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Experiencing Emotions in Different Media Types: Psychological Processes and Neural Correlates

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„...Die bewegliche Kamera nimmt mein Auge, und damit mein Bewusstsein mit: Mitten in das Bild, mitten in den Spielraum der Handlung hinein. Ich sehe nichts von außen. Ich sehe alles so, wie die handelnden Personen es sehen müssen. Ich bin umzingelt von den Gestalten des Films und dadurch verwickelt in seine Handlung. Ich gehe mit, fahre mit, ich stürze mit – obwohl ich körperlich auf demselben Platz sitzen bleibe..."

Bela Balázs (1938)

English summary

The overall aim of the present dissertation project was to investigate how responses to emotional information are modulated by the presentation medium. While many studies have used different types of stimulus materials to study emotion processing, so far only few studies have focused on media-specific affective processes. Models of media reception have, however, recently integrated psychological theories and theories from literary and film studies. They thereby provide useful frameworks for understanding affective and aesthetic responses to media stimuli. Based on these models, this dissertation project focuses on three basic questions: Are emotional responses domain-specific and are pictorial stimuli emotionally more powerful than verbal material? What are the psychological processes and neural mechanisms underlying the dynamic unfolding of emotional responses in movies? What are modulating factors of processing emotional information in different media types?

To capture differences between verbal and pictorial materials, a functional magnetic resonance imaging (fMRI) study was designed, which in contrast to previous studies, controlled the perceptual complexity of the material. The main results are 1) comparable valence effects for words and pictures, when controlled for complexity; 2) interactions of valence and modality in mainly perceptual and language brain regions; and 3) stronger valence effects for complex photos compared to pictograms in frontal emotion processing regions. A second fMRI study was designed to investigate the dynamic unfolding of emotional responses in movies. Its main results are 1) continuous sadness ratings show time-variable responses with sadness peaks toward the predicted emotional scene climax; 2) dynamic movie context modulates activations in anterior and posterior cortical midline regions and their coupling with posterior sensory and subcortical reward areas. The third literature-based study aimed at discussing modulating factors of emotional media reception. It summarizes results of emotion processing in different media types, and relates them to current theories of emotion. It finally discusses them in the context of media reception models

and argues for a crucial role of immersive processes for emotional responses to different media types.

The results of this dissertation confirm that different media stimuli, symbolic verbal as well as more realistic, multimodal stimuli can have powerful emotion effects. The dissertation describes media-specific emotional responses that support experience-based neural representations of emotions. It further emphasizes the relevance of interactions of cortical midline, posterior sensory and subcortical reward networks in the dynamic processing of emotional information in audiovisual stimuli. Finally, it discusses the crucial role of immersive processes and its underlying mechanisms in emotional media reception.

Deutsche Zusammenfassung

Das Hauptziel dieses Dissertationsprojektes liegt darin zu untersuchen, wie Reaktionen auf emotionale Informationen durch das Präsentationsmedium moduliert werden. Während viele Studien unterschiedliche Stimulusmaterialien verwendet haben, um Emotionsverarbeitungsprozesse zu untersuchen, haben sich bisher nur wenige gezielt mit medien-spezifischen affektiven Prozessen auseinander gesetzt. Aktuelle Modelle der Medienrezeption verknüpfen psychologische Theorien mit Theorien der Literatur- und Filmwissenschaften und liefern damit den nötigen Rahmen zum Verständnis von affektiven und aesthetischen Reaktionen auf Medienstimuli. Vor dem Hintergrund dieser Modelle, fokussiert sich dieses Dissertationsprojekt auf drei Grundfragen: Sind emotionale Reaktionen domänenspezifisch und sind bildliche Stimuli emotional wirkungsvoller als verbales Stimulusmaterial? Was sind die psychologischen Prozesse und neuronalen Mechanismen, die der dynamischen Entwicklung emotionaler Reaktionen in Filmen zugrunde liegen? Was sind modulierende Faktoren der Verarbeitung emotionaler Informationen in unterschiedlichen Medien?

Um Unterschiede in der Verarbeitung von bildlichem und verbalem Material zu untersuchen, wurde eine funktionale Magnetresonanztomographie (fMRT)-Studie entwickelt, in welcher, im Unterschied zu bisherigen Studien, die perzeptuelle Komplexität des Materials kontrolliert wurde. Die Hauptergebnisse sind 1) vergleichbare Valenzeffekte für Wörter und Bilder, wenn sie für Komplexität kontrolliert werden; 2) Interaktionen von Valenz und Modalität in vor allem perzeptuellen und Sprachregionen; 3) stärkere Valenzeffekte für komplexe Fotos im Vergleich zu Piktogrammen in frontalen emotionalen Hirnregionen. Eine zweite fMRT-Studie wurde entworfen, um die dynamische Entfaltung emotionaler Reaktionen auf Filme zu untersuchen. Die wichtigsten Ergebnisse sind 1) kontinuierliche Traurigkeitsbeurteilungen zeigen zeitlich variable Reaktionen mit emotionalen Gipfeln im Bereich der vorhergesagten emotionalen Szenenklimaxe; 2) dynamischer Filmkontext moduliert Aktivierungen in anterioren und posterioren

kortikalen Mittellinienregionen und deren Verbindung mit posterioren, sensorischen und subkortikalen Belohnungsarealen. Die dritte literaturbasierte Studie hatte das Ziel, modulierende Faktoren der emotionalen Medienrezeption zu diskutieren. Sie fasst Ergebnisse der Emotionsverarbeitung in verschiedenen Medien zusammen, setzt diese in Relation zu Theorien der Medienrezeption und argumentiert für eine kritische Rolle von Immersionsprozessen bei der Verarbeitung emotionaler Informationen in verschiedenen Medien.

Die Ergebnisse dieser Dissertation bestätigen, dass unterschiedliche Medienstimuli, symbolisch verbale als auch realistischere, multimodale Stimuli eine starke emotionale Wirkung haben können. Die Arbeit beschreibt medienspezifische Reaktionen, welche eine erfahrungsbasierte Repräsentation von Emotionen unterstützen. Weiterhin hebt sie die Bedeutung von Interaktionen kortikaler Mittellinienregionen mit posterioren sensorischen Regionen und subkortikalen Belonungsarealen in der dynamischen Verarbeitung sozio-emotionaler Informationen in audiovisuellen Materialien hervor. Schlussendlich diskutiert sie die bedeutsame Rolle von Immersionsprozessen und deren zugrundeliegenden Mechanismen in der emotionalen Medienrezeption.

List of figures

List of tables

Table of contents

1 Introduction

Since early in human history, people used external media, like cave paintings, drawings and later writing to express their thoughts and feelings (Gärdenfors, 2006). Paleolithic cave drawings, depicted animals, humans and abstract symbols (White, 1992), Egyptian hieroglyphs were used to write prayers, worship the gods or write about the afterlife (te Velde, 1985). Ancient Greek myths and theatre plays told dramatic stories of gods and half-gods. In the 16th century Shakespeare recounted tragic stories, which usually ended in the central characters' death, or comedic ones, which unfolded around romantic conflicts, their tragic separations and happy reunions. Until the present day a vast body of literary work from a variety of genres has been created. At the same time Hollywood has become one of the biggest creators of artificial emotional experiences, entertaining us with a host of film genres, such as historical dramas, action movies or romantic comedies. Pictures, written stories or movies all have in common that they convey affective meaning and make viewers, readers and listeners experience a vast variety of emotions (Gallese & Guerra, 2012; Mar & Oatley, 2008; Jacobs, 2015a,b; Appel & Richter, 2007; 2010). The ability to experience emotions is suggested to being a main reason for the motivation to read (Oatley & Duncan, 1994; Altmann et al., 2012). Movies, which have been named "emotion machines" due to their powerful emotional impact are similarly created to entertain and move us (Tan, 1996). Sharing the ability to evoke emotional experiences, media types are based on different perceptual settings and symbolic domains and may therefore engage different psychological mechanisms: In theatre plays we see actual people on a stage, in movies images of people are visible on a two- or three-dimensional screen, while literature makes use of learnt language skills and our imagination to convey affective meaning.

Psychological research has taken advantage of a broad range of media types with the aim to induce emotions and study the human emotion system. It has

traditionally focused on the use of rather simple and highly controllable stimuli. Commonly used emotion induction instruments are sets of single words (Bradley & Lang, 1999; Võ et al., 2009), sentences, facial emotional expressions (Ekman & Friesen, 1977; Lundqvist et al., 1998), or emotional pictures (Lang et al., 1999, 2008). Emotion induction instruments have been used in a broad range of studies, as in research on psychiatric disorders (e.g., Silani et al., 2007; Schlochtermeier et al., 2011; Rosenblau et al., 2012) or emotion regulation (Ochsner et al., 2002; Lieberman et al., 2007). To increase the ecological validity of the stimulus material, the use of dynamic and social stimuli has recently been emphasized in emotional research (Fischer & Van Kleef, 2010; Westermann et al., 1996; Schaefer et al., 2010), making use of movies (e.g., Gross & Levenson, 1995; Schaefer et al., 2010, Dziobek et al., 2006), cartoons (Brink et al., 2011), or poems and narratives (Aryani et al., 2015; Altmann et al., 2012; Lüdtke et al., 2014; Zeman et al., 2013, Bohrn et al., 2013). Wilson-Mendenhall and colleagues (2013) provided an overview of methods used to study emotion and affect. Differentiating between sensory modalities, they report that visual methods, such as faces, pictures, films, or reading sentences, are the most frequently used techniques, with 70 %, followed by auditory (music, sounds, listening to words or sentences) with 9 %, and multiple modalities and imagery techniques with 6 %. Recall, olfaction, taste or tactile stimuli take up the smaller proportion of studies (between 1 % and 4 %).

To understand emotional processes related to the medium that is used to convey affective meaning, a high amount of complexity has to be taken into account. Psychological research has introduced a range of models that describe semantic processes related to the symbolic information domain. Extensive theoretical work has also been developed on the human emotion system. Affective phenomena specific to media stimuli on the other hand were, until recently, mostly neglected in standard experimental psychology (Jacobs, 2015a,b). Media reception has presently become a focus in a growing body of literature. This led to the introduction of frameworks that integrate perspectives from aesthetic theory, literature and film studies with (neuro-) psychological perspectives (Schrott & Jacobs, 2011; Jacobs, 2015a,b; Tan, 1996;

Kuchinke et al., 2013; Gallese & Guerra, 2012). Before presenting the empirical chapters and literature review, I will give an introduction to these three groups of theories and provide an overview of empirical findings on the affective impact of different media types. Then, I will describe the research questions, hypotheses and general methodology of the dissertation project. Finally, I will briefly summarize the studies.

1.1 Domain-specificity and grounding of semantic representations

In the past an extensive discussion has focused on potential differences in the processing of different information domains such as verbal or pictorial information (Paivio, 1971, 1986). Main theories of cognition have either claimed that different processing paths together with different semantic representations existed for verbal and pictorial information, or argued for a common semantic representation system that is accessed by both words and pictures. Based on early findings of mental imagery, dual-coding theories (e.g., Paivio, 1971; Paivio & Csapo, 1973) postulated that information is processed along separate channels for pictures and linguistic stimuli, leading to representations in distinct domain-specific semantic systems (Paivio, 1971, 1986; Glaser, 1992). Revising Paivios' theory, Glaser (1992) and Barsalou and colleagues (2007) later proposed that conceptual processing mainly takes place in a simulation system, rejecting the idea of amodal symbols in the brain. This view has become very popular and has been formulated in many different forms, but has also been critisized severely (e.g., Gallagher, 2011; Mahon, 2015; Caramazza, 2104). Rather than in amodal symbols, simulation accounts (Barsalou, 2008; Decety & Grèzes, 2006; Gallese & Goldman, 1998; Damasio, 1994) usually claim that semantic knowledge is grounded in experience-based simulations of modal perceptions, bodily states and situated action (often called embodiment). They assume that cognition is grounded in experience-based reenactments of perceptual, motor and interoceptive states. In other words, multimodal representations are stored in memory and are reactivated when knowledge is needed to represent a category (Barsalou, 2008). They

have been supported by findings of language being grounded in sensorimotor brain regions (Pulvermüller, 2005; 2013). Another early theory has suggested shared information processing for pictorial and verbal material and a domain-general amodal representation system (Caramazza, 1996; Caramazza & Shelton, 1998), proposing that semantic information is represented in a functional unitary system that is directly accessed by both visual objects and words. Still arguing that conceptual representations rely on non-sensorimotor, abstract processes, Mahon and Caramazza (2008) and Caramazza and colleagues (2014) criticized several interpretations made by the mainstream literature on embodied cognition.

As the debate on whether our semantic system involves abstract symbols or is grounded in perception and action is still not conclusively resolved (Arbib et al., 2014; Zwaan, 2014), the nature of its connection to the brain's affect system remains underresearched and unconcluded. According to theories assuming a functional unitary system, the emotional impact of a stimulus should solely rely on its meaning (Caramazza, 1996). In line with dual-processing models it has been assumed that pictorial information has a more direct connection to the affect system than symbolic language (DeHouwer & Hermans, 1994). According to experience-based perspectives, emotional content, in terms of experiential information, contributes to semantic representation and processing (Kousta et al., 2011). This is in line with modern accounts, which view emotion and cognition as highly interdependent (Pessoa, 2008). Further illustrating the complex connection of semantic and emotional processing, the next section provides an overview of psychological theories of emotion.

1.2 Emotion theories

The question of what is an emotion has led to manifold theories in the psychological literature over the past 130 years. The first psychologist asking it was William James in 1884. He proposed that physiological reactions to external stimuli lead to interpretations and subsequently an emotional feedback response (James, 1884). In 1962, Schachter & Singer introduced the two-factor theory of emotion, which states that emotions are based on two factors, the physiological change and the cognitive interpretation and attribution to external events. Another group of theories, appraisal accounts, differ from feedback and main bodily accounts of emotion, assuming that the evaluation of a stimulus comes first, followed by the physiological and emotional response (e.g., Scherer, 2001; 2005). Prominent appraisal theories assume that emotional episodes are constituted by several components, i.e., by complex, dynamic and sub-processes including physiological and cognitive components (Scherer, 2001).

Arguing for a strong bodily basis of emotions, several theories have described the existence of biological categories of emotion, which are distinct and constituted by specific bodily, componential response patterns (Ekman, 1992; Panksepp, 1982). Ekman (1992) describes the existence of six basic categories of emotion that are expressed in prototypical facial emotional expressions, happiness, anger, fear, sadness, disgust and surprise. Panksepp (1982) claims that emotions are grounded in neuroevolution. According to his theory emotions can be differentiated in seven basic emotional systems: seeking, anger, fear, lust, care, panic as well as play, which involve specific key brain areas and neuromodulators. Another influential bodily emotion theory, proposed by Damasio (Damasio & Dolan, 1999; Damasio, 2008), describes the nature of feelings as divergence from the homeostatic optimum, which has an intrinsic value. He claims that feelings are not a specific human phenomenon and rely on the evolutionary old brain stem, which represents homeostasis. Interoceptive (drive) and

exteroceptive (emotion) divergences from homeostasis are monitored in the central nervous system, and lead to innate action programs.

Based on empirical findings that emotional response patterns are often heterogeneous and that different emotional categories have common features, categorical views of emotions have been criticized (Russell, 1980; Posner et al., 2009; Barrett, 2009). Dimensional views such as Russell's circumplex model (Russell, 1980; Posner et al., 2009), describe the existence of a core affect system constituted by valence (pleasure/displeasure) and arousal (activation/deactivation), which together create a neurophysiological state. Supported by extensive evidence, the core affect system, the basic component of emotional response patterns, is suggested to being based on limbic brain networks (Posner et al., 2009). While agreeing with the existence of a core affect system, the involvement of cognitive and sensorimotor areas in emotional processing has recently been emphasized (Niedenthal et al., 2009; Barrett & Lindquist, 2008). It is thus suggested that, like conceptual representations, emotions are at least partly grounded in experience-based embodied simulations (Niedenthal et al., 2009; Barrett & Lindquist, 2008), which is also described as the brain's mirror system (Gallese & Lakoff, 2005; Gallese & Guerra, 2012; Frith & Frith, 2006). Barrett's (2014) conceptual act theory particularly emphasizes the role of cognitive, neocortical processes in emotion (Barrett, 2014). Accordingly, rather than assuming basic categories of emotion, prototypical emotional episodes are constituted by perceptual properties of the stimulus, the appraisal process, attribution, core affect, cognitive processes, behavior as well as neuronal and chemical processes (Barrett, 2014). Focusing on social emotions, Walter (2012) described two pathways of empathizing with and understanding affective states of others, an automatic, affective road that corresponds partly to before-mentioned mirroring system and a cognitive, high road, that is the basis for mentalizing. In a comment to Walter's article (2012) Jacobs (2012) points to the importance of turning such still rather descriptive neurocognitive models into process models which do not only specify components of mental activities such as "empathy" but also specify how these components interact

with each other dynamically to produce behahavioral and neural effects specific to the mental activity.

Accounting for the extensive theoretical work that has been accomplished on the human emotion system, the recently published quartet theory of human emotions integrates several perspectives from psychology, neurobiology, sociology, anthropology and psycholinguistics (Kölsch et al., 2015). With the inclusion of uniquely human emotions such as complex social ("moral") emotions and explicitly considering the role of language, this interdisciplinary theory aims at bridging a gap in the understanding of the human emotion system. It suggests four classes of emotions that are grounded in distinct neuronal systems. These constitute a "quartet" of affect systems, consisting of brainstem- (ascending activation), diencephalon- (pain/pleasure), hippocampus- (attachment-related affects) and orbitofrontal-centered (moral affects) affect systems. These systems interact with each other as well as with so-called emotional effector systems, which include motor systems, peripheral physiological arousal, attentional and memory systems. Activity from both, affect and effector systems, is synthesized in a preverbal emotion percept, which can be transformed into symbolic code like language. According to the model, the interaction of emotion and language has two main functions: the expression and communication of emotions and the regulation of emotions.

Box 1 The brain basis of emotion

Based on the identification of functional brain clusters, psychological constructivist models have described several brain systems as candidates for being the bases of emotion (Lindquist et al., 2012; Kober et al., 2008). Core limbic and paralimbic brain areas are described as the network that constitutes core affect. Medial posterior cortex and mPFC (medial prefrontal cortex) areas are the bases for conceptualization of emotion, while cognitive and motor areas support language and executive attention. An occipital/visual group of the brain is also described as part of the neural basis of emotion (Lindquist et al., 2012) as it is modulated by affective states (Damaraju et al., 2009) and is highly connected to areas involved in core affect (e.g., amygdala, AMY orbitofrontal cortex, OFC; Barrett & B1ar 2009; Pessoa & Adolphs 2010).
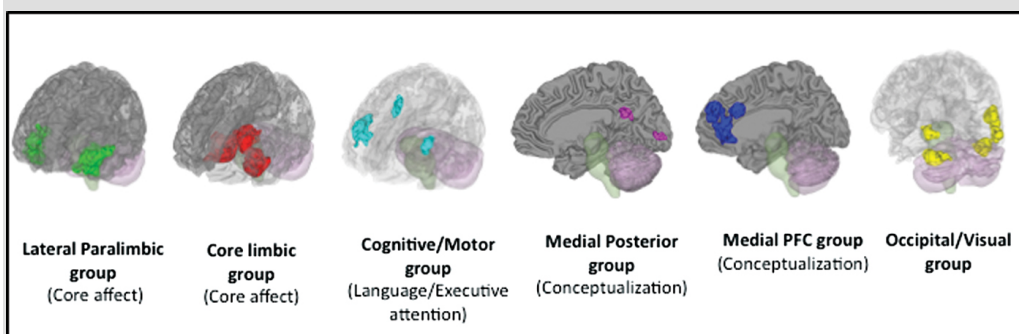
Figure 1.1: Functional clusters of emotion by Kober and colleagues (2008), from Lindquist et al. (2012), reproduced with permission[1]

The Quartet Theory (Kölsch et al., 2015) describes four affect systems as the neural bases of emotion. The brainstem-centred system activates and deactivates higher order brain systems (orange), the diencephalon-centred system includes the thalamus and hypothalamus and is mainly responsible for pain and pleasure and homeostatic emotion states (green), hippocampus-centred is the basis for autobiographical and memory with strong emotional content and is proposed to generate attachment-related affect (blue). The orbitofrontal-centred (red) system evaluates external and internal stimuli, generates so-called somatic markers that are relevant necessary for

[1] Figure from Lindquist, K., Tor, W.D., Kober, H. Bliss-Moreau, E., Feldmann-Barrett, L., The brain basis of emotion: A meta-analytical review, Behavioral Bain Sciences, (2012) 35, page 127, reproduces with permission.

decision-making. It is sensitive to reward and punishment and generates moral affects. The different affect systems activate the reward circuit (ventral striatum and pallidum, anterior cingulate cortex, ACC, OFC) of the brain and interact with effector (motor, physiological arousal, attention and memory systems) and language systems of the brain.
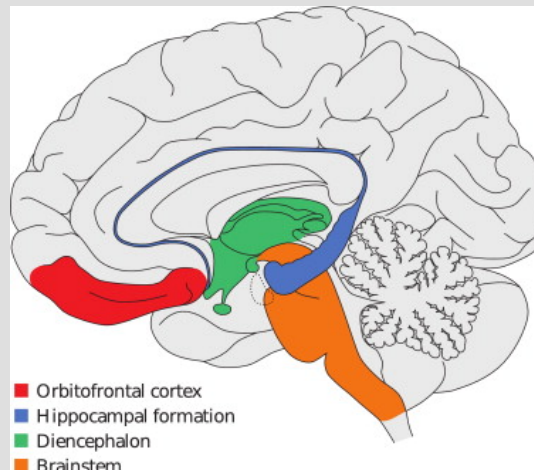
Figure 1.2: Quartet of affect systems (from Kölsch et al., 2015, reproduced with permission[2])

Walter (2012) described brain circuits that are activated by affective states of others in social settings. He differentiates between bottom-up signals processed by an automatic, affective pathway consisting of the anterior Insula, cingulate cortex, AMY, vmPFC (ventromedial prefrontal cortex) and inferior frontal gyrus, and top-down cognitive informat 2 ion processed by a cognitive high road, the cognitive representation of the other's mind (also referred to as theory of mind, ToM), consisting of temporoparietal junction, STS (superior temporal sulcus), dmPFC (dorsomedial prefrontal cortex), PMC (primary motor cortex) and vmPFC. The affective, low road corresponds in part with descriptions of the brain's mirroring or embodied simulation system (Gallese & Lakoff, 2005; Frith & Frith, 2006), while the cognitive ToM system has also been described as mentalizing network (Frith & Frith, 2006).
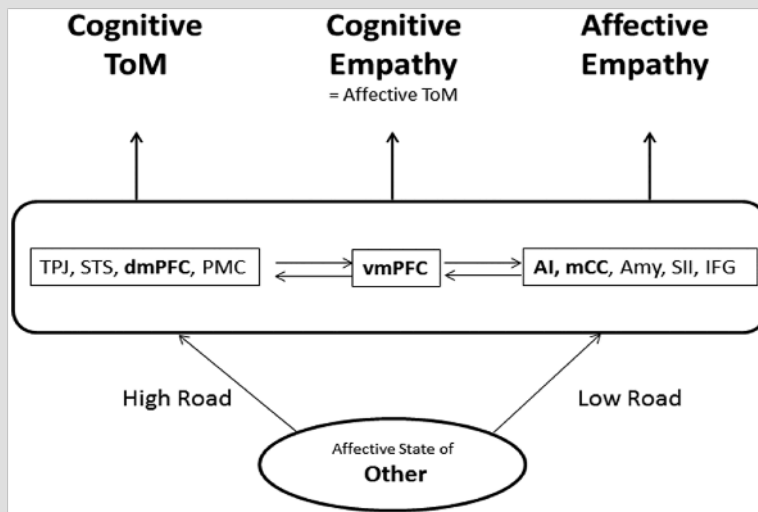
Figure 1.3: Brain circuits for empathy and theory of mind (Walter, 2012, reproduced with permission[3])

The DFG-funded cluster of excellence "Languages of Emotion" (LoE) at the Freie Universität Berlin studied the expression and perception of affect from different perspectives and disciplines. One of its basic resear3ch topics regarded emotional processes specific to media reception such as creating fictional worlds and inducing powerful basic and aesthetic emotions. The specific interest of this dissertation project lies in the differences and similarities of processing emotional information in different media types, focusing on different domains (verbal and pictorial settings), potential advantages of more complex materials and on the unfolding of emotional responses in dynamic materials. The basic question it tackles is whether emotional information in words or written narratives elicits similar or notably different emotional responses as information in pictures or movies? In other words, does the description of a snake lead to the same emotional experience as a picture of a snake? What are the differences in emotional processing related to the medium and what are the implications for models of emotion processing? Experiencing mediated emotions in different forms and facets is part of our everyday lives. Understanding emotional

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3

processes related to the presentation medium, is therefore of high relevance for psychological research in order to advance the understanding of the human emotion system. The next section will present models that aim at understanding affective experiences specific to media reception.

