own and other studies. This was found, for example, using IAPS pictures and measuring tonic and phasic changes (Denburg, Buchanan, Tranel, & Adolph, 2003; Smith, Hillman, & Duley, 2005). One study measured physiological activity while participants were involved in discussing emotionally engaging topics (Levenson et al., 1994), and other studies have asked younger and older adults to re-experience autobiographical emotional memories (Labouvie-Vief, 2003; Levenson et al., 1991). Short films have also been used to elicit affective reactions in the participants while physiological measurements were taken (Tsai, Levenson, & Carstensen, 2000). These studies all showed an age-related decrease in physiological activity, although the reaction pattern of the system to emotionally elicited stimuli was similar in younger and older adults.

It is conceivable that the large body of evidence indicating a lower frequency of negative experiences and a gradual allocation of affective-cognitive processing to positive information is a reflection of physiological decrements in perception - i.e., older adults may not have a positive bias, but rather, a selectively attenuated affective functioning for negative information (Labouvie-Vief, 2003). However, this is placing all our faith in physiological measures of affective functioning, and ignoring older adults' self-reports that demonstrate a dissociation of appraisal processes and physiological reactivity, supporting a dual process in affective functioning (e.g., Study II, Gross et al., 1997; Lawton, Kleban, Rajagopal, & Dean, 1992). This dual affective processing indicates that older adults may separate subjective and experiential feelings from their physiological bodily feelings, which may actually explain the attenuation of negative experiences with age.

Looking ahead - future studies

During the last few decades, the view of aging as a continuous general degeneration of cognitive and affective functioning has been challenged by a more differentiated view on the development of later stages of life (Levenson, 2000; Magai, 2001). One general lifespan hypothesis to be further investigated in future studies is that affective functioning passes from bottom-up and stimuli-driven processing, to top-down and goal-driven processing, relying on the affective apperceptual mass that is accumulated with emotional experiences across the lifespan. Thus, in older adults, the appraisal of arousal may be relatively dissociated from physiological activity (i.e., somatic markers and bodily feelings may be separated from the perception of affective quality).

The age-related increase and decrease in positive and negative experience respectively is one repeatedly-occurring finding that deserves closer attention. Is positive experience a consequence of the gradual attenuation of physiological reactivity, a gradual increase in affective regulation, or the result of increasing affective apperceptual mass in older adults? Any one of these suggestions, or a combination of them, may support changes in affective functioning in advancing age and warrants further investigation. One possible line of inquiry may be to investigate differences in emotional heterogeneity and differentiation between older adults and relate these to their affective experiences. In a recently published fMRI study on antecedent-focused and response-focused emotional regulation strategies, Goldin and colleagues (Goldin, McRae, Ramel, & Gross, 2007) found that cognitive reappraisal and emotional-expression suppression differed, both temporally and in efficiency, in attenuating negative experiences. Interestingly, appraisal regulation reduced activation in amygdala and insular cortex, but suppression increased activity in the same regions, given evidence of reduced subcortical activation in older adults for emotional stimuli (especially negative). This would be an interesting paradigm to use investigating older adults' regulation abilities.

Another line of inquiry would be to study and compare affective processes and memory mechanisms in psychiatric disorders, such as depression and post-traumatic stress disorders (PTSD). For example, people suffering from depression often focus on negative memories and they also tend to attend to the negative aspects in their experiences. In PTSD patients, traumatic memories debilitate cognition. A greater understanding of the processes behind emotional regulation (in older adults) could provide important clues to the underlying mechanisms in PTSD and in other affective disorders (see Ochsner & Gross, 2005), as the prevalence of affective disorders is lower in the elderly population than in younger adults (Isaacowitz, Charles, Carstensen, 2000). Given the evidence from the research presented in the review indicating stable or even enhanced abilities in emotional processes, such as emotional regulation, studies investigating both normal and pathological affective processing in older adults may be of interest for the general population.

Conclusions

The dissertation was originally set out within a framework conceptualizing affective functioning in terms of stability, decrements, or enhancements in older adults. Based on the relationship between physiological changes (mainly arousal) and emotional experiences, affective functioning in older adults had previously been thought to reflect the general age-related decline in physiological activity. However, the conclusion, based on reviewing previous research and on Studies I, II, and III, indicates that some age-related changes in emotional functions are better framed in terms of changes between top-down and bottom-up processes, rather than as quantitative changes in a monolithic affective function. For example, the affective apperceptive mass may influence the emotional memory enhancement effect that was found in both older and younger adults after a year's retention interval. SCRs and subjective arousal ratings did not explain the enhancement effect in older adults. There is also mounting evidence of increasing affective duality across the lifespan. Attenuated physiological activity, at least sympathetic activity indexed by SCR, may reduce the perception of bodily feelings, but not emotional functioning based on affective apperceptive mass.

> "Indian Summer is not real summer. During the Indian Summer of life there are premonitions of the imminent winter in which it is embedded, and there is a painful awareness of one's inescapable, death-bound plight. (Our plight is that we know our fate, and we feel the turbulent catabolic air-bumps before the inevitable crash). For this reason, a pleasant stretch of weather in the late Fall is doubly welcome, and we enjoy the rays of the sun while they last, suppressing our certain knowledge of the threat of what lies beyond the turn".
>
> (Schneidman, 1989: 693).

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