1.3 Emotions and media: Theories

In psychological models, Leder and colleagues (2004; see also Leder et al., 2015) and Scherer (2005) described the bases of aesthetic-affective perception and variables that modulate the impact of aesthetic stimuli. Created to understand responses to visual art, Leder and colleagues (2004) pictures aesthetic-affective experiences as a process, which includes five steps: perception, implicit and explicit classification based on cognitive schemata, cognitive mastering and evaluation. According to these models (Leder et al., 2004; Scherer, 2005), cognitive and emotional processes interact on all levels.

With the aim to explain the processes underlying literary reading, Jacobs' neurocognitive poetics model (Schrott & Jacobs, 2011; Jacobs & Schrott, 2015; Jacobs, 2011; 2015a,b) makes predictions about cognitive-affective, behavioral and neural responses to literature. The central assumption of the model is that reading is performed by a slower route of "foreground" reading (explicit processing) and by a fast "automatic" route of literal "background" reading (implicit processing). The slow route on the other hand is hypothesized to support aesthetic processes (aesthetic trajectory). It is assumed to rely on the adaptation of explicit schema elements and induce aesthetic feelings such as interest and fascination (Schrott & Jacobs, 2011; Jacobs & Schrott, 2015; Jacobs, 2015a,b, see Figure 1.4). The fast route is assumed to facilitate immersive processes, which have been decribed as "diving into" or "losing oneself" in a textual world (Jacobs & Schrott, 2015), through effortless word recognition, sentence comprehension, activation of familiar situation-models, and the

23

experiencing of non-aesthetic, narrative or fiction emotions, such as sympathy, suspense, or "vicarious" fear and hope. Different terms have been used in the literature for immersive phenomena in reading (Jacobs & Schrott, 2015) such as transportation into textual worlds (e.g., Hakemulder, 2013; Ryan, 2001; Jacobs & Schrott, 2015) or absorption of attention and concentration while reading (Nell, 1988; Jacobs & Schrott, 2015). Kuiken and colleagues (2004) further described processes of identification with the narrative world, usually the narrator or character, which lead to self-modifying feelings druing reading. According to Ryan (2001) immersion is a relationship with an imagined world in a text, which extends spatially and temporally beyond the frame of the text.
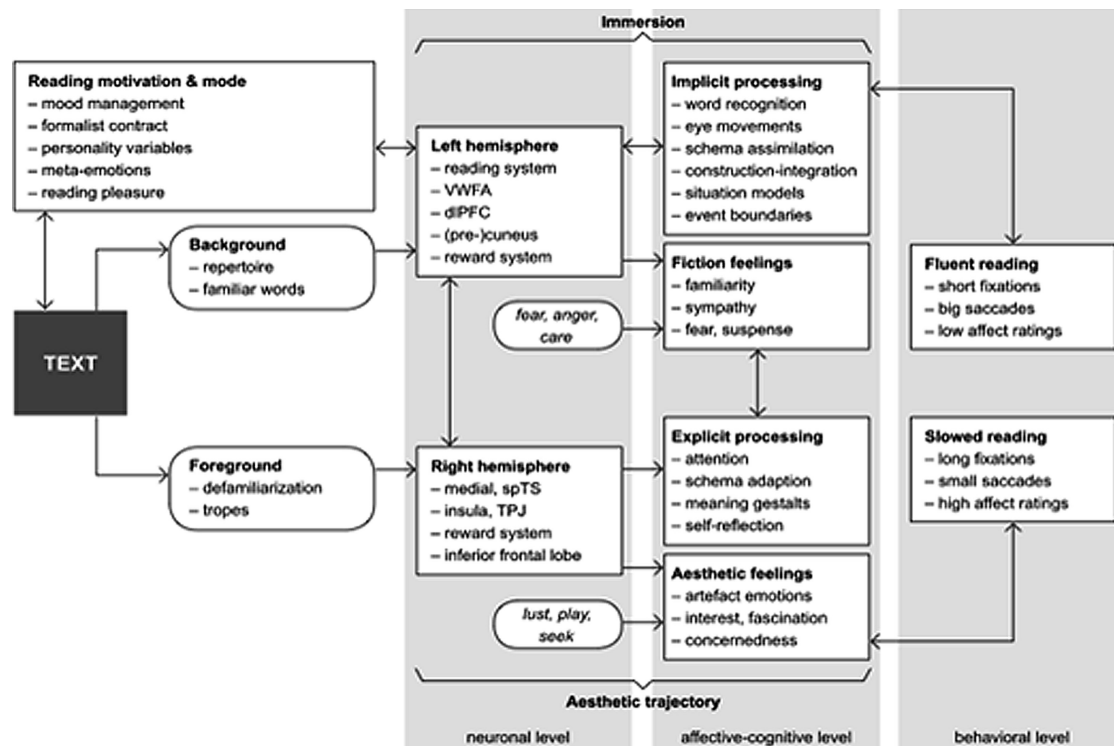
Figure 1.4: Simplified version of the neurocognitive model of literary reading (Jacobs, 2015a) showing the two routes of reading literary text (background and foreground).

Describing emotional experiences of film viewing, Ed Tan (1996) integrated film and psychological theory. Based on Frijda's appraisal theory of emotion (1986), and Bordwell's cognitive theory of the film narrative (1985), he describes affective processes of film viewing. In his theory, viewers in films get caught in the diegetic effect, the narrative structure of the film controls attention by promising further reward while watching and bringing the story to closure. He distinguishes between fictional emotions that are based on the fictional characters, and artefact emotions that are responses to the aesthetic quality of the film. Other cognitive film theories have described the aesthetic quality of a movie as the basis for viewer's emotions (Plantinga & Smith, 1999; Smith, 2003). Both, Smith's (2003) mood cue account and the cognitive-perceptual account (Plantinga & Smith, 1999) try to extend cognitivist theories by including the dynamics of the film viewing experience. Neophenomenological film theories take a different approach (Sobchack, 1992; 2004). Here emotions are seen as an embodied experience based on the perception of the movie's orchestration and on the viewer's embodiment of the movie perception. Both approaches have in common that they include the dynamic unfolding of the film and share several assumptions. According to both, the aesthetic quality is directly related to the viewer's emotional response, which is based on an unfolding of the emotional response within the dynamic composition of the movie. This can be seen as a process in which emotional responses to the aesthetic quality on the one hand, and the language-based comprehension of the plot, on the other hand interact. Both approaches have been integrated in a standardized method of descriptive film-analysis, which has been built as web-based infrastructure to examine the dramaturgical and compositional bases of affective experience (eMAEX, Kappellhoff & Bakel, 2011; Kuchinke et al., 2013) (see Figure 1.5).
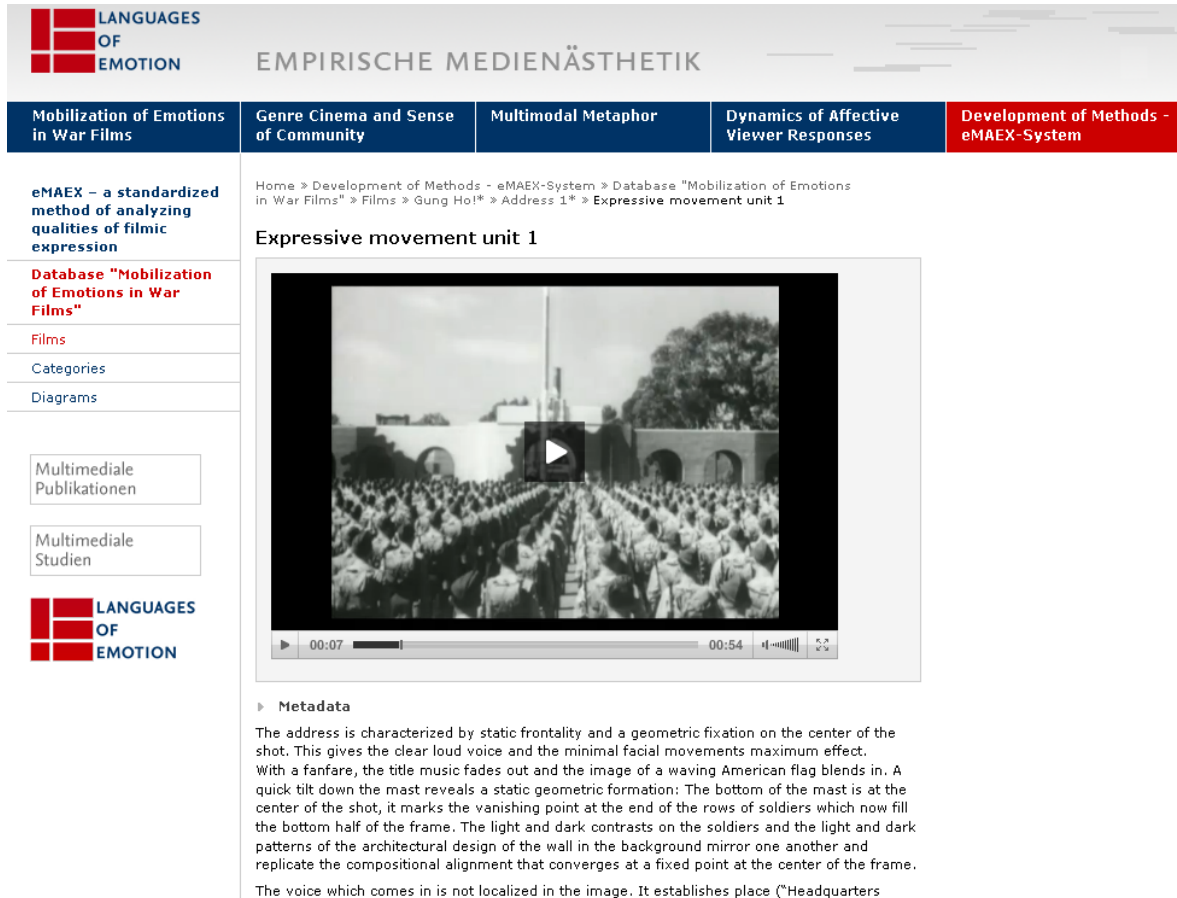
Figure 1.5: Screenshot of the eMAEX system (Kappelhoff & Bakels, 2011; Kuchinke et al., 2013): a web-based, standardized method of analyzing qualities of filmic expression.

Several film theories have described the phenomenon of getting involved while movie viewing, terming it *filmic immersion*. According to Balázs' (1938), immersion is a viewing experience in which the moving camera captures the gaze of the observer, taking it, together with their consciousness into the middle of the moving picture. The viewer thus sees everything just like the character of the movie sees it. Curtis and Voss (2008) explain immersion in movies as a simulated effect mainly based on the kinetic experiences of the movement of the viewer in the movie space. According to Curtis, immersion is an aesthetic effect, which makes different forms of involvement possible, beyond a naturalistic image (Curtis, 2008). A film hence does not necessarily have to be visually realistic. Curtis (2008) further describes immersion as not being restricted to a somatic involvement. Immersion rather means, beside a somatic involvement, a transfer of the self as a disembodied being.

Introducing the research field of neurocinematics, Hasson and colleagues (2008a) suggested that movies are composed to control our brains. Based on accounts of embodied cognition, Gallese and Guerra's neuroscientific account of film perception (2012) shows some parallels to neophemomenological views of film (Sobchack, 1992, 2004) and filmic immersion (Balázs, 1938; Curtis, 2008). Focusing on how the fictional world of a movie appears so real, it argues that embodied simulation provides the neurobiological grounding for this *reality effect* (Gallese & Guerra, 2012). In this view, film can be seen as the mediator of intersubjectivity. Through mirror mechanisms people feel and perceive a movie similar to reality. Embodiment in the cinema comes in different forms: It is relevant at the receptive but also the creative side. Bodies and objects in the film as well as the filmmaker are perceived as bodies in the sense that our mirror system (MNS, or the closely related embodied simulation system, ES) responds to the film as a body as well as to the filmmaker who controls the camera perspective and style. We see the movie through his eyes (Gallese & Guerra, 2012).

Making use of the emotion induction potential of a range of media stimuli, an extensive literature on emotion processing has been published, which I will summarize in the following section.

1.4 Emotions and media: Empirical findings

Neuroscientific research has used a broad range of verbal, pictorial and multimodal stimulus materials to study emotion processing. Single words with affective connotoations typically activate an emotional processing network including limbic and paralimbic regions, cortical midline, reward-related and primary visual cortex (e.g. Hamann & Mao, 2002; Jacobs et al., 2015; Posner et al., 2009; Lewis et al., 2007; Straube et al., 2011; overview: Citron, 2012). The AMY is usually only activated by highly arousing words (Kuchinke et al., 2005). More complex language stimuli, such as sentences, or narratives activate brain regions that indicate interactions between mentalizing and emotion processing (e.g., Altmann et al., 2012; 2014). Intense emotional content in written narratives is further reported to cause a joint recruitment of both emotional and language regions of the brain (Hsu et al., 2014; 2015a,b,c; Wallentin et al., 2011). Besides mentalizing regions, engaging in stories was also shown to recruit premotor networks that are related to the embodied simulation of another's actions (Nijhof & Willems, 2015). Like reading, listening to emotional stories similarly recruits emotion processing, language as well as mentalizing networks (Hervé et al., 2012; 2013). In spoken language, emotional prosody, the affective intonation of speech, comes into play. Emotional prosody activates the human-selective voice area and a posterior part of the superior temporal sulcus, which corresponds to the processing of the emotional content of the speakers voice (Beaucousin et al., 2007; Schirmer & Kotz, 2006). Studying correlations between activations of participants brains when listening to language, Nummenmaa and colleagues (2014) reported a modulation of synchronizations between subjects in sound and speech comprehension networks (as well as embodied simulation networks) by valence and arousal.

Another main group of stimuli used in emotion research are pictures. These are often reported to have behavioral advantages and evoke stronger brain responses compared to words (Citron, 2012; Kensinger & Schacter, 2006). Often used pictorial

stimuli such as IAPS pictures (International Affective Pictures System, Lang et al., 1999; 2008) produce responses in the emotional network (Britton et al., 2006), and engage processes related to the depicted content in face, object or social processing regions. Photos of natural sceneries usually show specific activations in regions associated with object recognition such as the lateral occipital cortex and thalamus compared to photos of facial emotional expressions. Face stimuli usually evoke common activations in emotional networks and activate specific regions such as the FG (fusiform gyrus) and the STS (e.g., Sabatinelli et al., 2011). Facial emotion expressions have also been presented dynamically as short movie clips. Compared to static faces, dynamic facial emotional expressions are reported to evoke stronger responses in emotional and regions related to mentalizing and mirroring (review: Arsalidou et al., 2011; meta-analysis: Krumhuber et al., 2013).

A recent development toward the use of more naturalistic and complex stimulus materials and their powerful emotion effects (Westermann et al., 1996; Schaefer et al., 2010) has led multimodal film stimuli to become popular in emotion research. Film stimuli have been used without sound, but also with music or the complete, movie composition. When comparing uni- and multimodal stimuli, several converging findings indicate additive emotion effects (Pehrs et al., 2014; Klasen et al, 2012, 2014; Dolan et al., 2001; Baumgartner et al., 2006). Stronger responses in limbic and paralimbic structures for emotionally congruent compared to emotionally incongruent multimodal stimuli have been reported (e.g., Dolan et al., 2001). Multimodal stimuli such as audiovisual movies further show emotional modulations in regions associated with cross-modal convergence in the temporal lobe (e.g., Klasen et al., 2012, Eldar et al., 2007). With the increasing use of more naturalistic stimuli new methods have been introduced, that better capture complex and dynamic brain processes. Goldin and colleagues (2005) reported different emotional networks correlating linearly with continuous sadness ratings of film clips, which included activations in mPFC, IFG, STG, and AMY. Happiness co-varied with a network including the medial frontal gyrus (MFG), IFG, dorsolateral PFC, temporal lobes (TL), and the

caudatus (CAUD). Viinikainen and colleagues (2012) showed that continuously rated subjective valence in movies reveals a u-shaped correlation with activations in emotion regions as well as in sensory simulation regions. Raz and colleagues (2014) report that beside emotional brain areas, networks related to embodied simulation and mentalizing are recruited when participants empathically engaged in movies. Nummenmaa and colleagues (2012) further showed that while viewing movies, subjectively rated valence modulated widespread synchronizations between subjects in emotion and simulation networks, while arousal modulated synchronizations in dorsal attention networks.

Besides making use of their emotion induction and naturalistic properties, recent research has focused on specific mechanisms of emotional media reception. Several studies have investigated emotional effects of music. Reviewing findings on music reception, it is reported that music consistently evokes emotions and modulates emotional responses to visual stimuli, involving limbic, paralimbic and reward-related brain networks (Kölsch, 2010; Kuchinke et al., 2013). In other domains research is sparser. Reading figurative or poetic language has been reported to involve the reward system of the brain, if judged as pleasant (Bohrn et al., 2013; Zeman et al., 2013). Emotional text was further shown to activate mentalizing brain regions more, if primed with context being fictional as compared to real, indicating that fictional text triggers simulation and imagination (Altmann et al., 2012). Suspense in reading narrative texts was similarly shown to correlate with regions associated with mentalizing (Lehne et al., 2015). Hsu and colleagues (2014) studied effects of immersive reading experiences, described as the feeling of "getting lost in a book", reporting higher correlations with brain activity for fear-inducing compared to neutral text passages, in a region related to affective empathy, the mid-cingulate cortex.

The above-reported findings show that manifold brain networks are involved in processing emotional information in different media types, including perceptual

and language regions, reward areas, as well as brain regions related to empathy, embodied simulation and mentalizing. The studies are however far from conclusive, while research focusing on and comparing specific media-related emotional mechanisms is still scarce.

1.5 Research questions and hypotheses

The overall aim of this dissertation project was to understand the processing of emotional information in different media types from a psychological and neuroscientific perspective. First, two fMRI studies were conducted, to explore the neural correlates of emotional information processing in different media types. The first study focused on the question of domain-specificity of emotional responses, comparing pictorial and verbal stimuli (question 1). The second study focused on the neural correlates underlying the dynamic unfolding of emotions in movies (question 2). In a third study, an extensive literature review was conducted, to summarize and discuss the psychological processes and underlying neuronal mechanisms as well as the modulating factors of processing emotional information in different media types (question 3). In the following the research questions and related hypotheses are described in more detail.

Question 1: Domain-specificity of emotional responses: Are pictorial stimuli in general more powerful?
This question was theoretically based on accounts of domain-specific mental processing as described in section 1.1. Neuroscientific investigations regarding aspects of emotional experiences usually focus on one stimulus modality (e.g., pictorial or verbal). Similarities and differences in the processing between the different modalities have rarely been studied directly. The comparison of verbal and pictorial emotional stimuli often reveals a processing advantage of emotional pictures in terms of larger or more pronounced emotion effects evoked by pictorial stimuli. Previous studies, however, compared complex photographs to simple words. The aim

of this study was therefore to investigate the neural correlates of processing emotional verbal as compared to pictorial material and to examine whether potential emotional advantages of pictures are related to stimulus complexity. Based on modern grounded or experience-based accounts of semantic and emotional respresentation (e.g., Barsalou, 2008; Decety & Grèzes, 2006; Kousta et al., 2011; see section 1.1), we assumed that the complexity of the stimuli might partly account for their powerful emotion effects in previous studies. We therefore hypothesized that

H1a) pictorial and verbal emotional information should evoke comparable responses in emotional brain regions if controlled for complexity,

H1b) stimulus complexity should modulate emotional brain responses to verbal and pictorial stimuli.

Assuming a close connection of perceptual, cognitive and emotional processes (Pessoa, 2008; Kousta et al., 2011), we hypothesized that

H1c) pictorial and verbal emotional information should evoke different modality-specific brain activations.

Question 2: What are the neural mechanisms underlying the dynamic unfolding of emotions in movies?

As described in section 1.4 several film theories describe film viewing as an emotionally engaging and immersive viewing experience (Balász, 1938) and assume that emotional responses unfold within the dynamic composition of the movie (Smith 2003, Plantinga & Smith, 1999; Sobchack, 1994; 2004). Integrating film-theoretical views, the descriptive film-analytic model eMAEX (Kappellhoff & Bakels, 2011; Kuchinke et al., 2013), assumes that these emotional responses are based on the dynamic interplay of the aesthetic quality of the movie, and the language-based comprehension of the plot. Neuroscientific investigations of emotional responses in movie viewing have shown an involvement of widespread emotional, multisensory

and midline brain regions (see section 1.5). Expecting that emotional responses to movie stimuli unfold within the movie's context, we asked how the multiple brain networks involved in movie viewing are modulated by the movie's dynamic composition. We hypothesized that

H2a) a presentation within the dynamic movie context should lead to more intense emotional responses to the affective scene climaxes, than if presented without context.

Based on studies showing contextual modulations in midline regions as well as activations and coactivations of midline and sensory brain regions related to immersive experiences (Wilson-Mendenhall et al., 2013; Christoff, 2012), we hypothesized that

H2b) a presentation within its dynamic context should lead to stronger activations in emotional and midline brain regions,
H2c) dynamic movie context should modulate the coupling of emotional and midline networks of the brain.

Question 3: What are the similarities and differences of processing emotional information in different media types and what are the modulating factors?

Modern accounts of emotion processing (see section 1.3) assume a close connection of sensorimotor representations as well as language and emotion. Models of affective media reception emphasize the emotional power of fictional stimuli and the role of immersive processes, which are described as "getting transported into a textual world" or "seeing a movie with the eyes of the movie character" for the emotional involvement with movies or narratives (Hakemulder, 2013; Jacobs & Schrott, 2014; Balázs, 1938; see section 1.4). The third research question therefore focused on media-specific emotional mechanisms and on factors modulating the emotional impact of different media stimuli. We hypothesized that

H3a) there are systematic processing differences in sensorimotor, perceptual and language brain regions, related to domain-specific and perceptual stimulus properties, H3b) complexity should increase the emotional impact of the stimulus materials

Based on theories emphasizing the role of immersive processes for involvement in movies or narratives, we hypothesized that

H3c) rather than objective realism, the immersion potential of a medium plays a crucial role for their emotional impact.

1.6. General methodology

In order to manipulate complexity in the first study, verbal and pictorial material was selected from different stimulus sets. Words were selected from the Berlin Affective Word List Reloaded (BAWL-R; Võ et al., 2009). Pictograms and photos were selected from the "International Picture Naming Project at CRL-UCSD" (IPNP; Bates et al., 2000). To reduce complexity, photos and pictograms both showed only the object on a white background. To increase complexity of the verbal material, the three-word-phrases were constructed by extending the concrete words by an article and an adjective. In order to produce comparability, only those photos and pictograms whose German expression matches the BAWL-R label were included. This lead to a database of 235 photos, pictograms, phrases, and words each. Based on a pre-study, the final stimulus material was carefully selected so that in each stimulus condition a set of 40 positive and neutral items only differed in their mean valence rating. Positive and neutral photos and pictograms were matched for arousal and visual complexity. Positive and neutral phrases were matched for arousal, imageability and length, while words were matched for arousal, imageability, word frequency, number of letters, number of phonemes, and number of orthographic neighbors.

For the second study we closely cooperated with film scholars from the cluster "Languages of Emotion". Based on film-analytical methods described in section 1.4 (Kappelhoff & Bakels, 2011; Kuchinke et al., 2013) the stimuli were chosen from romantic comedies, with standardized sets of scenes with standard compositional structure, to control patterns of composition. The final selection was again accomplished in a pre-study, based on continuous valence ratings of the 30 preselected clips. A homogeneous set of 24 stimuli in terms of valence was selected, showing the expected patterns with emotional climaxes (negative valence) at the end of the clips. To manipulate context, the clips were cut and partly replaced. The climaxes, which were identical in all three conditions, were combined with either no context, with their original coherent movie context (complete "separation scene") or with a replaced context (the immediately preceding part of the movie with same length, which was not part of the "separation scene" thus not a coherent part of the separation scene). The stimuli were cut at preexisting breaks of the movie, so that the cuts were not noticeable and the clips appeared like continuous scenes. We used the complete composition in order to provide a naturalistic movie viewing experience (music, sound and German synchronized dialogue).

FMRI was chosen as neuroimaging measure because of its good spatial and temporal resolution. It measures neuronal activity indirectly by detecting changes in blood oxygen level (BOLD). The blood flow to regions increases with increasing neural activity, resulting in higher levels of oxygenated blood. FMRI is based on nuclear magnetic resonance. It makes use of protons in the human body, which have particular magnetic properties and have an immanent rotation, a so-called "spin". A magnetic resonance tomograph creates an external magnetic field, in which protons react with a compensating movement. Using short impulses the spins are deflected and raised to a high-energy state. When the impulse stops, the spins return to their original state (relaxation time) and thereby release energy, which can be recorded. The time protons take to return to their original energy state depends on the sort of tissue. Due to the different relaxation times, different MR-signals can be obtained from

different brain structures. T1-weighted images represent longitudinal relaxation times and show anatomical structures. T2-weighted images represent transverse relaxation times and show functional changes, as in changes in the BOLD signal.

After the measurement, preprocessing is applied to the data, which includes several steps. The data are realigned to control movement-induced image displacements, the functional images are then co-registered to an anatomical reference image. Then the images are normalized to a standard brain image and spatially smoothed. The data analysis usually follows a standard univariate general linear model approach (GLM) in which experimental conditions are modeled and then contrasts between the experimental conditions are calculated. Beside standard GLM approaches, connectivity analyses are often used in fMRI research. Functional connectivity delivers information about correlations between one brain region and the rest of the brain, while effective connectivity makes predictions about the directionality of connections. We used Psycho-Physiological Interactions (PPI) to measure the functional connectivity of the brain regions of interest. Emphasizing the need to assess the relevance and wide-ranging effects of neuroscience research as well as its central assumptions, Slaby (2010) objects to the uncritical use of fMRI. A further limitation of fMRI is that interpretations of results are often at least partly based on reverse inference (Poldrack, 2011; Hutzler, 2014) and should therefore be viewed with care and in the context of the empirical literature.

To assess behavioral responses to the stimulus material, both studies used subjective rating procedures to measure the emotional experiencing of the participants. In the first study, valence was measured online in the scanner. Arousal was measured after the scanning session, when the stimuli were presented a second time. To diminish task-related brain activity in the second study, it did not include a task in the fMRI experiment, the participants were instructed to watch the movie clips passively. Continuous ratings of sadness, adapted from Nagel and colleagues (2007) were conducted in a second viewing of the same material after the main experiment. This method was chosen to not distract attention from the movie clip during the

rating, as here participants move the mouse on an axis from sad to happy, while viewing the movie clip on the same screen. The mouse movements are represented by a smiley which changed its expression (smiley face to sad face) according to the position of the mouse on the screen.

The aim of the literature review was to capture main regularities and important findings of single studies that best illustrate a comparison between media types and help formulating outstanding research questions. It therefore focused on review articles and neuroimaging studies. Rather than providing an exhaustive overview of the literature, we presented recent (after 2000) studies that were highly informative for the comparison between media types focusing on the development toward more complex and realistic materials. For the search keywords (i.e. *emotion processing*, *fMRI, narratives*, *movies*, *films*, *virtual reality*, *multimodal*, *dynamic, complex*) were used web of science and pubmed.

The next three chapters will be presenting the two empirical and one literature study. To give an overview, a summary of the studies is provided below.

1.7 Summary of studies

Study 1 Emotional picture and word processing: An fMRI study on effects of stimulus complexity

This study focused on the first research question: What are the neural correlates of processing emotional verbal as compared to pictorial material? Are potential emotional advantages of pictures related to stimulus complexity? In this study, We first developed a new stimulus database comprising valence and arousal ratings for more than 200 concrete objects representable in different modalities including different levels of complexity: words, phrases, pictograms, and photographs. Using fMRI we then studied the neural correlates of the processing of these emotional stimuli in a valence judgment task, in which the stimulus material was controlled for

differences in emotional arousal. No superiority for the pictorial stimuli was found in terms of emotional information processing with differences between modalities being revealed mainly in perceptual processing regions. While visual complexity might partly account for previously found differences in emotional stimulus processing, the main existing processing differences are probably due to enhanced processing in modality specific perceptual regions. We suggest that both pictures and words elicit emotional responses with no general superiority for either stimulus modality, while emotional responses to pictures are modulated by perceptual stimulus (complexity).

Study 2 Context matters: Anterior and posterior midline cortical responses to sad movie scenes

This study focused on emotional responses to emotional movie scenes and tried to answer the second question: What are the neural correlates of processing sad movie excerpts and how are they modulated by dynamic movie context? In this study, continuous ratings of sadness and fMRI, were used to investigated context-dependent responses to sad movie scenes. 24 healthy participants passively watched sad scene climaxes taken from 24 romantic comedies, while brain activity was measured using fMRI. To study effects of context, the emotional climax excerpts were presented with either coherent scene context, replaced non-coherent context or without context. In a second viewing, the clips were rated continuously for sadness. The ratings varied over time with peaks of experienced sadness within the assumed climax intervals and trend-wise higher ratings if presented with coherent compared to replaced context. Activations in anterior and posterior cortical midline regions increased if presented with both coherent and replaced context, while activation in the temporal gyri decreased. This difference was pronounced for coherent context. PPI analyses showed a context-dependent coupling of midline regions with occipital visual and sub-cortical reward regions. Our results demonstrate the pivotal role of midline structures and their interaction with extrinsic and reward areas in processing contextually embedded socio-emotional information in movies.

Study 3 Emotion processing in different media types: Realism, complexity and immersion

The main question (question 3) of this study was: What are the psychological and neural mechanisms of processing emotional information in different media types and what are modulating factors? It has the objective to understand the emotional impact of these different types of media. First, the neuroimaging literature were reviewed in regard to common and distinctive networks involved in emotional processing of different media types: pictorial, verbal, audiovisual materials, interactive and virtual settings. The findings are then discussed in the context of realism and immersion potential of the material. In this literature review, we focused on studies published after 2000, using a limited list of keywords. The presented literature paints an inconclusive picture regarding advantages of more naturalistic materials in terms of emotion impact. It rather shows that all media types, whether it is simple words or complex movies, may induce consistent emotional responses, mirrored in activations in core emotion regions. Regions related to the (embodied) simulation of another's bodily state, and mentalizing, the cognitive representation of another's mental state, are particularly reported in response to more complex, narrative or social materials. Other media-specific responses are described in sensory or language brain regions, while dynamic and multimodal stimuli are reported to yield behavioral advantages together with increased emotional brain responses. Finally, the role of immersive processes for emotional engagement in different media settings is discussed. It is suggested that the potential of stimulus materials to make viewers or readers immerse, is a crucial moderating factor for emotional responses, which is particularly pronounced for media types such as realistic virtual settings, fictional texts or movies. At the end, rather than giving a final conclusion, open questions and implications for future research on emotion processing are formulated.

Chapter 2
Emotional picture and word processing: An fMRI study on effects of stimulus complexity

2.1 Introduction

Most studies investigating emotional information processing use either verbal or pictorial stimuli to induce emotion, reliably revealing the involvement of limbic and paralimbic regions, such as the AMY, the hippocampus, the medial prefrontal cortex, the ACC, the insula, or the visual cortex (e.g., Phan et al., 2002; Britton et al., 2006; Herbert et al., 2009). It has been claimed that pictorial stimuli are able to induce higher emotional reactions, but it still remains an open question whether it is indeed the modality that is responsible for stronger emotional responses or whether the previously found superiority of pictures may rather be attributed to perceptual stimulus features such as differences in perceptual complexity, i.e. the amount of visual details of a stimulus.

Differences in the processing of verbal and pictorial information have been discussed extensively in the past without being explained conclusively. While some authors claim that pictorial and verbal information is processed in much the same way (Caramazza, 1996), dual coding theories (e.g., Paivio, 1991; Glaser, 1992) postulate that information in pictures and words is processed differently and along distinct channels, thus creating separate semantic representations. Arguing for shared information representation and similar processing of pictures and words, Caramazza (1996) claimed that semantic information is represented in a functional unitary system that is directly accessed by both visual objects and words. In contrast, Glaser postulated a distinction between a semantic system to which pictures have a privileged access and a lexicon, which includes only linguistic knowledge (e.g., Glaser, 1992; Glaser & Glaser, 1989). More recent influential theories of semantic processing propose that meaning is represented as embodied simulations of previous experiences (e.g., Kiefer & Pulvermüller, 2011), suggesting a unitary experience-based representation system.

While the theories, which try to explain differences between picture and word processing, are still underdetermined, the neuropsychological and neuroimaging data

is equally inconclusive. Either the involvement of different networks, supporting a dual coding perspective (e.g., Sevastionaov et al., 2002; Azizian et al., 2006; Seifert, 1997), or high concordance in early processing of words and pictures (Khateb et al., 2002; Schendan et al., 1998) and a shared semantic network, involved in the processing of words and pictures are reported, with few modality-specific areas (Vandenberghe et al., 1996). However, a common finding is an observed processing superiority of pictures as compared to words (e.g., Azizian et al., 2006; Seifert, 1997), suggesting that pictures have a faster and more direct access to meaning, while words are discussed to require additional translational activity at the representational level before accessing the semantic system.

Rather than trying to solve this ongoing debate, the present study focuses on the processing of emotional information in pictures and words. Here the literature is sparse with only few studies having compared both stimulus categories. In a behavioral study, DeHouwer and Hermans (1994) found that emotional pictures, but not words, produced interference effects in a word–picture affective Stroop task. Also, naming times were faster for negative pictures, but not for negative words. In line with theories of dual coding (Paivio, 1991; Glaser, 1992), these authors concluded, that pictures also have a privileged access to emotional information, which they suggest is represented in the same system as semantic information. Recent event-related potential (ERP) studies, on the other hand, revealed that emotional words and faces (Schacht & Sommer, 2009) as well as emotional words and pictures (Hinojosa et al., 2009) may be decoded by the same cortical system, but at different processing speeds. The existent ERP evidence hence seems to support a notion of emotional pictorial stimuli that are processed with superiority, regarding processing speed, as compared to symbolic word stimuli, while probably using similar brain areas (Schacht & Sommer, 2009; Hinojosa et al., 2009). In an fMRI study, Kensinger and Schacter (2006) found processing differences with an overall superiority, i.e. stronger and more widespread activations, for pictures as compared to words, as well as a lateralization of responses between the modalities in the AMY. The authors presented

positive, negative, and neutral words as well as pictures taken from the International Affective Picture System (IAPS, (Lang et al., 2008)) in a semantic categorization task. Both, emotional words and pictures showed enhanced activity of several regions of the prefrontal and anterior temporal cortex, and in occipital visual processing regions, while the AMY showed a lateralized emotion effect with left-lateral activations for words and more pronounced bilateral activations for pictures. This study thus suggests an overall superiority regarding the strength of activations for the pictures

The observed pictorial superiority in processing speed and strength of activations might be accounted for by the involvement of different neural systems as suggested above (DeHouwer & Hermans, 1994). Nonetheless, the alternative perspective, that semantic content and its emotional valence is represented in a unitary system, which is accessed by both pictorial and verbal information, might also apply. While the previously observed differences in processing speed could be attributed to translational activities necessary for the words, as suggested above (Schacht & Sommer, 2009; Hinojosa et al., 2009; Vanderploeg et al., 1987), we propose an alternative explanation: Some of the previously observed processing advantages, regarding the strength of activations of emotional pictures, may be attributed to differences in perceptual complexity or the amount of visual information of the stimuli rather than to distinct modality-specific processes. As pictorial stimuli are characterized by more complex visual features than words, and since pictures and words are expected to be processed in parallel in early perceptual processing stages, the pictorial stimuli might be able to activate more semantically related details and memories. Given that higher semantic complexity in itself has been suggested to be a constitutive part of emotional representations (the 'semantic cohesiveness' hypothesis (Maratos et al., 2000), it can be assumed that such differences in terms of amount of detail, color, and discriminability between lexical and pictorial stimuli accounts for many of the observed processing differences. The potential effect of visual complexity in emotion processing has indeed been emphasized in the past (e.g., Lang et al., 1998; Phan et al., 2003), but to our knowledge the impact of visual

complexity of emotional pictures or words has not yet been studied directly. However, examining the neural correlates of visual complexity in the processing of abstract non-emotional, visual stimuli, Jacobsen and colleagues (2006) observed parametric increases with increasing visual complexity in right hemisphere anterior and dorsolateral prefrontal regions and the bilateral fusiform gyrus. Remarkably, these regions also revealed higher activation for emotional pictures in the Kensinger and Schacter study (2006).

The goal of the present study was to examine differences and similarities in the processing of emotional verbal and pictorial information and the role of stimulus complexity for explaining previous results. Therefore, the processing of pictorial and verbal emotional stimuli was compared in a valence judgment paradigm, while physical differences were maximally controlled. For this, concrete neutral and positive objects were presented in different modes: (a) as pictorial stimuli, we used visually reduced but still complex photos, as well as visually highly reduced black and white pictograms; and (b) as verbal stimuli, we used complex adjective-noun-phrases, as well as single words, so that both stimulus modalities (pictorial and verbal) were presented in two levels of complexity. Based on the notion of a unitary representational system and proposing the existence of a common emotional system, we expected that pictorial and verbal emotional stimuli would reveal comparable emotional effects when pictorial stimuli are reduced in visual complexity. Common emotional effects for both modalities should be revealed in emotion processing networks, i.e., the AMY, the hippocampus, the ACC, occipital regions, and in the medial prefrontal cortex, with no significant differences between stimulus modalities in subcortical and frontal emotional regions. Moreover, emotional effects should be modulated by the complexity manipulation leading to stronger effects for the more complex stimuli for both the verbal and pictorial materials.

2.2 Methods

2.2.1 Participants

Twenty-one right-handed, healthy young German native speakers (male: 8, female: 13; age: mean=24.29, SD= 3.481 (ranging from 18 to 32)) participated in the study. Participants had normal or corrected to normal visual acuity and no known neurological condition. After being informed about potential risks and screened by the study psychologist, participants gave written informed consent before participating. The experimental standards were approved by the German Psychological Associations (DGPs, the Society) ethics committee. Data were handled anonymously. Some of the participants received course credits; others were remunerated at the rate of eight Euro per hour.

2.2.2 Material

A total of 160 positive and neutral concrete objects were presented as stimuli, half of which as words and as pictograms, the other half as phrases and as photos. Thus, the whole experiment comprised the presentation of 40 positive and 40 neutral words, 40 positive and 40 neutral phrases, 40 positive and 40 neutral pictograms, and 40 positive and 40 neutral photos, while words and photos, and pictograms and phrases, respectively, referred to the same objects. Per stimulus category four additional negatively valenced stimuli were used as filler items.

Words were taken from the BAWL-R (BAWL-R; Võ et al., 2009), pictograms from the "International Picture Naming Project at CRL-UCSD" (IPNP at CRL-UCSD (http://crl.ucsd.edu/~aszekely/ipnp/index.html)). Photos were selected to only show the object on a white background. Three-word-phrases were constructed by extending the concrete word by an article and an adjective. In order to produce comparability, only those photos and pictograms whose German expression matches the BAWL-R label were included leading to a database of 235 photos, pictograms, phrases, and words each. In a pre-study, all photos and pictograms were rated for

valence, arousal and visual complexity, all words and phrases for valence, arousal and imageability by at least 20 participants. The final stimulus material was carefully selected so that in each stimulus condition the 40 positive and neutral items only differed in their mean valence rating (all p's<0.001). In addition, photos and pictograms were matched in arousal and visual complexity between positive and neutral items (all p's>0.34). Positive and neutral phrases were matched for arousal, imageability and length (all p's>0.28), while words were matched for arousal, imageability, word frequency, number of letters, number of phonemes, and number of orthographic neighbors (all p's>0.26).

2.2.3 fMRI experiment

Stimuli were presented in the scanning session using goggles with Presentation 12.1 software (Neurobehavioral Systems Inc.) in randomized order, pictograms and photos in 300x300 pixel resolution, placed in the middle of the screen, verbal stimuli using font type "Arial", size 40, both black on a blank white screen. Each trial (see Figure 2.1) began with the stimulus that lasted for 2000 ms on its own, followed by a fixation cross (+) presented for 500 ms and then followed by a valence judgment task, consisting of a 7 stepped rating scale lasting for 3500 ms, ranging from -3 (very negative) via 0 (neutral) to +3 (very positive). This was then followed by a fixation cross and a randomly jittered inter-trial interval (average 2500 ms), used to sample the hemodynamic response at different time points (trial duration = 8500 ms - 11500 ms). Participants viewed 84 stimuli in each stimulus type, with 40 positive, 40 neutral and four negative filler items per stimulus type, presented in two runs with four blocks each in randomized order, so that the whole experiment lasted 47 minutes.
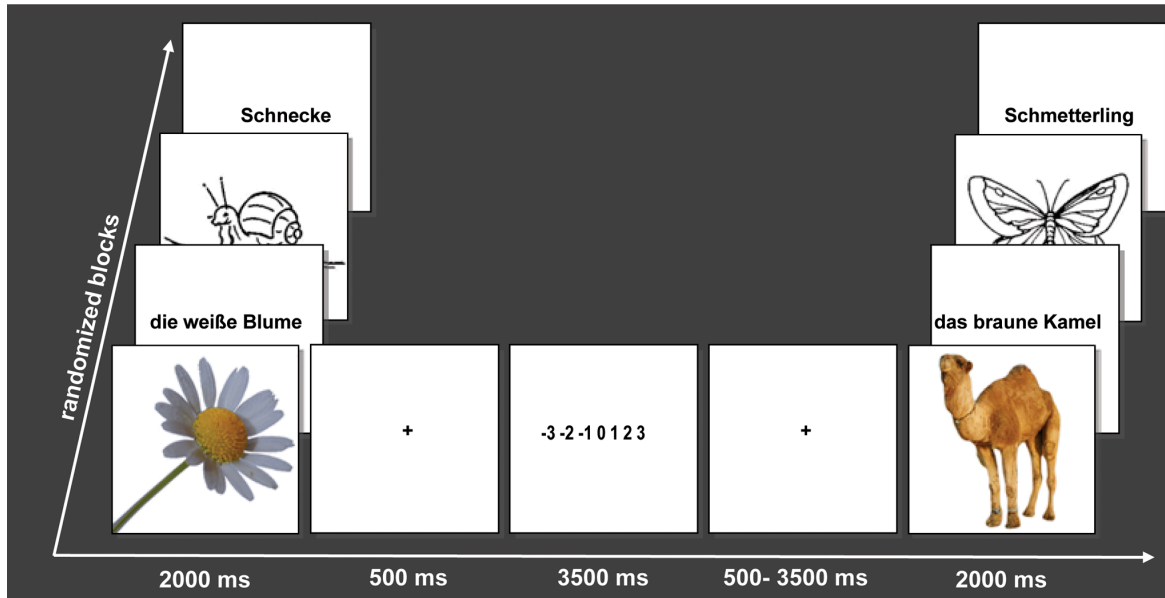
Figure 2.1: Experimental design with examples of stimuli (photos, pictograms, phrases and words; Schnecke = Snail; die weiße Blume = the white flower; Schmetterling = Butterfly; das braune Kamel = the brown camel).

2.2.4 Data acquisition

Participants were informed about the experimental task and the scanning procedure before the scanning session. Before the experimental session a block of ten trials, which were not part of the stimulus set, was presented, to let the participants become acquainted with the task. The participants were instructed to use their right index finger to press the button and the palm of the hand to scroll a tracking ball. Form fitting cushions were used to prevent head movements. Earplugs and headphones were provided to attenuate scanner noise. After the scanning the stimuli were presented again on a computer screen and were rated for arousal. Imaging was performed with a 3T Siemens (Erlangen, Germany) Tim Trio MRI scanner equipped with a 12-channel head coil at the D.I.N.E. (Dahlem Institute for Neuroimaging of Emotion). In each of the two runs 740 whole-brain functional T2*weighted echoplanar (EPI) (TR: 2000ms, TE: 30ms, 90° Flip Angle 37 slices, matrix: 64 x 64, field of view (FOV): 192 mm; 3x3x3 mm voxel size, no gap) were acquired. Additionally, a T1-weighted matched-bandwidth high-resolution (voxel-size 1.0 x 1.0 x 1.0 mm) anatomical scan with same slice prescription as EPI was acquired.

2.2.4 Data analysis

The MRI data were processed using SPM 8 (http://www.fil.ion.ucl.ac.uk/spm/). The images were slice-time corrected, realigned to the mean volume, spatially normalized to the standard EPI template provided by the Montreal Neurological Institute (MNI template). Then images were spatially smoothed with an 8 mm full-width at half-maximum (FWHM) Gaussian kernel. After preprocessing, the data were analyzed in an event-related design time-locked to stimulus onset in the context of the GLM as implemented in SPM 8 on two levels. In a first GLM analysis the experimental conditions of positive and neutral photos, pictograms, phrases and words were included as regressors in the design. On the second-level a 4(stimulus type)*2(valence) repeated-measurement-ANOVA was calculated to assess effects of valence and stimulus type (modality and complexity). To further specify common and differential valence effects between the modalities, conjunction and interaction analyses were performed. For the conjunction, a method implemented in SPM 8 using a global null hypothesis as described by Price & Friston and colleagues (1997), which is based on the calculation of a minimum T-statistics, as it was originally introduced by Worsley and Friston (2000). Subsequently, to retrieve additional information of valence and complexity that go beyond the categorical distinction, a second parametric GLM analysis was calculated in which a single experimental condition effect was incorporated on the first-level, that included individual valence ratings and item-specific stimulus complexity, as well as the interaction between valence and complexity, as mean-centered parametric modulators in the design. Stimulus complexity was defined as jpeg comprimation size, of each respective stimulus, which has previously been used as an objective measure of image complexity (Martinovic et al., 2008). The acronym jpeg refers to an international digital still image compression standard and stands for Joint Photographic Experts Group (Wallace, 1991). According to this encoding standard, the jpeg file size increases with increasing image components, if the image resolution is constant. In this way, the height of the expected hemodynamic response was

parametrically adjusted for all events as a function of each subject's valence ratings and each stimulus' visual complexity as well as the interaction of both. In SPM the modulators are orthogonalized according to the sequence in which they are added in the design (Büchel et al., 1997). On second level one-sample t-tests were conducted to investigate brain activations that had a linear relationship as a function of individual valence ratings, visual stimulus complexity as well as of the interaction of valence ratings and complexity. For valence an overall effect was calculated. Otherwise all analyses were conducted separately for the pictorial, comprising the photos and pictograms, and the verbal stimuli, comprising the words and phrases, to examine the simple effects with their specific response patterns. To protect against false-positive activations in both analyses, only clusters with more than 10 voxels were considered. All reported activations for the main effects survived a threshold corresponding to $p < 0.001$, uncorrected. Behavioral data were analyzed with SPSS 13 (SPSS 13.0 for Windows). Correlation analyses and repeated measures analyses of variances with reaction times, valence ratings, arousal ratings and complexity as dependent variables and stimulus type, modality, valence categories as independent variables were conducted.

2.3 Results

2.3.1 Behavioral results

There was no reaction time difference in the valence judgments between verbal and pictorial materials ($p=0.120$), and no significant reaction time difference in the valence judgments between positive and neutral stimuli ($p=0.499$). Although our stimuli were matched for arousal, valence, and imageability in each stimulus condition in a pilot study, the inner-scanner ratings of the stimuli revealed differences in mean valence ratings for positive stimuli between verbal and pictorial stimuli (mean verbal=1.17; SD=0.443; mean pictorial=0.935, SD=0.460, $F(1,79)=14.927$, $p=0.000$). Post-scanning ratings of arousal revealed no differences in arousal between stimulus types ($p=0,683$). Stimulus types differed in mean complexity, the respective jpeg

picture comprimation size showing a significant main effect (F(3,319)=152,137; p=0.000) between stimulus types, with photos (mean=22.666; SD=10.114) being the most complex, followed by pictograms (mean=14.895; SD=6,310), phrases (mean=7.530; SD=1.087), and words (mean=3.992; SD=1.050). Valence ratings were correlated with stimulus complexity only for phrases (Pearson's correlation=0.224; p=0.045), while no other significant correlations were observed (all p's> 0,287).

2.3.2 Imaging results

2.3.2.1 Overall and simple effects of positive valence

As depicted in Table 2.1 and Figure 2.2 the main overall effect of positive valence revealed activations in an emotion processing network including the right ACC (BA 24), the left frontal pole (Brodmann Area, BA 10), as well as the left parahippocampal gyrus extending to the AMY, and in visual processing regions, namely the right lingual gyrus and the left cuneus (BA 18). To differentiate between modalities, the simple valence effects were analyzed separately for pictorial and verbal materials revealing, for the pictorial materials (photos and pictograms), significant activations for positive valence in the right lingual gyrus (BA 17), as well as in the right ACC (BA 32) and left frontal pole (BA 10). For the verbal material (phrases and words) widespread activations were observed in frontal emotion processing regions including the right ACC (BA 24), the left frontal pole (BA 10), the left insula (BA 13), and the left caudate tail, as well as in language processing regions: the left precentral gyrus (BA 4), the thalamus, and the left temporal pole (BA 38). In the parametric analysis, effects for individual valence ratings as a linear function of increasing valence were found for the overall effect in a similar but more widespread network including the lingual gyrus, the bilateral frontal cortex (BA 11, 10, 8), the left ACC (BA 24, BA 25), the left caudate body and the left parahippocampal gyrus, extending to the AMY. In the simple effects besides activations in the left medial frontal gyrus and the right ACC, additional activations for the pictorial material were found in the left caudate body and the subgenual part of the ACC as depicted in Figure 2.3. For the verbal material the network was more extensive including the right ACC

(BA 32), the left middle frontal gyrus (BA 8), the left caudate body, the right insula (BA 13), the right precentral gyrus (BA 4), and the thalamus with additional activations in the left transverse temporal gyrus, the left hippocampus extending to the AMY, in the left cerebellar declive, the right inferior frontal gyrus (BA 47), and the left superior parietal lobe (BA 7) (see Table 2.1, Figure 2.3).
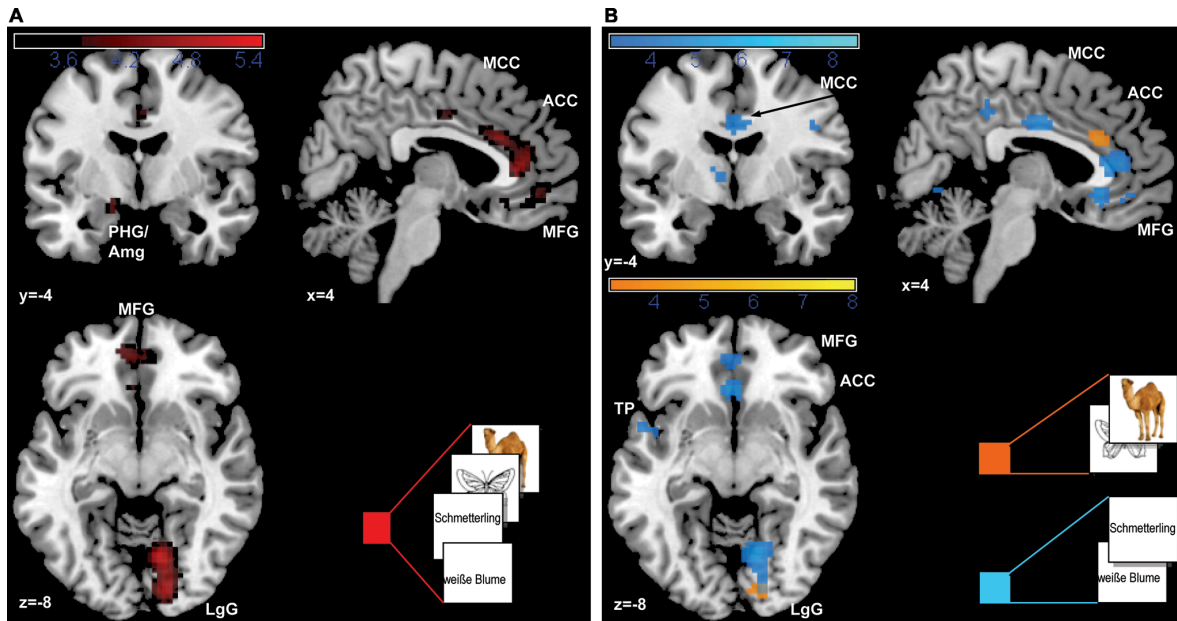
Figure 2.2: Main effects of positive valence. Activations for (A) all stimuli and (B) simple effects for pictorial and verbal material are presented at p<0.001. Abbreviations: Amg = amygdala; ACC = anterior cingulate cortex; LgG = lingual gyrus; MCC = mid cingulate cortex; MFG = medial frontal gyrus; PHG = parahippocampal gyrus, TP = temporal porle.
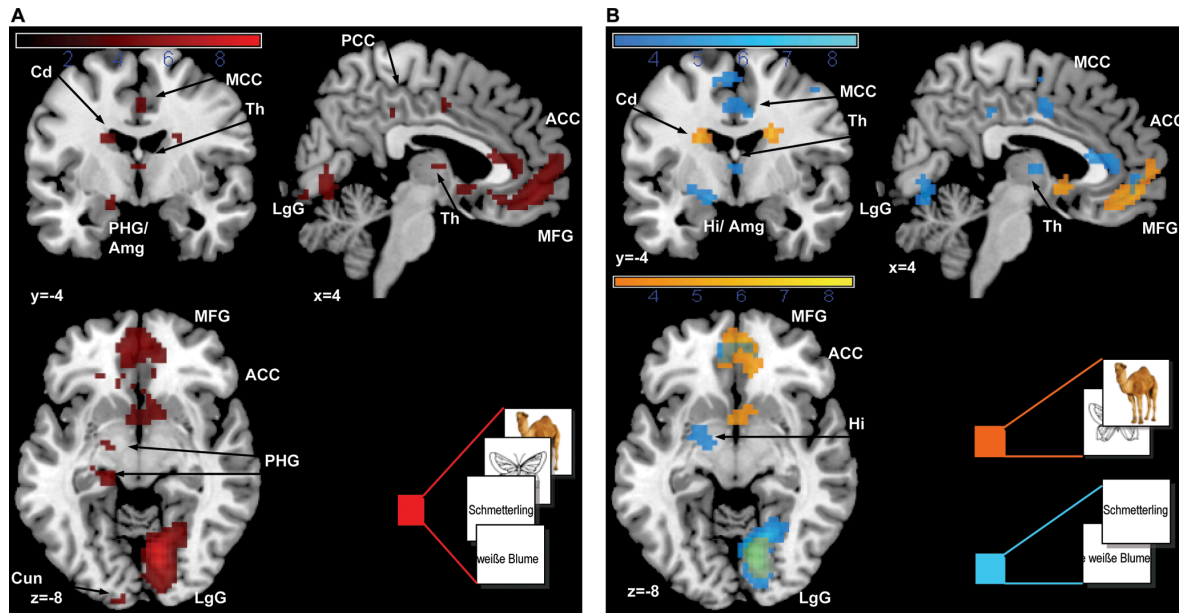
Figure 2.3: Parametric main effects of subjective ratings. Activations for (A) all stimuli and (B) simple effects for pictorial and verbal material are presented at p<0.001. Abbreviations: Amg = amygdala; ACC = anterior cingulate cortex; Cd = caudate nucleus; Cun 0 cuneus; Hi = hippocampus; LgG = lingual gyrus; MCC = mid cingulate cortex; MFG = medial frontal gyrus; PHG = parahippocampal gyrus; PCC = posterior cingulate cortex; Th = thalamus.

Table 2.1: Main effects of valence. Anatomical locations, hemisphere (left/right, L/R), brodmann area (BA), mni (Montreal Neurological Institute) coordinates, cluster size (Voxel) and T-scores of activation maxima at p<0.001 and cluster size>10 are shown.

Anatomical area	L/R	BA	MNI coordinates			Voxel	T score
Effects of positive valence							
Overall							
anterior cingulate cortex	R	24	6	35	7	180	4.97
medial frontal gyrus, frontal pole	L	10	-9	50	-5	141	4.78
midcingulate cortex	R	24	3	-4	40	14	3.71
parahippocampal gyrus, amygdala	L		-15	-7	-14	20	4.26
lingual gyrus	R	18	12	-67	-8	328	5.33
cuneus	L	18	-3	-100	7	28	4.01
Pictorial							
anterior cingulate cortex	R	32	0	29	25	32	4.20
medial frontal gyrus, frontal pole	L	10	-6	50	-5	14	3.78
lingual gyrus	R	17	15	-88	-8	23	3.79
Verbal							
medial frontal gyrus, frontal pole	L	10	-3	44	-8	27	3.59
anterior cingulate cortex	R	24	6	35	7	125	4.60
midcingulate cortex	R	24	0	-7	31	52	4.24
	R	31	3	-37	40	14	3.62
precentral gyrus	R	4	48	-13	28	41	4.59
frontal lobe, white matter	L		-30	-13	34	12	3.65
paracentral lobule	L	31	-6	-28	46	12	3.37
insula	L	13	-36	-13	19	15	3.66
caudate nucleus, caudate tail	L		-36	-28	-2	10	3.71
temporal pole	L	38	-51	5	-8	15	3.68
thalamus	L		-9	-4	4	10	3.42
lingual gyrus	R	18	12	-67	-5	242	5.10

Anatomical area	L/R	BA	MNI coordinates			Voxel	T score
Positive effects of individual valence ratings (parametric)							
Overall							
medial frontal gyrus	R	10	3	50	-8	147	6.08
middle frontal gyrus	L	11	-24	32	-11	11	4.43
superior frontal gyrus	L	8	-24	32	49	86	5.45
anterior cingulate cortex	L	10/32	-6	53	1	644	6.26
posterior cingulate cortex	L	30	-9	-55	13	27	4.28
precentral gyrus	L	4	-48	-10	55	133	4.69
postcentral gyrus	L	40	-57	-22	16	62	4.73
postcentral gyrus	L	4	-12	-40	61	20	4.58
caudate nucleus, caudate body	L		-21	-7	22	23	5.07
parahippocampal gyrus	L	28	-18	-25	-11	40	5.82
parahippocampal gyrus, amygdala	L	28	-15	-4	-14	30	4.60
thalamus	R		3	-7	7	11	4.57
middle occipital gyrus	L	18	-24	-91	-2	17	4.47
cuneus	L	19	-6	-94	25	162	7.01
lingual gyrus	R	18	9	-67	-11	629	9.31
Pictorial							
medial frontal gyrus, frontal pole	L	10	-3	56	-2	381	6.68
medial frontal gyrus	L	8	-24	29	46	13	4.16
	R	11	9	35	-11	45	5.97
anterior cingulate cortex	R	25	0	8	-5	39	5.22
	R	24	9	26	10	13	4.81
caudate nucleus, caudate body	L		-21	-4	22	23	5.26
lingual gyrus	R	18	12	-76	-8	274	8.28
Verbal							
middle frontal gyrus	L	8	-27	32	49	48	6.47
inferior frontal gyrus	R	47	27	8	-17	17	5.23
anterior cingulate cortex	L	32	-9	47	-5	198	5.87
midcingulate cortex	L	31	-12	-25	43	727	6.74
precentral gyrus	R	4	30	-34	55	11	4.63
	R	4	36	-16	58	41	4.41
thalamus	L		-3	-13	7	32	5.37
precentral gyrus	R	4	51	-16	43	15	5.26
superior parietal lobe	L	7	-24	-55	58	29	4.87
transverse temporal gyrus	L	41	-57	-22	13	119	6.04
parahippocampal gyrus/ amygdala	L	28	-15	-7	-11	43	5.51
insula	R	13	42	5	10	13	5.01
caudate nucleus, caudate body	L		-21	-10	22	14	4.66
white matter	L		-12	-58	16	20	4.26
cuneus	R	7	21	-82	28	26	4.13
lingual gyrus	R	18	12	-70	-8	723	8.68
cerebellum, declive	L		-27	-67	-17	25	5.02

2.3.2.2 Conjunction and interaction of simple valence effects

To identify common valence effects for the modalities a conjunction of the simple pictorial and verbal valence effects was analyzed, which revealed significant common activations in the right lingual gyrus and the ACC (Table 2.2, Figure 2.4A). To compare valence effects between modalities, the interaction of valence and modality (verbal, pictorial) was examined, revealing increased activations for verbal material (Table 2.2, Figure 2.4B) in the right insula (BA 13) and the left midcingulate cortex (BA 31), as well as in a network of language processing regions including the right superior temporal gyrus, the right inferior temporal gyrus and the bilateral precentral gyrus (BA 3). No increased activations were found for the pictorial as compared to the verbal valence effects.
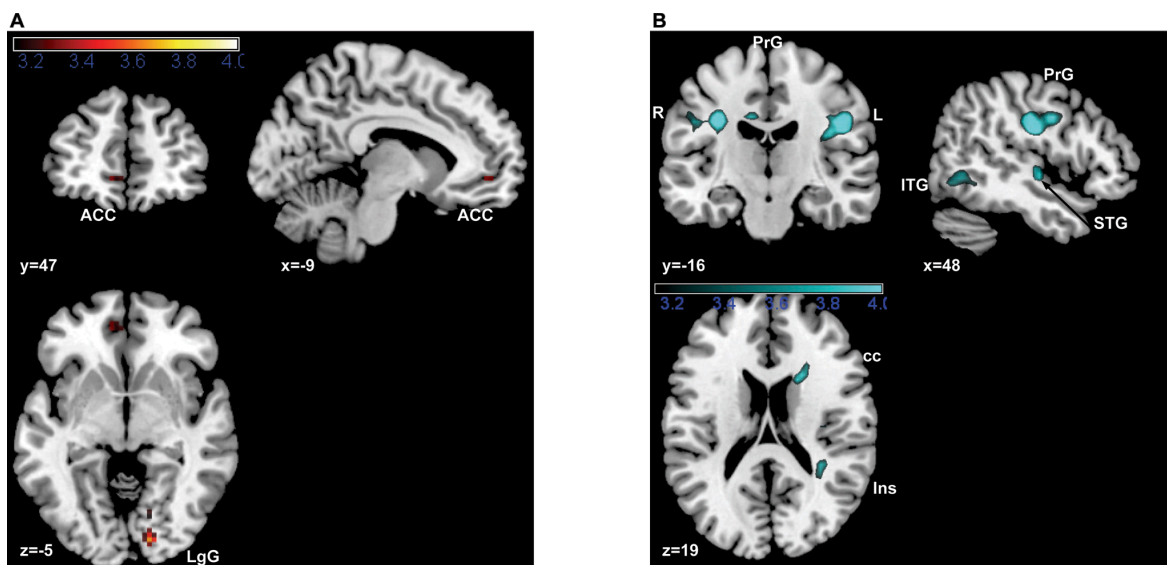
Figure 2.4: Conjunction of simple valence effects (A) is depicted **and interaction effect of valence and modality** is depicted only for (pos verbal > neut verbal) > (pos picorial > neut pictorial) **(B)**, as there were no significant activations for (pos pictorial > neut pictorial) > (verb pos > neut verbal). Both are depicted at p<0.001. Abbreviations: ACC = anterior cingulate cortex; cc = corpus callosum; ITG = inferior frontal gyrus; Ins = insula; LgG = lingual gyrus; PrG = precentral gyrus (R = right; L = left); STG = superior temporal gyrus.

Table 2.2: Conjunction effects and interaction of valence and modality. Anatomical locations, hemisphere (left/right, L/R), brodmann Aarea (BA), mni (Montreal Neurological Institute) coordinates, cluster size (Voxel) and T-scores of activation maxima at p<0.001 and cluster size>10 are shown.

Anatomical area	L/R	BA	MNI coordinates			Voxel	T score
Conjunction of verbal and pictorial valence effects							
lingual gyrus	R	17	15	-88	-5	12	3.64
anterior cingulate	R	24	0	23	25	1	3.18
	L	32	-9	47	-5	15	3.32
Interaction of valence and modality							
(pos verbal>neut verbal)>(pos neut			-				
pictorial)				-	-		
precentral gyrus	L		-30	-13	31	121	5.30
midcingulate cortex	L		-3	-4	31	60	4.26
precentral gyrus	R	3	48	-16	28	176	5.18
superior temporal gyrus	R	22	51	-10	-5	27	4.31
inferior temporal gyrus	R	19	48	-61	-5	38	3.67
insula	R	13	33	-40	19	16	3.73
corpus callosum			18	14	22	21	4.16
			-	-	-		
(pos pictorial>neut pictorial)>(pos verbal>neut verbal)			-	-	-		

2.3.2.3 Simple interaction effects of valence and complexity

The role of visual complexity for emotion processing was examined separately in verbal and pictorial stimulus material. In a first categorical analysis, stronger valence effects for the complex photos as compared to the simple pictograms were revealed in the right ACC (BA 32), the left medial frontal gyrus (BA 11) as well as in the right middle occipital gyrus (BA 18) and the cuneus. The beta values, which are depicted exemplarily for the ACC (Figure 2.5A, right), show an increase in activation from neutral to positive for the photos and a decrease for the pictograms. For verbal material no significant differences in valence effects were observed between words and phrases. In the subsequent parametric analysis, for the interaction of individual valence ratings and specific stimulus complexity, significant effects were found for the pictorial material only in the cerebellum. For the verbal material, again, no significant activation differences were observed. A visual inspection of the interaction parameters for these contrasts revealed that, for the pictorial stimuli, pictograms and

photos overlap regarding high interaction parameter values (Table 2.3, Figure 2.5B, right).[1]
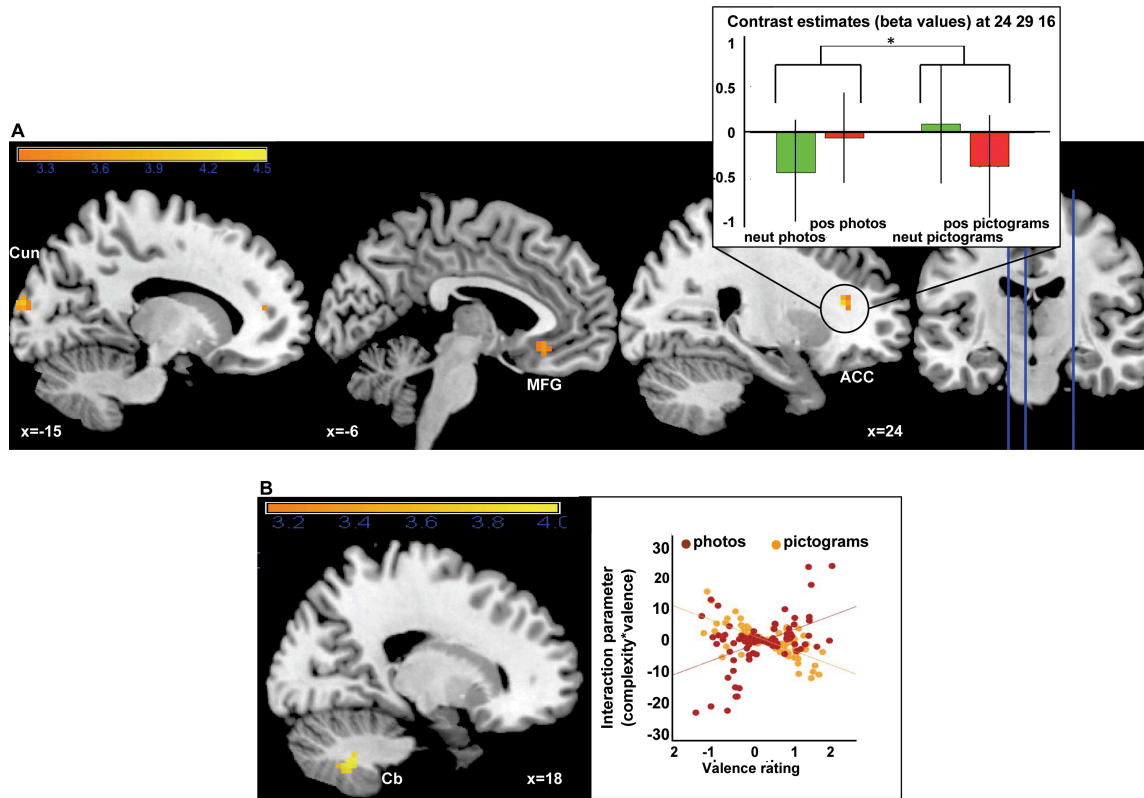
Figure 2.5: Interaction effects of complexity and valence for pictorial stimuli. (A) Simple categorical interaction effects of complexity and valence for pictorial stimuli (pos photos>neut photos)>(pos pictograms>neut pictograms). Bar plot at right (**A**, top right) represents contrast estimates at peak voxels of the frontal poles. **(B)** Simple parametric interaction effect of complexity and individual valence ratings (complexity*rating) for pictorial material. Plots at the right represent the interaction parameters in relation to valence ratings for pictograms and photos. All activations are presented at p<0.001.Abbreviations: ACC = anterior cingulate cortex; Cb = cerebellum; Cun = cuneus; MFG = medial frontal gyrus.

Table 2.3: Categorical and parametric interaction effects. Anatomical locations, hemisphere (left/right, L/R), brodmann area (BA), MNI (Montreal Neurological Institute) coordinates cluster size (Voxel) and T-scores of activation maxima at p<0.001 and cluster size>10 are shown.

Anatomical area	L/R	BA	MNI coordinates			Voxel	T score
Interaction of categorical valence and complexity							
(pos photos>neut photos)>(pos pictograms>neut pictograms)							
medial frontal gyrus	L	11	-6	29	-11	13	3.63
anterior cingulate cortex	R	32	24	29	16	11	4.18
cuneus	L	18	-15	-97	16	31	3.94
middle occipital gyrus	R	18	9	-94	10	67	4.39
(pos pictograms>neut pictograms)< (pos photos>neut photos			-	-	-		
(pos phrases>neut phrases)>(pos words>neut words)			-	-	-		
(pos words>neut words)>(pos phrases>neut phrases)			-	-	-		
Parametric interaction of valence ratings and complexity							
Pictorial							
cerebellum	R		18	-55	-41	54	4.75
Verbal			-	-	-		

2.4 Discussion

The present study investigated the processing of positive emotional information and the role of visual complexity in verbal and pictorial material using a valence judgment task. Based on the notion of a unitary semantic representational system we proposed the existence of a common emotion system, and firstly hypothesized that an emotion network is involved in the processing of positive as compared to neutral stimuli with no relevant differences between the modalities. Secondly we expected stronger emotional effects for more complex stimuli, assuming that more detailed visual information would evoke enhanced emotional processing. In parts our observations supported these hypotheses. Both stimulus modalities

activated an emotion network and, as expected, no superiority for pictorial stimuli in emotional processing was observed. An increase of emotional responses related to complexity was only found for pictorial, but not for verbal stimuli.

The first major question of this study concerned effects of valence in our perceptually controlled stimulus set and the differences in valence effects between the modalities. As expected, an overall effect of positive valence for all stimulus conditions revealed activations in a network of limbic and paralimbic regions associated with emotion processing including the parahippocampal gyrus extending to the AMY, the frontal pole and the ACC. The AMY has been associated with multiple roles in emotional processing and seems consistently involved in emotional enhancement of perception (Keil et al., 2009; Vuilleumier et al., 2004), while the frontal pole has been proposed to play a specific role in the processing of positive valence (Maddock et al., 2003; Davidson, 1998; Lane et al., 1999), and the ACC has been shown to be involved in valence judgment tasks Bush and colleagues (2000), or more generally in affective decision making (e.g., Bermpohl et al., 2006; Shackman et al., 2011). Apart from limbic and paralimbic areas, visual occipital regions were activated. Such co-activations of visual regions with the AMY are consistent with previous findings and can be attributed to the involvement of the AMY in emotional enhancement of visual processing (Keil et al., 2009; Vuilleumier et al., 2004; Kensinger & Schachter, 2006). The results of the parametric effects of individual valence ratings revealed a similar pattern, while activations here were stronger and more widespread.

Interestingly, the differential valence effects for verbal and pictorial stimuli are at odds with the previously reported superiority of pictures over words (Kensinger & Schachter, 2006). In our data no reaction time differences between pictorial and verbal stimuli were observed and in contrast to previous studies the valence effects for pictorial stimuli actually appeared less strong and less widespread than for the verbal material. While common activation patterns of both modalities were observed in the ACC and the frontal pole as well as in occipital regions, our data also revealed

more widespread activations for the verbal material, with additional activations in the insula, the subgenual part of the ACC, the caudate tail, and the midcingulate cortex. These regions have previously been associated with emotion processing and response selection (Olsen et al., 2007; Kuchinke et al., 2011; Vogt, 2005). Further valence dependent activations for verbal stimuli were observed in language processing regions, in the precentral gyrus and the left temporal pole, which is in line with previous findings of reading emotional words (Herbert et al., 2009). This might be due to effects of emotional enhancement of language perception and evaluation. The parametric analysis of the effects of individual valence ratings supports these findings by showing similar but slightly more widespread patterns of activations for both pictorial and verbal material. For the pictorial stimuli significant activations were now also found in regions that had in the categorical analysis only been activated in the verbal condition, namely in the caudate nucleus and the subgenual part of the ACC. The verbal stimuli revealed additional significant activations in the left AMY as well as in the superior parietal lobe, the transverse temporal cortex, the cerebellum, and the inferior frontal gyrus (BA 47), which are associated with language and semantic processing (Booth et al., 2007; Binder et al., 1997). Finding a significant activation in the left AMY only in the verbal condition might suggest a lateralization of emotional responses related to the modality and to functional differences between emotional words and pictures, as it has previously been reported by Kensinger and Schacter (2006).

Confirming what is already visible in the simple differential emotional effects, overlapping emotional effects in occipital regions and in the ACC were revealed in the conjunction analysis. In the interaction analysis, then, neither stronger valence effects for the pictorial as compared to the verbal stimuli, nor any activation differences in the AMY or other subcortical emotion processing regions were found. Thus, our pictorial stimuli did not show the previously reported superiority in emotional processing (Kensinger & Schachter, 2006). In contrast, increased activations were observed for the verbal stimuli, mainly in language processing regions, such as the

superior temporal gyrus, the inferior temporal gyrus and the precentral gyrus. These may be attributed to feedback-projections from subcortical regions to modality-specific perceptual regions. Some of these activations were found in the right hemisphere though. However, while there is ample evidence in the literature for a dominance of the left hemisphere in language processing, the right hemisphere has also been shown to contribute to language processing, for example when concrete words are processed Ferstl and colleagues (2007), which is the case in this experiment.

Considering, that the main novelty of this study regarded the reduction of complexity in the pictorial material in comparison to previous studies, not finding any superiority of responses for the pictures, but rather increased valence effects for the verbal stimuli, already indicates that visual complexity contributed to the previously observed processing superiority of emotional pictures. To better understand the role of complexity in our data, we looked at the interaction of valence and complexity. This revealed as hypothesized, that stronger valence effects were indeed associated with higher visual stimulus complexity, but differently for the two modalities, pointing to an important role of stimulus complexity in visual emotional information processing. We find, in accordance with our hypothesis, stronger effects for complex photos as compared to simple pictograms, whereas –unexpectedly- no effects of complexity in the verbal material, when comparing valence effects between complexity categories, words and phrases. Photos as compared to pictograms activated a network of emotion processing and evaluation in the medial frontal gyrus and the ACC, as well as primary visual processing regions, the middle occipital gyrus and the cuneus. The results of the parametric analysis on the other hand only showed a significant activation in the cerebellum. Considering the overlapp of interaction parameters for photos and pictograms, the fact that photos, besides being more complex, are also more colorful and realistic than pictograms, may partly explain their stronger emotion effects. Indeed, the role of color for emotional responses has been discussed before. Some authors found differences in early processes of the electro-cortical response (Cano et

al., 2009; Wiens et al., 2011), while several others presented evidence against a role of color for the emotional response, or for only small effects of color (Codispoti et al., 2011; Bradley & Lang, 2003). Another explanation might be, that since pictures are 2-dimensional images of the real world and as photos are more realistic than pictograms, their realistic quality might contribute to the elicited emotional response. Color might then also be considered as one potential property contributing to the higher realistic quality of photos. For the verbal material, in the parametric analysis, as in the categorical analysis, no differences related to complexity were observed. Thus, as expected, the higher amount of visual information in the photos triggered increased perceptual and semantic processing associated with stronger responses in a semantic and emotion processing network. In the verbal material, on the other hand, complexity did not show an influence on the emotion effect.

2.5 Conclusion

At odds with previous findings, we find no stronger or more widespread emotion effects for pictorial than for verbal stimuli. Differences in emotional processing between the modalities were mainly found in language processing regions and might mainly be due to feedback projections to perceptual regions. A role of visual complexity and amount of visual information in the stimuli for the intensity of the emotional reaction was present for the pictorial stimuli, but more so in the categorical analysis, speaking for differences between photos and pictograms, such as color or realistic quality, that, besides complexity, may also play a role for the intensity of the emotional response.

It should be noted, that the present study bears some limitations in that it was restricted to positive stimuli, and the results would thus have to be replicated for stimuli of negative valence and an independent manipulation of stimulus arousal. Despite these limitations, our study is gives clarification to the debate on differences of emotional picture and word processing. It provides evidence, that there is no

general superiority of emotional responses for either verbal or pictorial stimuli, while showing that visual complexity might partly account for the previously found processing differences and stronger effects of emotional pictures. Our results thus do not speak for a central difference in emotional information processing between modalities, and an advantage for pictures, as proposed by deHouwer and Hermans (1994). However, they also do not suggest, that semantic content is the sole factor determining the emotional response, as assumed by theories proposing a functional unitary representation and emotion system (Paivio, 1991). Pictorial and verbal stimuli seem to share a common network of emotion processing, while some processing differences seem to exist. These might mainly be attributed to modality-specific emotional enhancement of perceptual processes, as they were mainly found in brain regions associated with language processing. The fact, that the left AMY was only significantly activated for the verbal stimuli might indicate some lateralization of emotion effects related to the modality. However this lateralization effect was not significant in the interaction analysis and could thus also be attributed to the overall stronger effects in the verbal condition.

Therefore we would support a view of a common emotional system for pictures and words, together with some processing differences, which we suggest are mainly related to stimulus-specific, emotionally enhanced perceptual processing. A theory of an experience-based semantic representation system might apply, in which concrete symbolic information is re-experienced from memory while pictorial information, being more realistic, is experienced more directly (Kiefer & Pulvermüller, 2011) and is consequently more dependent on perceptual stimulus features such as visual complexity. Still, both stimulus modalities would activate overlapping embodied representations of emotional meaning.

Studies using stimuli to evoke emotions should take into account the variability of responses to pictorial material due to perceptual properties. Pictorial stimuli seem to have the advantage of being more realistic; verbal stimuli on the other hand have an

advantage in controllability, while, although highly symbolic, they are able to evoke comparably strong emotional responses. As the present study was only designed to examine effects of visual complexity, future research should further investigate the processes involved in the evaluation of emotional information related to other perceptual stimulus features, such as realistic quality. Apart from the modulation of emotional responses by visual complexity it remains an open question how emotional meaning is represented in general and how it is accessed given how realistic or symbolic a stimulus is.

Chapter 3

Context matters: Anterior and posterior cortical midline responses to sad movie scenes

3.1 Introduction

When the earliest motion pictures were presented around the turn of the 20th century, they were silent and in black and white. While being very popular from the beginning, movies have since progressed to a highly composed and edited medium, depicting fictional worlds and stories (Cutting et al., 2012). A reason for their high popularity is their ability to make the viewer experience and feel strongly with highly complex social and emotional events (Schlochtermeier et al., in press; Kuchinke et al., 2013; Pehrs et al., 2015) which although being fictional, can be highly immersive (Appel & Richter, 2010; Jacobs, 2015a, b; Jacobs & Schrott, 2015; Tan, 1996; Visch et al., 2010), and perceived similar to real life events (Gallese & Guerra, 2012). Considerable progress has been made to clarify the cognitive and neural processes subserving the perception of complex audiovisual materials (e.g., Hasson et al., 2008a,b; Nummenmaa et al., 2012; Zacks et al., 2010; Pehrs et al., 2014). Besides recruiting sensory networks, complex audiovisual stimuli have been shown to engage widespread parietal as well as prefrontal, limbic and default mode network (DMN) areas (Hasson et al., 2008b; Jääskeläinen et al., 2008; Nummenmaa et al., 2012; Raz et al., 2014). DMN and emotion-processing brain regions were especially shown to be recruited during the presentation of complex and dynamic materials that depict social situations and stories, when watching movies or reading and listening to narratives (Altmann et al., 2012; 2014; Nummenmaa et al., 2012, 2014, also Raz et al., 2014, Viinikainen et al., 2012). While it is assumed that movies are composed to capture attention and control our sensory brain activations (Hasson et al., 2008a), we propose that powerful emotional responses in movies depend upon and develop within the movie's compositional context, engaging sensory, attentional and DMN regions.

The midline core of the DMN, which includes anterior and posterior midline structures, the posterior cingulate cortex (PCC) and mPFC (Andrews-Hanna et al., 2010), usually shows relative deactivations under external stimulation (Christoff, 2012) and is associated with an intrinsic processing mode (Gusnard & Raichle 2001;

Greicius et al. 2003). It is assumed to represent internal awareness, indicating self-referential and mentalizing processes, as opposed to extrinsic networks, which represent external awareness, such as perceptual and attention processes (Raichle et al., 2001; Raichle & Snyder, 2007). Midline DMN regions are however also recruited in multiple tasks, like in socio-emotional working memory (Spreng et al., 2009; Spreng & Schacter, 2012; Meyer et al., 2012) processing of self and others (Uddin et al., 2007; Qin & Northoff, 2011), ToM (Gallagher & Frith, 2003; Saxe & Kanwisher, 2003), or semantic processing and narrative comprehension (Fairhall & Caramazza, 2013; Ferstl et al., 2008, Altmann et al., 2012, 2014; Tamir et al., 2015). Recent research further indicates that core regions of the DMN play a role in the integration of complex context information concluding that different brain regions are sensitive to different processing timescales (Lerner et al., 2011; Hasson et al., 2009; Ames et al., 2015). These studies showed that with longer presentations of segments of a movie or narrative stimulus, activation in regions with longer processing timescales, including the mPFC, ACC, PCC and temporoparietal junction (TPJ), became more aligned between subjects. Shorter timescales, by contrast, revealed an alignment of regions involved in sensory processing, such as visual or auditory areas, indicating that these regions are only involved in tracking shorter durations of information. Of note is that coherent (e.g., thematically related sentence pairs) rather than incoherent linguistic stimuli elicit increased activation in DMN regions (PCC, mPFC and precuneus) (Ferstl & von Cramon 2001; Ferstl et al., 2008). Also, the connectivity of language regions with PCC and ACC (Smirnov et al., 2014) and the alignment of PCC and mPFC can be triggered by valid contextual information (coherent contextual framework) as compared to an invalid context (Ames et al., 2015). Sporns (2013) further highlights the role of parts of the DMN, such as the parietal cortex, precuneus, PCC and ACC, as cortical network hubs that integrate information over time and across segregated neural brain regions.

Considerable evidence shows that processing complex socio-emotional information that is dynamically conveyed in movies engages both extrinsic, perceptual

brain regions as well as intrinsic regions related to information integration, mentalizing or story comprehension. A parallel recruitment and interplay of internally directed, mentalizing, and externally directed executive networks, which are otherwise anti-correlated, may be possible with low levels of intentionality if both require a balanced amount of cognitive load with minimal interference (Dixon et al., 2014). This recruitment and interplay has been suggested as pivotal for immersion into virtual worlds such as movies (Christoff et al., 2009; Christoff, 2012). Other evidence has been reported for the co-occurrence of extrinsic, perceptual and intrinsic mentalizing networks for certain forms of meditation that focus on the integration of external and internal awareness (Josipovic et al., 2011) and for immersion in imaginative social situations (Wilson-Mendenhall et al., 2013).

The complex neural network dynamics implicated in the processing of affective movie stimuli are however far from being conclusively resolved (Okon-Singer et al., 2013). To understand the powerful emotional effects of movies, it remains to be asked how the neural responses to affective movies are modulated within their dynamic context. The aim of the present study was to understand how the neural correlates during perception of an affective movie scene are modulated by its compositional context. Based on behavioral pilot studies, we assumed that affective movie scenes evoke specific dynamic affect patterns (specific variations of affective responses over time), and that movie scenes are composed to increase emotional responses. Our experiment thus was designed to test the assumption that emotional responses to a movie evolve within its composition and that a coherent movie context will increase emotional responses to affective scene climaxes. This study further tested whether such context-dependent responses were associated with activations in emotional and midline DMN regions and their coupling with sensory brain regions, based on findings related to immersion in virtual and social worlds (Christoff et al., 2009; Christoff, 2012; Golland et al., 2006; Wilson-Mendenhall et al., 2013). To control the compositional structure of our stimuli, the movie stimuli were explicitly chosen and selected using film-analytical methods, in particular a tool that explores the dynamics

of the audiovisual shaping of emotion in film (eMEAX, Kappelhoff & Bakels, 2011). Based on film-theoretical considerations (Kappelhoff, 2004), we assume that movies contain compositional patterns, termed "affective movement patterns" by film scholars (Kappelhoff & Bakels, 2011; Bakels, 2014), which were hypothesized to elicit specific patterns of emotional responses. All scenes were chosen from "Romantic Comedies" and matched for their compositional affect structure (Figure 3.1 A). They consisted of "affective movement patterns" and depicted complex social, affective events: Sad affective climaxes showing the falling out of the protagonist couple. In order to study how responses to the affective peaks are modulated by compositional movie context, we used fMRI as well as continuous behavioral ratings of sadness to assess both neural and behavioral responses to the movie scenes.

To examine how the original, coherent context as compared to a replaced part of the movie modulated the impact of the affective peaks, these, in all conditions identical movie excerpts, were presented with either the coherent context (complete "closed movement pattern") or with a replaced context (see Figure 3.1 B, C), consisting of an immediately preceding part in each movie. As a third baseline condition the climaxes were presented without context. Assuming specific affective response time-courses and hypothesizing that the presentation of the coherent context should increase emotional engagement, we firstly (a) predicted peaks of subjectively rated sadness within the scene climaxes and highest experienced sadness for the coherent compared to the replaced context condition. On a neural level we expected (b) strongest activations in the emotional network and intrinsic midline brain structures for the coherent context condition. Secondly, based on the literature on contextual and affective processing in movies (e.g., Hasson et al., 2008a,b; Nummenmaa et al., 2012), we expected (c) subjectively rated sadness to modulate the emotional and midline brain networks, and activations in midline brain networks to increase with viewing time. Finally, based on the suggestion that contextual integration and emotional engagement in movies is associated with the parallel recruitment of otherwise decoupled intrinsic and extrinsic network structures, (d)

extrinsic sensory, and intrinsic midline networks were predicted to be less decoupled when the movie clips were preceded by a coherent context (Christoff et al., 2009; Christoff, 2012).
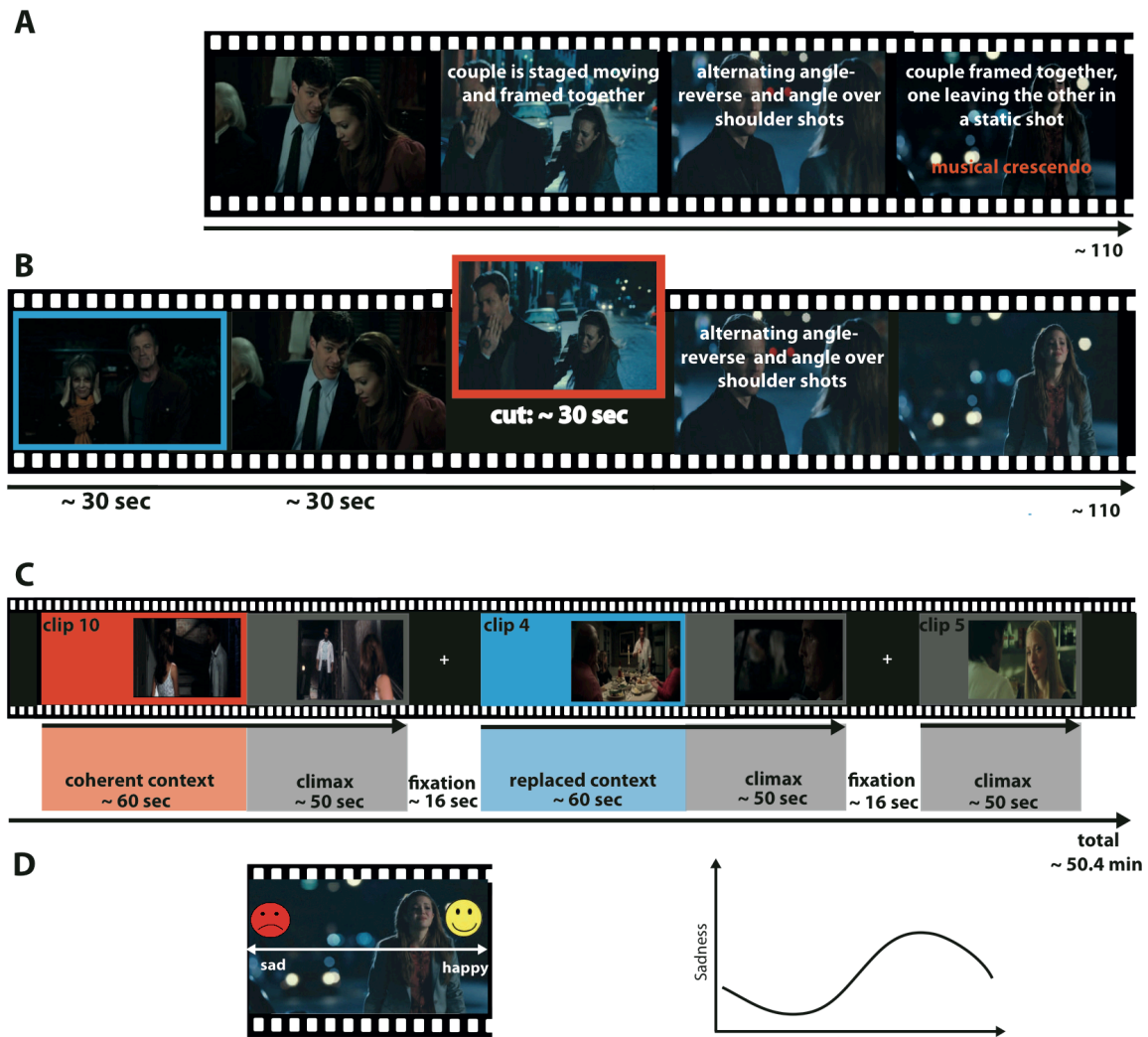
Figure 3.1: Experimental design. An illustration of the compositional structure of the coherent, un-replaced clips (original scene structure) is shown at the top (**A**). **B** illustrates the replacement of the scene contexts (cut and removal of 30 sec. and replacement with preceding movie excerpt) keeping the climax excerpts identical across conditions. The design of the scanner experiment (first viewing) with the stimulus conditions coherent, replaced (30 seconds removed and replaced) and no context (presented in randomized order with a total scanning time of approx. 50.4 min) is depicted below (**C**). **D** shows an illustration of the dynamic rating procedure (left: the rating with a smiley that is moved on an axis on the screen; right a putative random sadness rating time-course), which was conducted after the scanner experiment and consisted of the same order and randomization as during the scanner presentation (Nagel et al., 2007).

3.2 Methods and materials

3.2.1 Participants

Twenty-four right-handed, healthy young German native speakers (male: 13, female: 11; age: mean=26.08, SD=6.07 (ranging from 21 to 48)) participated in the study. Participants had normal or corrected to normal visual acuity and no known neurological condition, psychiatric disorder or current medication affecting the central nervous system. Participants were informed about the experimental task and the scanning procedure before the scanning session. After being informed about potential risks and screened by the study psychologist, participants gave written informed consent before participating. The experimental standards were approved by the German Psychological Associations (DGPs, the Society) ethics committee and the data were handled anonymously. The participants either received course credits or were remunerated at the rate of eight Euro per hour.

3.2.2 Experimental design

Stimuli and design are summarized in Figure 3.1. The stimuli were 24 video segments depicting the emotional climaxes of so-called "separation scenes" taken from Hollywood "Romantic Comedies", These "separation scenes" were chosen as they are characterized by distinct compositional patterns (affective movement patterns, Kappelhoff & Bakels, 2011) characterized by typical staging and camera angles, ending with an emotional climax, accompanied by a musical crescendo, in which the protagonist couple argues and separates (Figure 3.1 A). The stimuli were first selected based on film-scientific methods (Kappelhoff & Bakels, 2011; for list of films and time, see appendix) to control patterns of composition. The final selection was accomplished in a prestudy, based on continuous valence ratings of the 30 preselected clips. A homogeneous set of 24 stimuli in terms of valence was selected, showing the expected patterns with emotional climaxes (negative valence) at the end of the clips. The climaxes, which were identical in all three conditions, were presented with either no context, with their original coherent movie context (complete "separation scene")

or with a replaced, context (the immediately preceding part of the movie with same length, which was not part of the "separation scene" thus not a coherent part of the separation scene) (Figure 3.1 B). The stimuli were cut at preexisting breaks of the movie, so that the cuts were not noticeable and the clips appeared like continuous scenes. The stimuli included their complete sound composition (music, sound and German synchronized dialogue). They were presented in randomized order and with context conditions randomized across participants, so each participant viewed all 24 emotional climaxes (8 with coherent context, 8 with replaced and 8 without context, each). The clips were viewed passively in the scanner, using goggles with Presentation 12.1 software (Neurobehavioral Systems Inc.), separated by fixation crosses (16 sec.) with a total duration of 50.4 min.

3.2.3 Behavioral measurements and analysis

After the fMRI experiment, the participants viewed the same stimuli a second time and were briefly trained and then asked to rate them continuously for sadness (Figure 3.1 C). Using an adapted version of Emujoy (Nagel et al., 2007) the participants rated the videos while watching them by using a mouse to move a smiley face along a screen axis (sad vs. happy), which changed its appearance from smiling to neutral to a sad facial expression. The ratings varied continuously between +1 and -1. Rather than during the scanning session, the ratings were conducted separately, to minimize influences of a task to the processing of the audiovisual stimuli. Differences of self-reported emotion measures between first and second viewing have been shown to be negligible (Goldin et al., 2005), while online ratings of emotion have been subject to criticism as they are known to influence neural processing (Hutcherson et al., 2005; Lieberman et al., 2007). This makes the interpretation of fMRI results difficult because activations may be related to the rating and not the evoked emotion. Further, the evoked emotion itself might differ. For the analysis of the behavioral data, the continuous sadness ratings were transformed into time-courses with two-second intervals for each subject. Then, mean time-courses and standard deviations across subjects were calculated in Excel (Microsoft Office 2008, Released January 2008).

Single individual ratings were excluded, if they showed responses in less than three time-points (corresponding to mouse movements) over the whole excerpt. The rating time-courses were then aggregated over the timeframes of climaxes and contexts, respectively. Aggregated means of climaxes and contexts were compared with paired one-tailed T-Tests using SPSS (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.).

3.2.4 FMRI acquisition and analysis

The participants were instructed to relax and watch the clips attentively. Form fitting cushions were used to prevent head movements. Earplugs and headphones were provided to attenuate scanner noise. Imaging was performed with a 3T Siemens (Erlangen, Germany) Tim Trio MRI scanner equipped with a 12-channel head coil at the D.I.N.E. (Dahlem Institute for Neuroimaging of Emotion). In each of the two runs 680 whole-brain functional T2*weighted EPI (TR: 2000 ms, TE: 30 ms, 90° Flip Angle 37 slices, matrix: 64 x 64, FOV: 192 mm; 3 x 3 x 3 mm voxel size, no gap) were acquired. Additionally, a T1-weighted matched-bandwidth high-resolution (voxel-size 1.0 x 1.0 x 1.0 mm) anatomical scan with same slice prescription as EPI was acquired. The MRI data were preprocessed using SPM 8 (Available: http://www.fil.ion.ucl.ac.uk/spm/, Released January 11). The images were slice-time corrected, realigned to the mean volume and spatially normalized to the standard EPI template provided by the MNI template. Images were then spatially smoothed with an 8 mm FWHM Gaussian kernel.

3.2.5 General linear model (GLM)

After preprocessing, the data were analyzed in an event-related design time-locked to stimulus onset and duration (climax interval) in the context of the general linear model (GLM) as implemented in SPM 8 on two levels (Friston et al., 1995). On the first level, the experimental conditions of climax intervals (average durations = 50 sec.) with coherent, replaced (average durations = 60 sec.), and no context were included as regressors of interest. Movement parameters as well as the preceding

contexts were included as regressors of no interest in the design matrix. On the second-level, T-Tests were calculated to assess effects of context (coherent vs. no context; replaced vs. no context and coherent vs. replaced) on the responses to the climaxes. To assess brain activations modulated by continuous sadness ratings and progression of viewing time, a second GLM was calculated that included average time-courses of sadness ratings as well as a regressor for viewing time in the design. These were included as parametric modulators, which are serially orthogonalized in SPM (Büchel et al., 1998). To identify effects of sadness independent of viewing time, the viewing time regressor was entered as first, and sadness as second parametric modulator. All results were cluster-threshold corrected for $p = 0.005$ uncorrected with a cluster size of 15 voxel which corresponds to a desired threshold of multiple comparison of $p < 0.05$ estimated with 10000 iterations (Slotnick et al., 2003).

3.2.6 Psycho-physiological interactions (PPI)

Seed-based psycho-physiological interactions analyses were conducted (Friston et al., 1997). The ACC and PCC were chosen as seed regions, based on assumptions of being core hubs of the intrinsic network or DMN. The eigenvariates for the ACC (3/38/28) and PCC (-6/-40/25) were extracted for each subject in a 5 mm ROI surrounding the group activation peak for the main effect of context, and adjusted for the effects of interest contrast. These were used to calculate the interaction terms for each contrast (coherent vs. no context; replaced vs. no context and coherent vs. replaced), which were then included as regressors of interest in separate GLM's for ACC and PCC. The activation time-courses and the relevant contrasts (coherent vs. no context; replaced vs. no context and coherent vs. replaced) were included as covariates of no interest to ensure that the variance explained by the interaction terms would be above the variance explained by task or physiological correlations (Friston et al., 1997; O'Reilly et al., 2012). The results were again cluster-threshold corrected for $p = 0.005$ uncorrected with a cluster size of 15 voxel which corresponds to a desired threshold of multiple comparison of $p < 0.05$ estimated with 10000 iterations (Slotnick et al., 2003).

3.3 Results

3.3.1 Subjective continuous ratings of sadness

The purpose of the behavioral analysis was to determine the time-courses of emotional experiencing of the film clips as well as to assess differences in mean ratings of the scene climax intervals. Aggregated sadness ratings for both context conditions are depicted in Figure 3.2 A (black line: mean; colored lines: SD). Below mean time-courses of sadness ratings of the 24 scene climaxes are depicted separately for the different context conditions (coherent, replaced, no context; Fig. 3.2 B). Behavioral ratings of sadness confirmed that the clips elicited time-variable emotional responses as well as specific, comparable time-courses with peaks of sadness in the ratings within the climax intervals at the end of the clips (Figure 3.2 A, C). The depicted standard deviations however show a high variability between subjects (Figure 3.2 B). Aggregating the ratings for the scene climaxes and calculating one-tailed paired T-Tests revealed that they were rated as significantly sadder than the aggregated ratings for the scene contexts in both context conditions ($t(23) > 5.14$; $p < 0.01$; Figure 3.2; Figure 3.2 B). The aggregated sadness ratings over the timeframes of the scene climaxes further yielded a trend toward higher ratings for sadness for the scene climaxes with coherent context compared to the scene climaxes with a replaced context ($t(23) = 1.32$; $p = 0.09$). Both context conditions did not differ significantly from the no-context condition (both p's > 0.23).
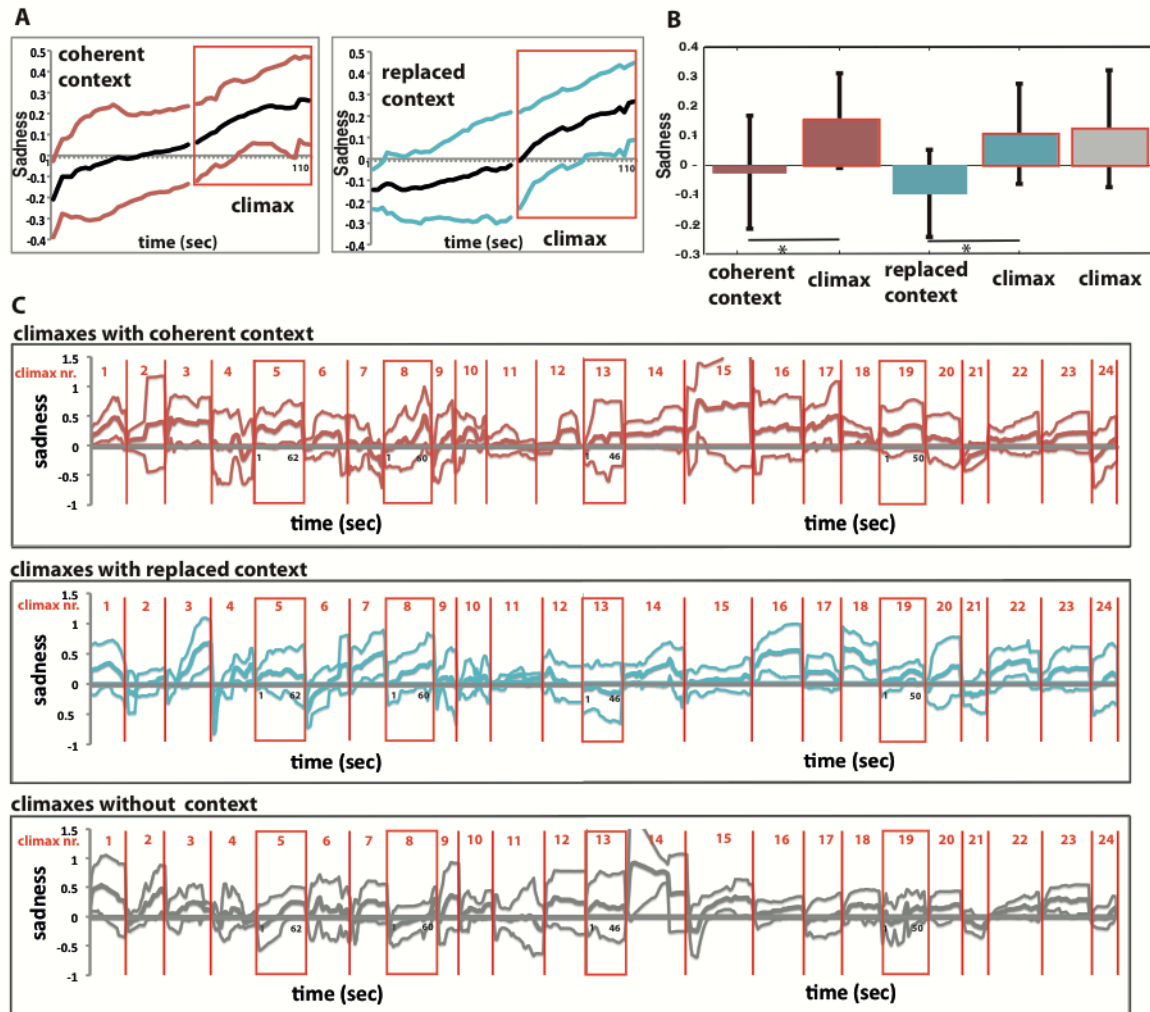
Figure 3.2: Continuous sadness ratings. Average time-courses of ratings of sadness for both context conditions are depicted at the top (**A**) showing an increase in sadness toward the end of the clip (assumed climax interval). This is further confirmed when comparing the aggregated means of context and climax intervals (**B**). Below (**C**), time-courses of mean sadness ratings together with standard deviations (+/- SD) are depicted for the 24 climax intervals separately for coherent (red), replaced (blue) and no context (grey) conditions, showing time variable emotional responses and peaks of sadness within the climax intervals.

3.3.2 Brain activity

3.3.2.1 GLM 1: Effects of context

We first calculated a GLM to investigate how context modulated the responses to the scene climaxes (see Table 3.1). T-Tests, comparing climaxes presented with coherent versus no context (coherent > no context), revealed significant activations in midline brain regions, including the precuneus extending to PCC, the ACC, the right fusiform gyrus (FG) and both superior frontal gyri (SFG) (Table 1, Figure 3.2 A). For replaced versus no context (replaced > no context), the climaxes evoked significant activations in a network including the precuneus, ACC and left inferior parietal lobe (IPL) (Table 1, Figure 3.3 A). The condition without context showed stronger activations compared to the condition with coherent context (no context > coherent context) in a network including the middle temporal (MTG) and superior temporal gyri (STG) SFG, and in MTG, STG and cuneus compared to the replaced context condition (no context > coherent context; Table 3.1, Figure 3.3 B). The presentation with coherent compared to replaced context (coherent > replaced) revealed activations in right FG, left cuneus and right precuneus, while no activations were yielded for replaced versus coherent context. Percent signal change plots showed highest activation for the coherent context condition and lowest for the no context condition in precuneus, ACC and PCC (Figure 3.2 A). The STG revealed the opposite activation pattern, with highest activation for a presentation without context and lowest for a presentation with coherent context (Figure 3.2 B).
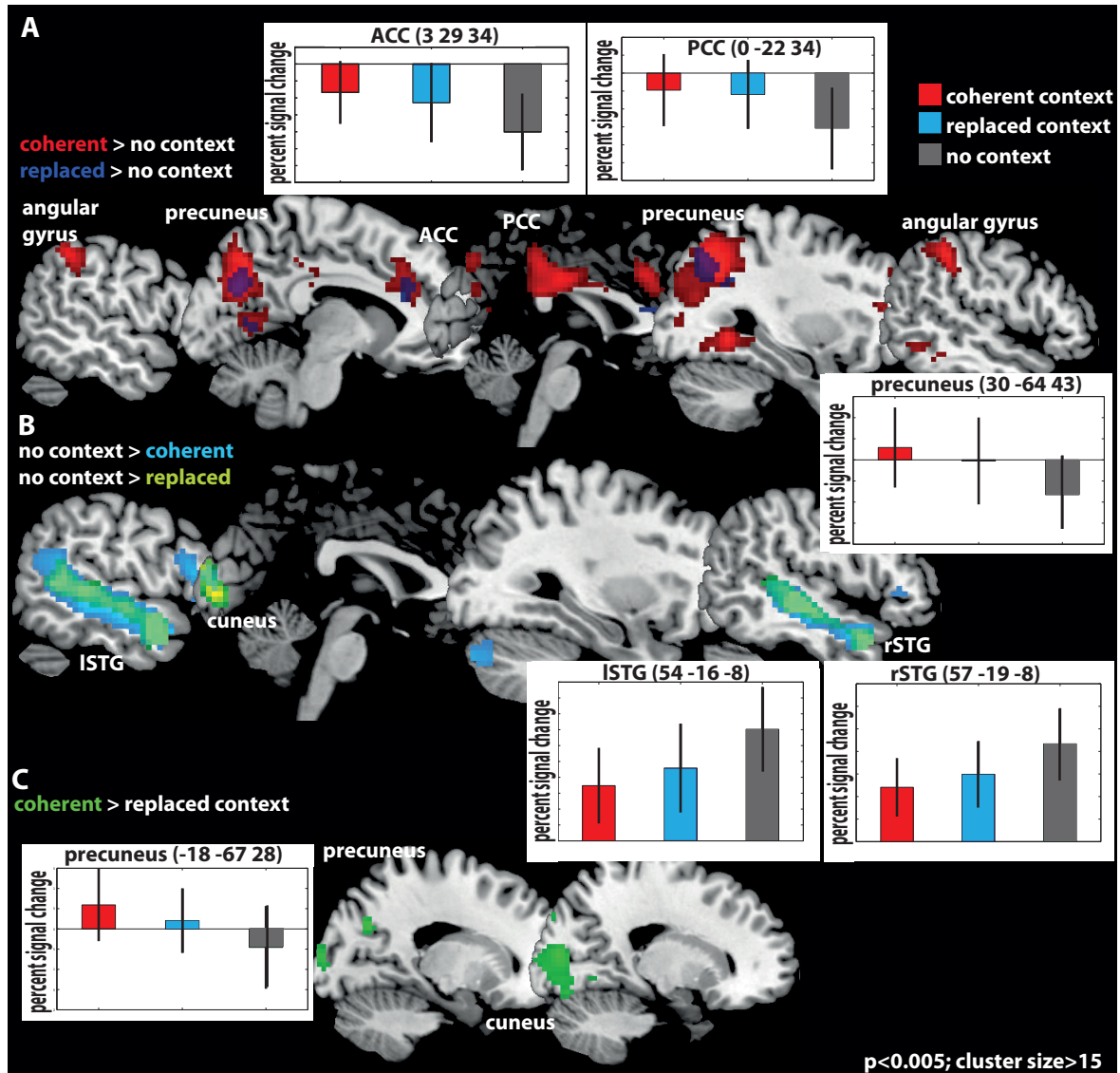
Figure 3.3: Context effects. BOLD responses to climaxes for effects of context and signal change plots (red = coherent; blue = replaced; grey = no context) are depicted with (**A**) BOLD responses of coherent > no context in red as well as replaced > no context in blue; (**B**) BOLD responses of coherent < no context in light blue and replaced < no context in yellow; and (**C**) coherent versus replaced context in green. (ACC = anterior cingulate cortex; PCC = posterior cingulate cortex; lSTG = left superior temporal gyrus; rSTG = right superior temporal gyrus)

Table 3.1: Effects of context

	Brain region	L/R	Cluster size	T-value	p-value	MNI coordinates
Coherent > No Context						
	Precuneus/ Posterior cingulate cortex	L	3383	7.32	0.000	-12 -70 28
	Angular Gyrus	R		7.26	0.000	30 -64 43
	Fusiform gyrus	R	283	5.34	0.000	30 -55 -5
	Inferior frontal gyrus	L	95	4.84	0.000	-36 38 10
	Parahippocampal gyrus	L	120	4.72	0.000	-24 -52 -8
	Superior frontal gyrus	R	100	4.71	0.000	39 53 19
	Midcingulate cortex/ Anterior cingulate cortex	R	296	4.48	0.000	3 29 34
	Superior frontal gyrus	L	21	4.03	0.000	-24 11 46
	Superior frontal gyrus	R	19	3.31	0.002	24 8 58
Replaced > No Context						
	Precuneus	L	59	3.64	0.000	-12 -70 28
	Precuneus	R	174	3.59	0.000	12 -70 31
	Anterior cingulate cortex	L	42	3.06	0.001	-12 29 25
	Inferior parietal lobe/ Supramarginal gyrus	L	21	3.04	0.001	-39 -43 37
	Parahippocampal gyrus	L	22	3.03	0.001	-33 -46 -8
	Inferior frontal gyrus	L	17	2.95	0.002	-36 38 10
	Cuneus	L	42	2.89	0.002	-18 -76 10
No Context > Coherent						
	Middle temporal gyrus/ Superior temporal gyrus	L	1028	8.64	0.000	-54 5 -20
	Superior temporal gyrus	R	632	7.69	0.000	51 -25 -2
	Rolandic operculum	L	158	5.62	0.000	-48 17 22
	Cerebellum	R	143	5.06	0.000	27 -88 -32
	Cerebellum	L	112	4.79	0.000	-12 -82 -44
	Superior frontal gyrus/ Medial frontal gyrus	R	29	4.28	0.000	9 41 40
	Superior frontal gyrus	L	37	3.85	0.000	-12 56 19
	Precentral gyrus	L	27	3.73	0.001	-42 2 49
	Inferior frontal gyrus	R	27	3.66	0.001	54 29 1
No Context > Replaced						
	Cuneus	R	537	4.35	0.000	6 -94 19
	Superior temporal gyrus	R	397	4.22	0.000	54 -25 -2
	Middle temporal gyrus/ Superior temporal gyrus	L	564	4.14	0.000	-57 5 -17
Coherent > Replaced						
	Fusiform gyrus	R	324	4.78	0.000	24 -79 -14
	Cuneus	L	94	3.82	0.000	-12 -97 4
	Cuneus	L	45	3.74	0.001	-18 -67 4
	Precuneus	R	17	3.19	0.002	3 -82 40

p < 0.005, cluster size > 15, indented brain regions belong to one consecutive cluster

3.3.2.2 GLM 2: Parametric effects of viewing time and sadness

To identify brain networks that varied with the dynamic affect patterns of the movie, and with progressing movie viewing time, as an additional measure for the integration of contextual information while movie viewing, a second separate GLM was calculated. To calculate effects of sadness and viewing time we included regressors for viewing time and time-courses of subjective sadness ratings as parametric modulators (Table 3.2, Figure 3.4). To assess activation increases and decreases related to viewing time, we calculated a one-sample T-Test for the viewing time parameter. This revealed that activations increased linearly with viewing time in a widespread midline network including precuneus, PCC, mPFC and ACC (Table 3.2, Figure 3.4 A). Activations in an extrinsic network including left lingual gyrus and bilateral STG decreased linearly with viewing time (Table 3.2, Figure 3.4 A). Another one-sample T-Test was calculated revealing increasing activations with sadness in a network including the SFG, precuneus, ACC, mPFC and right caudatus while activations in bilateral STG and cuneus decreased with sadness (Table 3.2, Figure 3.4 B).
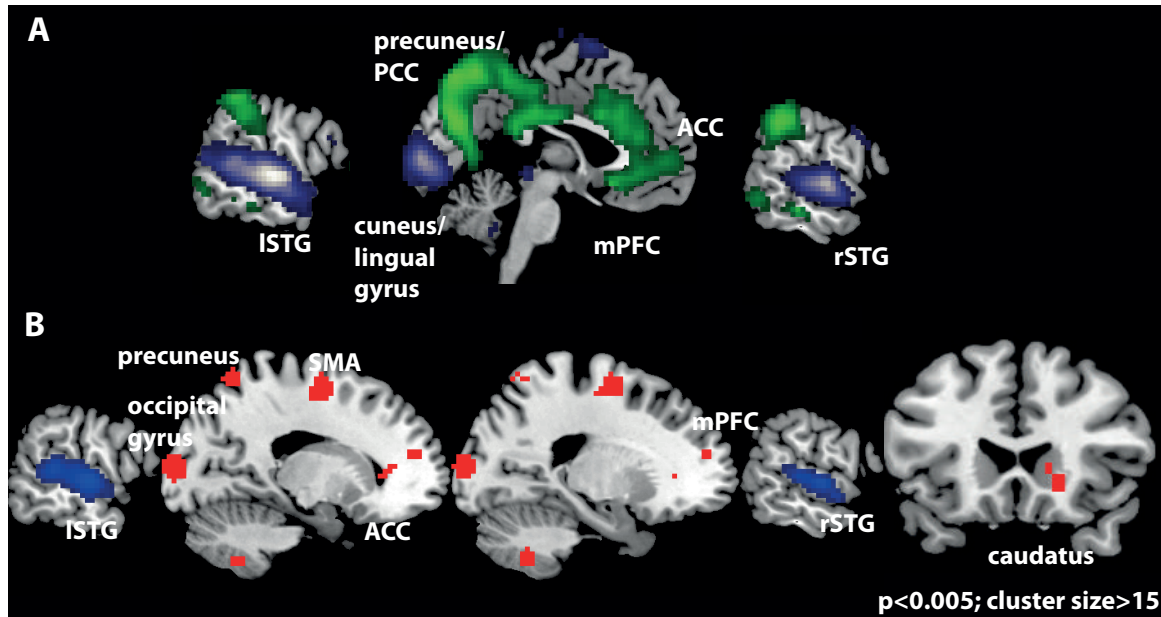
Figure 3.4: Parametric effects of viewing time and sadness. A shows BOLD responses to climaxes for parametric effects of viewing time with decreasing activations with viewing time in blue and increasing activations in green. **B** depicts parametric effects of sadness with decreasing sadness in blue-grey and increasing sadness in red. (lSTG = left superior temporal gyrus; lIFG = left inferior frontal gyrus, PCC = posterior cingulate cortex; ACC = anterior cingulate cortex; mPFC = medial prefrontal cortex; rIFG = right inferior frontal gyrus; SMA = supplementary motor area)

Table 3.2: Parametric effects of viewing time and sadness

	Brain region	L/R	Cluster size	T-value	p-value	MNI coordinates
Viewing time						
increase						
	Precuneus	L	15827	10.05	0.000	-9 -70 22
	Posterior cingulate cortex			4.89	0.000	-6 -40 25
	Cerebellum	L	331	5.67	0.000	-39 -61 -44
	Cerebellum	R	145	5.19	0.000	33 -46 -44
	Cerebellum	L	48	4.46	0.000	-24 -79 -50
	Precentral gyrus	R	26	4.32	0.000	39 -16 40
	Middle frontal gyrus	L	62	4.04	0.000	-24 20 61
	Anterior cingulate cortex/ Medial prefrontal cortex	R		5.32	0.000	3 32 28
	Cerebellum	L	19	3.56	0.001	-48 -67 -35
decrease						
	Superior temporal gyrus	L	1356	10.89	0.000	-60 -16 1
	Superior temporal gyrus	R	691	9.16	0.000	60 -13 1
	Lingual gyrus	L	1129	8.87	0.000	-9 -91 -2
	Precentral gyrus	R	65	5.79	0.000	54 -1 49
	Inferior frontal gyrus	L	153	5.52	0.000	-51 17 22
	Supplementary motor area	R	83	5.40	0.000	0 8 70
	Precentral gyrus	L	148	5.39	0.000	-45 2 52
	Cerebellum	R	55	4.89	0.000	6 -49 -41
	Brainstem	R	28	4.54	0.001	0 -31 -5
Sadness						
increase						
	Superior frontal gyrus/ Supplementary motor area	L	101	6.54	0.000	-18 -7 58
	Middle occipital gyrus	L	108	5.23	0.000	-18 -94 10
	Superior parietal lobe/ Precuneus	L	82	4.65	0.000	-21 -67 58
	Cerebellum	L	41	4.30	0.000	-21 -58 -47
	Precuneus	R	33	4.04	0.000	9 -52 58
	Caudatus	R	23	4.04	0.000	21 29 -5
	Anterior cingulate cortex/ Medial prefrontal cortex	L	15	3.87	0.000	-18 35 10
	Superior parietal lobe/ Precuneus	L	59	3.76	0.001	-18 -64 67
	Brainstem	R	30	3.73	0.001	0 -40 -38
	Superior frontal gyrus	L	22	3.50	0.001	-21 50 19
decrease						
	Superior temporal gyrus	L	639	5.96	0.000	-63 -16 1
	Superior temporal gyrus	R	348	5.94	0.000	66 -13 1
	Cuneus	L	80	4.53	0.000	-6 -82 16

p < 0.005, cluster size > 15, indented brain regions are part of one consecutive cluster

3.3.2.3 Psycho-physiological interactions

Subsequently, PPI's were calculated to investigate whether the neural coupling of midline DMN structures in response to the scene climaxes was modulated by the preceding movie context. We focused on the ACC (3/38/28) and the PCC (-6/-40/25) as seed regions, based on our findings and their proposed role as central cortical network hubs (Sporns, 2013; Van den Heuvel et al., 2011). The contrasts (coherent vs. no context, replaced vs. no context and coherent vs. replaced context) were multiplied with the eigenvariate of the voxels within a sphere with a 5 mm radius around the peak activation voxel of each cluster to obtain the interaction term. For both context conditions compared to no context the ACC and PCC were more strongly coupled with occipital visual processing regions, such as the cuneus, and the lingual gyri (Table 3.3, Figure 3.5). The ACC was further more strongly coupled with the caudatus for the coherent compared to the replaced and no context conditions (Table 3.3, Figure 3.5 B, D). The no context condition showed some significantly stronger couplings of the ACC compared to the replaced context condition including the SFG and the angular gyri.
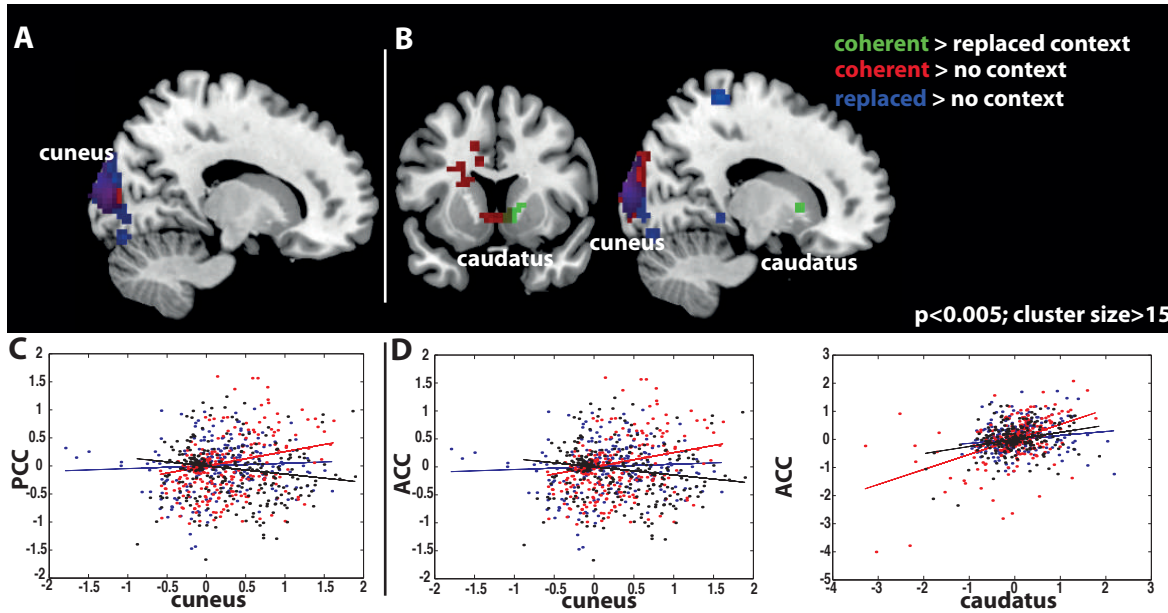
Figure 3.5: Psycho-physiological interactions. A PPI with a seed in the PCC (-6/-40/25) shows stronger coupling with occipital visual processing regions for both context conditions versus no context (**A**). **B**: A PPI with seed in the ACC (3/38/28) showed stronger coupling with occipital regions for both context conditions versus no context, but also a significantly stronger coupling for the coherent context condition in the caudatus compared to replaced context and no context. Showing the interaction and regression slopes for a representative participant, activations of the PCC of no context (black), coherent (red) and replaced (blue) context conditions are plotted against activations in the cuneus (**C**). Activations of the ACC are further plotted against activations in the cuneus and the caudatus (**D**). (ACC = anterior cingulate cortex; PCC = posterior cingulate cortex; PPI = psycho-physiological-interaction)

Table 3.3: Psycho-physiological interactions

	Brain region	L/R	Cluster size	T-value	p-value	MNI coordinates
Coherent > No Context						
	Seed area: PCC (MNI: -6/-40/25)					
	Cuneus	R	421	5.08	0.000	15 -91 13
	Seed area: ACC (MNI: -3/38/28)					
	Cuneus	R	1192	5.72	0.000	12 -100 16
	Pallidum	L	23	4.71	0.000	-15 -7 -8
	Caudatus	R	63	4.09	0.000	3 14 -5
	Caudate body	L	62	3.88	0.000	-18 23 25
	Midcingulate gyrus	L	19	3.80	0.000	-15 8 37
	Middle temporal gyrus	L	22	3.43	0.001	-45 -61 4
Replaced > No Context						
	Seed area: PCC (MNI: -6/-40/25)					
	Cuneus	R	555	6.06	0.000	18 -97 22
	Inferior temporal gyrus	R	32	4.57	0.000	42 -37 -11
	Hippocampus	R	23	4.24	0.000	30 -34 7
	Lingual gyrus	R	26	4.02	0.000	15 -82 -14
	Middle temporal gyrus	R	29	3.79	0.000	33 -67 13
	Seed area: ACC (MNI: -3/38/28)					
	Postcentral gyrus	R	35	5.04	0.000	12 -37 67
	Middle occipital gyrus	R	364	4.92	0.000	24 -85 1
	Fusiform gyrus	R	98	4.32	0.000	30 -40 -11
	Cuneus	L	217	4.09	0.000	-9 -100 19
	Parahippocampal gyrus	L	103	3.81	0.000	-24 -46 -8
	Middle temporal gyrus	L	15	3.64	0.001	-45 -79 22
	Inferior occipital gyrus	L	16	3.44	0.001	-33 -82 -8
	Inferior frontal gyrus	L	17	3.37	0.001	-36 26 7
	Cerebellum	R	15	3.34	0.001	12 -40 -5
	Middle temporal gyrus	R	19	3.27	0.002	45 -67 16
	Lingual gyrus	R	15	3.26	0.002	15 -82 -14
No Context > Coherent						
	Seed area: PCC (MIN: -6/-40/25)					
	—	—	—	—	—	—
	Seed area: ACC (MNI: -3/38/28)					
	Inferior parietal lobe	L	32	3.16	0.002	-51 -64 43

	Brain region	L/R	Cluster size	T-value	p-value	MNI coordinates
No Context > Replaced						
	Seed area: PCC (MNI: -6/-40/25)					
	Inferior parietal lobe	L	15	3.37	0.001	-51 -64 43
	Seed area: ACC (MNI: -3/38/28)					
	Superior frontal gyrus	L	71	4.09	0.000	-27 38 37
	Angular gyrus	L	79	4.01	0.000	-39 -67 49
	Middle frontal gyrus	R	63	3.76	0.001	45 23 40
	Angular gyrus	R	51	3.42	0.001	48 -73 37
	Precuneus	L	25	3.20	0.002	-3 -70 37
Coherent > Replaced						
	Seed area: PCC (MNI: -6/-40/25)					
	Brainstem	R	17	3.50	0.001	3 -22 -20
	Seed area: ACC (MNI: -3/38/28)					
	Caudatus	L	23	3.59	0.001	-9 5 7
	Caudatus	R	21	3.21	0.002	15 14 4
Replaced > Coherent						
	—	—	—	—	—	—

$p < 0.005$, cluster size > 15, ACC = anterior cingulate cortex, PCC = posterior cingulate cortex

3.4 Discussion

Narrative movies make us experience emotional events and feel with them, almost like in real life (Schlochtermeier et al., 2015). They are dynamic stimuli, depicting complex socio-emotional information. As such, processing them involves sensory brain regions as well as regions related to intrinsic, emotional and social information processing (Nummenmaa et al., 2012; Hasson et al., 2008b). The present study used continuous behavioral ratings of sadness and fMRI to study how subjective emotional experiences and neural responses to sad movie excerpts are modulated by movie context. In order to do this, the participants watched affective movie scenes passively, with either the original coherent context, a replaced non-coherent context or without a preceding movie context during fMRI scanning. Continuous behavioral ratings of sadness were obtained after the scanning sessions. Our findings show a

modulation of emotional and midline regions with dynamic changes in sadness and a modulation of midline and sensory regions when contextual information is integrated. In line with views of co-occurring networks in immersive viewing experiences (Christoff, 2012; Dixon et al., 2014) they further reveal novel insights into how activation and coupling of midline brain regions are dynamically modulated by movie context. We predicted that if sad movie clips are presented with their original, coherent context, experienced sadness should be more pronounced than if presented with no context or a replaced context. This stronger emotional engagement depending on the presented context was expected to be associated with a modulation of emotional and midline brain regions and their coupling with extrinsic, sensory regions.

The results of the behavioral sadness ratings were mainly in line with our hypotheses, revealing mean response time-courses with peaks of sadness within the climax intervals toward the end of the scenes, confirming the predicted affect patterns (Figure 3.2). Further confirming our prediction, climaxes preceded by coherent context were rated as sadder than those that were preceded by replaced contexts. The difference in experienced sadness was however only trend-wise significant, while both context conditions did not differ from the no context condition. This might be attributed to the high variability between the individual responses in our data. Responsible for this may be the fact that the clips were taken from romantic comedies, depicting complex, narrative episodes that would be more reliably measured using multiple emotion variables, such as happiness, sadness, funniness and romantic feelings, or valence and arousal (Schaefer et al., 2010). Another possibility is that the perceived sadness did not differ strongly between conditions and that a rating of empathic concern or subjective pleasantness would have been more appropriate measures to capture emotional engagement in movies (Raz et al., 2014; Menon & Levitin, 2005; Pehrs et al., 2015) and would thus have better detected the experiential differences.

In a first GLM analysis we investigated effects of context on the responses to the scene climaxes. When the climax excerpts were viewed with preceding movie context, compared to a presentation without context, activations in regions that are part of the DMN, the ACC, precuneus, and PCC, were increased, while activations in the STG were decreased. Complex modulations including DMN regions and sensory networks are consistently reported in free viewing of narrative movies (Hasson et al., 2008b; Nummenmaa et al., 2012; Viinikainen et al., 2012). Being highly complex stimuli, narrative movies involve a complex interplay of manifold processes, such as language and narrative comprehension, social processing and perceptual, audiovisual processes (Raz et al, 2014; Nummenmaa et al., 2012; Viinikainen et al., 2012; Pehrs et al., in 2015). Frontal medial regions especially are often reported in relation to story comprehension or socio-emotional comprehension (Nummenmaa et al., 2012, 2014; Ferstl et al., 2008). Frontal medial regions have also been connected to suspense in stories (Lehne et al., 2015), while the cingulate cortex has been associated with immersion in reading (Hsu et al., 2014). The STG, which was more strongly activated in the condition without context, is involved in multisensory processing and the multimodal integration of auditory and visual information (e.g., Kreifelts et al., 2007; Pehrs et al., 2014) vocally expressed emotions (Früholz et al., 2012), social perception and action observation (Yang et al., 2015). Together, the findings imply that when movie stimuli are presented without context, extrinsic perceptual networks associated with multimodal processing and integration, social and action perception are more activated, and intrinsic brain regions associated with socio-emotional or story processing are deactivated. While watching a movie excerpt with its preceding movie context, this desynchronized activation-deactivation pattern is reduced. This may be attributed to midline DMN activations being suppressed during exploration of the environment, while extrinsic regions related to the analysis of the environment are activated. These findings are in line with previously reported results, in which higher inter-subject correlations were reported for the integration of information in longer film clips in DMN structures (Hasson et al., 2008b; Jääskeläinen et al., 2008), emotional information in movies (Nummenmaa et al., 2012) and immersion in movies

(Christoff, 2012) or social situations (Wilson-Mendenhall et al., 2013). In accordance with findings related to text coherence (Ferstl & von Cramon 2001; Ferstl et al., 2008) and findings showing an increased alignment in midline DMN regions if coherent contextual information is integrated (Ames et al., 2015), the activation differences were most pronounced for the condition with coherent context. The precuneus revealed a significantly stronger activation for the coherent compared to the replaced context condition. Further, when observing the percent signal change plots, an increase of activations with context is visible in the precuneus and PCC with highest activations in the condition with coherent and lowest in the condition without context. An opposite activation pattern is visible in the STG.

Interestingly, the effects of the parametric analyses for both sadness and viewing time showed modulations in networks comparable to the networks modulated by the categorical context effects. The effects of progressing viewing time might indeed be interpreted in a similar vein, as an increase of information integration over time, and a decrease of unfocused external stimulus exploration: widespread activations in midline core structures of the DMN increased over the time-course of the movie excerpts, while activations in occipital and temporal regions decreased. Experienced sadness modulated a similar network including ACC and mPFC, precuneus as well as the SMA, caudatus and occipital regions. The SMA is involved in mirroring and in the representation of other's bodily and feeling states (e.g., Iacoboni, 2012), the caudatus in reward processing (Haber & Knutson, 2009; Haber, 2011), while visual regions are consistently reported to being modulated by emotion (e.g., Kober et al., 2008). In a recent functional connectivity study, a similar network including the ACC, mPFC, SMA and striatum was shown to be modulated by negative affect, while the PCC, Insula, caudatus, as well as parietal and visual areas were correlated with positive affect (Rohr et al., 2013). In SPM, parametric modulators are orthogonalized in serial order (Büchel et al., 1998). The effects of sadness might thus be seen as independent from the effects of progressing in viewing time and may be interpreted in the sense that emotional brain regions and other neural processes

involved in movie viewing, like sensory, socio-emotional processing or narrative understanding, are modulated based on the affective quality of the clip.

All in all, the modulations of similar midline DMN and sensory networks by the different analyses (effects of experimental context variations, parametric modulations of sadness and viewing time) might be due to the fact that the complex processes associated with movie viewing are modulated by affective quality and context, reflecting the integration and processing of multimodal, socio-emotional information. Depending on the changing input, the involved brain networks are probably dynamically recruited in line with the assumption that interplay of processing modes is mediated by processing demands (Dixon et al., 2014) and that functional brain connections are in constant flux (Sporns, 2013). Such a view is further supported by the results of the PPI analyses. The PPI's were calculated with the ACC and PCC as seed regions, based on their roles as central network hubs to assess their differential connectivity depending on the presentation of coherent, replaced or no context. The PPI for the ACC and PCC seeds when comparing the conditions with context and the condition without context revealed stronger coupling with occipital and posterior parietal regions, which are mainly connected to visual and motion processing in movies (Bartels & Zeki, 2004; Kauttonen et al., 2015). The PPI analysis with its seed in the ACC with coherent compared to replaced and no context further revealed a significantly stronger coupling in the ventral caudate nucleus, which is part of the reward system and involved in the outcome of events (Haber & Knutson, 2009; Haber, 2011), while the ACC is connected to monitoring ongoing behavior in reward prediction models (Bush et al., 2002). This contextual modulation of network interactions supports our assumption, that extrinsic, sensory and intrinsic, midline regions become more coupled when watching a contextually embedded movie clip. Co-occurrence and co-operation of otherwise anti-correlated networks has been suggested as being possible in states of low intentionality with low levels of interference and suggested as underlying complex mental states such as theory of mind or creativity (Christoff, 2012; Dixon et al., 2014; Golland et al., 2007). It has been

related to immersion with a social situation (Wilson-Mendenhall et al., 2013) and is suggested to occur during real life social interactions (Pehrs et al., 2015). Changes in network dynamics can be interpreted as interplay of processing modes being mediated by different processing demands (Dixon et al., 2014) and dynamic transitions of network connectivities due to changing input (Sporns, 2013). They may provide a framework for understanding the mental states underlying switching between sensory and higher order socio-emotional processing and their simultaneous engagement in emotionally engaging narrative movies. The additional unpredicted finding that the ACC was also more strongly coupled with reward areas in the coherent context condition may be interpreted in line with studies showing reward related responses to other dynamic stimuli such as sentences (Bohrn et al., 2013), poems (Zeman et al., 2013), or music (Koelsch et al., 2014; Blood & Zatorre, 2001) and its temporal coherence (Menon & Levitin, 2005; Farbood et al., 2015). This finding may also be viewed within reward prediction models, which describe the ACC as being involved in monitoring ongoing events or behaviors and the ventral striatum (ventral caudatus and putamen) in the outcome of events (Haber & Knutson, 2009; Haber, 2011; Bush et al., 2002).

While providing novel insights into how compositional context information in affective movie scenes modulates the dynamic recruitment of brain networks, this study bears several limitations. The behavioral ratings of sadness showed a high inter-rater variability, which we attribute to the stimulus material depicting complex socio-emotional information that might not be limited to sadness. Additional behavioral ratings might have been informative but were not applied in order to limit the duration of the experimental testing for each participant. Furthermore, the interpretations of our findings are partly based on reverse inference (Poldrack, 2011; Hutzler, 2014); alternative interpretations should therefore be considered. Firstly, an activity pattern in cortical midline regions may reflect lower levels of deactivations rather than activations, which may be seen in relation to the GLM intercept, which is defined by the events (16 sec. fixation) not included in the model. It is therefore

unclear whether our results are based on activations or deactivations in response to the different experimental conditions. We therefore interpret the results carefully in terms of dynamic changes in activations and connectivities within and between network hubs. Secondly, activation differences may be only partly related to differences in the emotional responses to the climax excerpts. The integration of non-emotional contextual information as well as attention processes may play a considerable role. Another potential limitation is that PPI analyses give no information regarding the direction of effects and its causality, which should be investigated in the future. Furthermore, the direct comparison of brain responses between coherent and replaced context conditions yielded only small effects. However, as the replaced context was taken from an immediately preceding part of the movie it also provided the climax excerpts with relevant context information and only small activation differences were to be expected. The findings are also limited by the applied methods. We used complex movie stimuli, including the full sound and music composition. An inter-subject correlation analysis or independent component analyses would have been further appropriate measures. These might have given additional insights into the functionality of the involved brain networks, were however not calculated due to the timing of the experimental design and the duration of the single stimuli.

3.5 Conclusion

Our findings provide strong evidence that if an emotional movie scene is presented with its compositional context, an intrinsic, midline DMN subnetwork as well as coupling of its central, anterior and posterior, hubs with sensory and reward regions is modulated. The DMN is uncontrolled in rest, showing activity that is associated with mind wandering (Raichle & Snyder, 2007). Our results go in line with findings showing that well composed movies engage brain networks in widespread brain regions (Hasson et al., 2008b), while if longer narrative and socio-emotional movie excerpts are presented, midline DMN and emotional regions are recruited

(Nummenmaa et al., 2012). A novel finding of our study is the context-dependent coupling of anterior and posterior midline regions with occipital visual and reward areas for coherent context, which indicates interplay of extrinsic and intrinsic brain regions, when integrating coherent context information and engaging in a socio-emotional movie stimulus (Christoff, 2012; Dixon et al., 2014; Golland et al., 2007) and a connection of context coherence to reward processes (Menon & Levitin, 2005; Farbood et al., 2015). By showing that emotional movie scenes increase activations in midline DMN regions and their coupling with regions related to context processing, our results present novel insights into the mechanisms involved in the dynamic unfolding of affective information in movies. Movies tell stories, simulate social situations, and are composed in order to immerse us into artificial story worlds (Schlochtermeier et el., 2015; Jacobs, 2015a, b; Jacobs & Schrott, 2015; Appel & Richter, 2010; Tan, 1996; Visch et al., 2010), creating a *reality effect* (Gallese & Guerra, 2012). We suggest that by co-occurrence and dynamic interplay of sensory, DMN and reward areas, viewers empathize with and feel the depicted emotional scenery as if they were in a real social situation. To further understand how emotional responses evolve within a narrative movie, future research should continue investigating how movies or other complex media input recruit brain regions dynamically, and modulate switching and interaction between intrinsic and extrinsic networks.

Chapter 4

Emotion processing in different media types: Realism, complexity, and immersion

4.1 Introduction

Commonly used emotion induction instruments are sets of single words (Bradley & Lang, 1999; Võ et al., 2009), sentences, vignettes (Bohrn et al., 2013; Hervé et al., 2013; Sabatinelli et al., 2006), music (Zentner et al., 2008), facial emotional expressions (Ekman & Friesen, 1977; Lundqvist et al., 1998), static pictures (Lang et al., 2008), cartoons (Brink et al., 2011), movie clips (Dziobek et al., 2006; Gross & Levenson, 1995; Schaefer et al., 2010; Pehrs et al., 2014), imaginative case scenarios (Wilson-Mendenhall et al., 2013), poems and narratives (Altmann et al., 2012; Lüdtke et al., 2014; Zeman et al., 2013), or virtual environments and video games (Schilbach et al., 2013; Mathiak et al., 2013). Emotion induction instruments usually conceptualize emotions either as basic categories or in a two-dimensional space along the axes "valence" and "arousal". These conceptualizations are based on theories assuming the existence of biological categories of emotion (Ekman, 1992; Panksepp, 1982), or on theories assuming a neurophysiological core affect system constituted by valence (pleasure/displeasure) and arousal (activation/deactivation) (Russell, 2003). A recent aim of affective neuroscientific research is to use more complex, dynamic and social stimulus materials to create more naturalistic settings and thus overcome the problem of studying real life phenomena in an artificial laboratory context (Fischer & Van Kleef, 2010; Klasen et al., 2014; de Gelder et al., 2015). Focusing on media reception, the particularly powerful emotion effects of watching narrative movies (Gallese & Guerra, 2012), or reading literature (Schrott & Jacobs, 2011; Jacobs, 2015a,b) have been emphasized. This review aims to analyze the emotional impact of different media types, focusing on the development from simple to more complex and realistic materials. It therefore illustrates similarities and dissociations of neural networks underlying emotional processing in different media types. It then discusses how the potential to make viewers or listeners dive into and immerse into artificial or virtual worlds (Schrott & Jacobs, 2011; Slater & Wilbur, 1997; Zwaan, 1993) may play a crucial moderating role for emotional responses to different media types. This article focuses on review articles and neuroimaging studies to capture main

regularities as well as important findings of single studies (based on a search in "pubmed" and "web of science" published after 2000). We used several keywords, i.e. *emotion processing*, *fMRI, narratives*, *movies*, *films*, *virtual reality*, *multimodal*, *dynamic, complex*. Rather than giving an exhaustive review of the literature, we present those studies that best illustrate a comparison between media types. As this procedure and the present state of research appear insufficient to reach final conclusions, outstanding research questions are formulated instead.

The basic question we address is how the response to affective information is moderated by the medium it is presented in. As an example consider a picture (i.e. photo of snake) from the International Affective Picture System (IAPS, Lang et al., 2008) and its corresponding verbal representation from the Affective Norms for English Text (ANET, (Bradley & Lang, 2007): "You watch a giant snake coiled in a display case. You freeze, as the snake's eyes move in your direction, and a red forked-tongue darts out."). Is a perceptually more realistic pictorial representation generally more engaging? What if a verbal description leads to a deeper attentive and semantic processing, engaging immersive processes like being transported into and absorbed by a story world (e.g., Gerrig, 1993; Hakemulder, 2013; Hsu et al., 2014; Jacobs, 2011; Jacobs, 2015a,b). We will examine this issue below by considering verbal, pictorial, dynamic audiovisual, virtual and interactive stimulus classes, followed by a discussion on the role of immersion in the different media settings.

4.2 Emotion processing in different media types

4.2.1 Verbal stimuli: Words, sentences, poems and narratives

Simple words, sentences, scripts, poems or narratives have been used as stimuli to induce emotional responses. Although being perceptually non-realistic, emotional content in verbal stimuli can evoke strong and reliable emotional responses on behavioral and brain level, engaging manifold brain networks, related to language, mentalizing, reward and emotion processing (Jacobs, 2015; overview: Citron, 2012).

In single word recognition, typically an emotion processing network including the ACC, OFC, hippocampus (HP), and extrastriate areas is activated (e.g., Hamann & Mao, 2002; Jacobs et al., 2015; Posner et al., 2009; Lewis et al., 2007; Straube et al., 2011; Citron, 2012), while AMY activations are usually only found for highly arousing words (Kuchinke et al., 2005). Research on more complex verbal materials, such as sentences, poems, and narratives suggests an involvement of reward areas (Bohrn et al., 2013; Zeman et al., 2013) as well as interactions between mentalizing, the cognitive representation of the other's mind (also referred to as ToM), and emotion processing (e.g., Walter, 2012). Activations are reported consistently in the emotional network together with regions related to mentalizing, such as TPJ, STS, middle temporal gyrus (MTG) and medial prefrontal cortex (MPFC) (Altmann et al., 2014; Hervé et al., 2013; Hsu et al., 2014; Hsu et al., 2015a,b,c). Furthermore, intense emotional content in written narratives is reported to cause a joint recruitment of both emotional and language regions of the brain (Hsu et al., 2015a,b,c; Wallentin et al., 2011) and while engaging in stories both, mentalizing and premotor networks that are related to the embodied simulation of another's actions, are activated (Nijhof & Willems, 2015). When listening to emotional stories, in addition to emotion processing, language and mentalizing networks (Hervé et al., 2012), the left anterior temporal lobe plays a key role (Ferstl & von Cramon, 2007). Emotional prosody further activates the human-selective voice area and the posterior part of the STS, corresponding to the processing of the emotional content of the speakers voice (Beaucousin et al., 2007). Synchronizations between subjects in sound and speech comprehension networks (as well as embodied simulation networks) are reported to being modulated by valence and arousal when listening to language (Nummenmaa et al., 2014).

4.2.2 Pictorial stimuli: Pictures of scenes, static and dynamic faces

Compared to words, perceptually more realistic pictures are often reported to have behavioral advantages and evoke stronger brain responses (Citron, 2012; Kensinger & Schacter, 2006). The literature indicates that complexity contributes to these findings. When controlling for complexity, Schlochtermeier and colleagues

(2013) did not replicate this effect, suggesting that a picture's perceptual complexity may account for its increased emotional brain response compared to a word. Pictorial stimuli usually depict complex sceneries or facial expression, which are presented statically or dynamically. They produce powerful responses in emotional brain regions (Britton et al., 2006), engaging processes related to the depicted content in face, object or social processing regions. Compared to photos of facial emotional expressions, photos of natural sceneries show specific activations in the lateral occipital cortex and thalamus as well as common activations in emotional networks. Faces, on the other hand, activate specific regions such as the FG and the STS (e.g., Sabatinelli et al., 2011). Increasing their complexity and realism by presenting facial expressions dynamically rather than statically, results in more pronounced activations for dynamic emotional expressions. They are reported to evoke stronger activations in regions, such as AMY, MTG, FG, STS and IFG, which together with findings of faster and better emotion recognition responses, have been attributed to emotional responding being facilitated through increased facial, movement or social processing (review: Arsalidou et al., 2011; meta-analysis: Krumhuber et al., 2013).

4.2.3 Dynamic audiovisual stimuli: Silent film clips, audiovisual movies and 3D movies

Apart from short sequences of facial expressions, several stimulus sets taken from fictional movies have been developed with the aim to induce powerful emotional responses on behavioral and brain level (e.g., Schaefer et al., 2010). Regarding neural correlates of emotions elicited by film, Goldin colleagues (2005) report different emotional networks for sadness including activations in MPFC, IFG, STG, and AMY, and happiness including medial frontal gyrus (MFG), IFG, dorsolateral PFC, temporal lobes (TL), and the caudatus (CAUD). Film stimuli have been used without sound, but also, increasing the stimulus' complexity, with music or including the complete, movie composition. When comparing uni- and multimodal stimuli, several studies report emotional modulations in regions associated with cross-modal convergence in the TL for multimodal stimuli (e.g., Klasen et al., 2012; Eldar et al., 2007) as well as stronger

responses in limbic and paralimbic structures, for congruent facial and vocal emotion expressions (e.g., Dolan et al., 2001). It is reported that emotional multisensory information is integrated at multiple levels, from unisensory cortices to higher order association areas (Klasen et al., 2014; Pehrs et al., 2014), which may lead to additive emotional effects (Zaki, 2013). Beside emotional brain activations, networks related to simulation and mentalizing are reported during empathic engagement in audiovisual movies (Raz et al., 2014), as well as correlations of subjective valence ratings with activations in emotion and sensory simulation regions (Viinikainen et al., 2012). Revealing the powerful emotional effects of film stimuli, Nummenmaa and colleagues (2012) showed that while viewing movies their valence modulated widespread synchronizations in emotion and simulation networks, and arousal modulated activation of dorsal attention networks.

4.2.4 Interactive settings and virtual environments

A recent plea to overcome the spectatorial perspective of participants passively watching, reading or listening to emotional or social situations, has lead to the introduction of methods that include virtual, real-life and interactive settings (Schilbach et al., 2013; de Gelder & Hortensius, 2014; Hasson & Honey, 2012). Several studies indicate that the inclusion of bodies, interaction, a further spatial dimension, or further modalities changes the way emotions are processed. Research on emotions in multimodal settings points to the relevance of all human senses for emotion processing (Klasen et al., 2014). Pleading for the inclusion of bodies in naturalistic emotion research, de Gelder and colleagues (2015) reported that the observation of bodily expressions activates more brain areas compared to facial expressions, including the FG and motor-related areas. In addition, the variation of spatial proximity modulates activation in visuospatial brain regions in threat situations indicating that a spatial dimension may add to the understanding of social emotions (Lloyd & Morrison, 2008). Using video games, Mathiak and colleagues (2013) showed that emotional as well as spatial and self-referential regions played a role in complex affect changes in a virtual environment, while active engagement in a video game

influences striatal (CAUD, PUT) reward circuits (Kätsyri et al., 2013). Interactive compared to passive perspectives are suggested to differentially involve simulation networks (Schilbach et al., 2013), indicating that besides recruiting additional brain areas and facilitating emotional responding, interactive or virtually realistic settings, as compared to passive perceptive ones, might change how we understand another person's feelings or thoughts and thus change the way we evaluate and experience emotional situations.
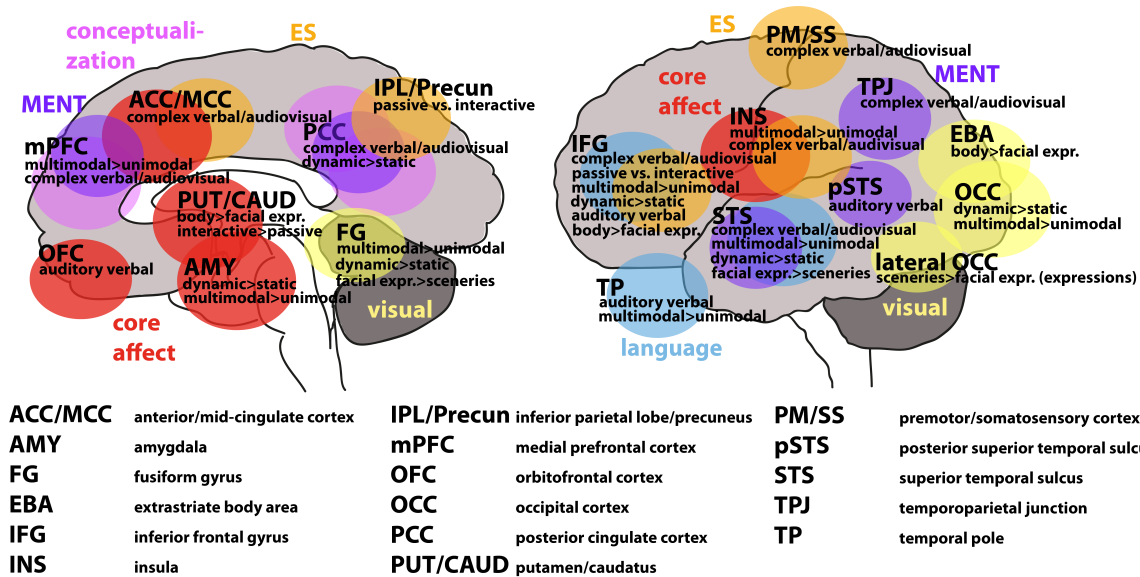

ACC/MCC	anterior/mid-cingulate cortex	**IPL/Precun**	inferior parietal lobe/precuneus	**PM/SS**	premotor/somatosensory cortex
AMY	amygdala	**mPFC**	medial prefrontal cortex	**pSTS**	posterior superior temporal sulcus
FG	fusiform gyrus	**OFC**	orbitofrontal cortex	**STS**	superior temporal sulcus
EBA	extrastriate body area	**OCC**	occipital cortex	**TPJ**	temporoparietal junction
IFG	inferior frontal gyrus	**PCC**	posterior cingulate cortex	**TP**	temporal pole
INS	insula	**PUT/CAUD**	putamen/caudatus		

Figure 4.1: Illustration of emotion effects. Main differences in emotion effects between the various media types and specific emotion effects evoked by more complex media types (as described by overview articles or the majority of single studies). For clarity, regions are assigned to the networks adapted from the constructivist model by Lindquist colleagues (2012) and descriptions of mentalizing (MENT) and embodied simulation (ES) networks by Gallese & Guerra (2012), Schilbach and colleagues (2013) and Raz and colleagues (2014), coded with different colors (core affect: OFC, ACC, PUT/CAUD, AMY; conceptualization: PCC, mPFC; visual: OCC, FG; language: IFG, TP, STS; mentalizing: TPJ, STS, mPFC, PCC, embodied simulation: IFG, IPL/PRECUN, INS, ACC/MCC, PM/SS (premotor/ somatosensory cortex). It should be noted that this is a simplification, i.e. only key brain regions are depicted and the networks do overlap.

In all, hard and fast distinctions between the processing of emotional information in different media types are conceivably difficult. Rather, the literature suggests a complex interplay of emotional information with language and sensory properties of a stimulus (a tentative overview of processing differences is illustrated in Figure 4.1). While common activations in core affective regions are consistently reported, emotional information engages several specific processes related to the setting, such as speech, language, movement, object and face recognition as well as multimodal integration, mentalizing, simulation and empathizing. Such interactions of emotional responses with the medium or setting may be interpreted within constructivist accounts of emotion (Kober et al., 2008; Lindquist et al., 2012; Wilson-Mendenhall, 2013). Latter theories propose that emotional experiences recruit situation-specific distributed modal systems of the brain, including the perception of the external environment, internal bodily sensations, and mentalizing, which may explain the media-specific involvement of sensory, sensorimotor or mentalizing processes for emotional processing. Providing a framework for the role of language in emotion processing, Kölsch et al.'s Quartet Theory (Kölsch et al., 2015) appears to be the first to include language in its model of the human emotion system. It proposes that language may function to communicate, evoke or regulate emotions. Beside stimulus-specific brain activations, the above-presented research suggests some processing advantages in the sense of behavioral advantages and additional and more pronounced emotional brain activations for more complex materials. If emotional information is presented in more than one modality (Klasen et al., 2014) or includes movement (Krumhuber et al., 2013), the additional information is integrated in multisensory brain regions, probably facilitating emotional responses, as shown by advantages in emotion recognition and increased connectivity with and activations in emotional brain regions (Zaki, 2013; Klasen et al., 2015; Wilson-Mendenhall et al., 2013). In a similar vein, information gained within dynamic interaction and from an additional spatial dimension is suggested to facilitate and modulate the understanding of other people and emotional responding (Schilbach et al., 2013; Gallese & Guerra, 2012), while music and affective prosody in language induce sensations directly

(Koelsch et al., 2015; Koelsch, 2014). Beside some advantages of more complex materials, the reported studies show that more realistic stimuli as well as purely symbolic language or artificial movies, are able to elicit reliable and strong emotional responses.

Along this line, several studies even suggest that especially fictional settings or artificial movies may have a high emotional impact due to their potential to let the reader simulate a story world (Altmann et al., 2014) or create a sense of reality (Gallese & Guerra, 2012), by recruiting the brain's mental and embodied simulation systems. Immersion, the concept of being absorbed by or diving into an artificial world (Jacobs, 2015a,b; Hakemulder, 2013; Hsu et al., 2014; Jacobs, 2011) provides a framework for this phenomenon. Its role for emotional engagement, its relation to realism and its neural mechanisms in different stimulus categories is therefore discussed in the next section.

4.3 Immersion

First of all it should be noted that the concept of immersion is far from unified (Jacobs, 2015). It has been defined as the psychological state of constructing a mental picture of and being transported into and absorbed by a story world (e.g., Appel & Richter, 2010; Hakemulder, 2013; Ryan, 2001; Schrott & Jacobs, 2011). Immersion potential in this context refers to the potential of a medium to induce immersive processes (Ryan, 2001; Jacobs, 2015a,b). A slightly different position, suggested by Slater (2003), states that immersion should refer to the technological property of a medium to make an artificial setting seem real, whereas the psychological response should be referred to as *feeling of presence*. While still lacking a unified conceptualization, immersive processes have been reported to being highly correlated (Jacobs, 2015) and interrelated bi-directionally with emotional engagement (Riva et al., 2007). To better understand the relation of emotional engagement, immersion and realism, Blascovichs' social threshold model (2002) may be helpful. It proposes that

the degree to which an artificial, immersive setting impacts a participant cognitively or emotionally can be referred to as social influence. Social influence, here, is determined by the subjective belief that characters are real (social presence), together with the degree that a presented behavior is realistic (behavioral realism). In other words, the immersion potential of a medium, the realism of the presented behavior, and the emotionality of the content, determine the degree of emotional engagement. In this sense watching a beach ball could be comparably engaging as watching a real human being, if the setting was immersive and its behavioral aspects realistic and emotional (Blascovich, 2002). Supporting the notion that characters do not have to be real to have an emotional impact, studies have shown that expressions of emotions in avatars are perceived and processed similar to human emotions (Moser et al., 2007; de Gelder et al., 2015). It is worth noting that the immersion potential of written narratives can be high beyond objective realism (Green, 2004) and was even reported to being the highest compared to film and music (Hakemulder, 2013). This issue is being tackled by an ongoing discussion on neurocognitive mechanisms underlying immersion and the sense of presence as well as on technological or compositional factors that may modulate the immersion potential of a medium. According to Ryan (2001), the most likely subjective cause for immersion in verbal narratives is theory of mind. It is also suggested to rely on symbol grounding, the grounding of language in sensory-motor brain areas (Barsalou, 2003) or the closely related concept of neuronal re-use (Anderson, 2010; Ponz et al., 2014), the functional re-use of brain areas, originally related to face, pattern and object recognition, for language (Schrott & Jacobs, 2011). With regard to movies, it has similarly been suggested that their *reality effect* relies on embodied simulation (Gallese & Guerra, 2012). In a similar line, presence in immersive virtual settings is proposed to rely on embodiment processes (Costa et al., 2013), which here may lead to multisensory body ownership illusions, the belief that virtual body parts are one's own (Slater & Sanchez-Vives, 2014). In virtual environments, sensory enrichment, visual scale or haptic feedback, have been proposed to increase the sense of presence by facilitating embodiment processes (Anderson, 2010). In literature, inducing fiction feelings like empathy, sympathy,

identification, suspense, or vicarious fear or joy facilitate immersion (Jacobs, 2015), as evidenced by activations in mentalizing regions being enhanced by fictional rather than realistic contextual knowledge (Altmann et al., 2014) and suspenseful plot (Hakemulder, 2013; Jacobs, 2015a,b; Lehne et al., 2015). Backgrounding elements of a story or poem, such as familiarity or situational embedding also facilitate immersion in reading, while in movies, compositional features may enhance immersive processes by facilitating embodiment (Gallese & Guerra, 2012). Prototypical facial expressions or close-ups of faces, for example, may enhance facial emotional processing (Arsalidou et al., 2011; Hasson et al., 2004). Attractive faces capture visual attention (Leder et al., 2010) and close-ups of tools engage motor simulation (Hasson et al, 2004). Bakels (2014) suggests that lighting, frequency of cuts, or changes in camera angle modulate embodied simulations. To illustrate our assumption that less realistic language stimuli as well as more realistic settings have a high immersion potential, Figure 4.2 shows the hypothetical immersion potential of the different stimulus categories in relation to realism and complexity in a 3-D space.
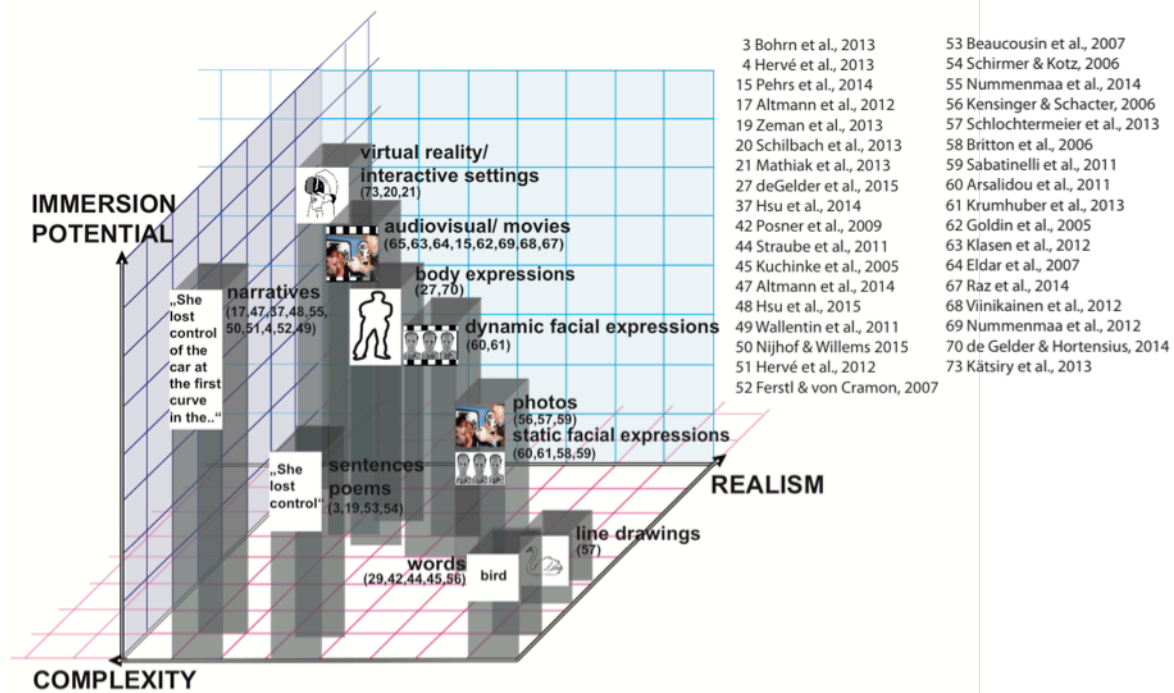
Figure 4.2: Hypothetical immersion potential of different stimulus categories. The graph illustrates the hypothetical immersion potential of the discussed stimulus categories (and studies using the materials for emotion induction) in relation to realism and complexity in a 3-D space. It should be noted that the localization of the categories in the 3-D space is not based on conclusive empirical findings. It rather represents a heuristic hypothesis, based on the literature on immersion and illustrates our assumption that perceptually non-realistic, complex language stimuli as well as very realistic settings may have a high immersion potential.

4.4 Conclusion and outstanding questions

This article summarized recent neuroimaging findings focusing on emotion processing in more complex or realistic materials. All considered media types evoke reliable emotional responses, involving manifold brain networks. Media-specific activations are reported in sensory and socio-emotional regions related to mentalizing and embodied simulation. Additional brain activations and a modulation of socio-emotional effects are found for dynamic, multimodal and interactive stimuli. Further, aesthetically composed movies, as well as materials that rely on our

imagination, such as narratives or scripts, are able to evoke strong emotional responses. We therefore propose that the *immersion potential* of a given stimulus material is a crucial factor determining emotional responses in different media settings. Specific technological or compositional features of a material/medium and its context control its immersion potential, e.g., by facilitating mentalizing and embodiment processes. Experimental evidence for neural correlates of the psychological state of immersion (Hsu et al., 2014; Wilson-Mendenhall et al., 2013), and the significance of simulation processes for passive compared to interactive settings (Schilbach et al., 2013) are still scarce and inconclusive. In sum, the current literature highlights the importance of investigating the emotional impact of imaginative and passive perceptive as well as interactive or real-life settings, to advance our understanding of the human emotion system. Differences in the processing of and interactions between media types may help understand the complex interplay of symbolic language and pictures as well as of self-referential and (inter-) action-related aspects for emotion processing.

5. General discussion and outlook

The main objective of this dissertation project was to investigate the differences and similarities between emotion processing in different media types. One main research question revolved around the processing of pictorial and verbal material and potential domain-specific emotional processes. Based on literature suggesting powerful emotion effects of more complex and multimodal stimulus materials such as movies, the second main research question focused on the mechanisms underlying the dynamic unfolding of emotional response in multimodal movie stimuli. The third main research question of this project dealt with explanations for the similarities and differences in the emotional impact of different media types and potential modulating factors. To capture emotional responses to words, pictures and movies, two experimental paradigms were developed. The first experiment focused on the question of domain-specificity of emotional processing. It compared emotional responses to pictorial and verbal stimuli while controlling the material for complexity. The second experiment was designed to investigate the emotional responses unfolding dynamically in movies. To study the psychological and neural mechanisms, we used rating procedures and fMRI. In order to describe the emotional impact and modulating factors of different media types, the third study consisted of a literature review, which provided an overview of neuroimaging studies and discussed the potential modulating role of realism, complexity and immersion.

5.1 Domain-specificity of emotional responses

The first main result of this dissertation project was that verbal material, although highly symbolic, evoked equally strong emotional brain responses compared to pictures, and that brain responses to more realistic pictorial stimuli were modulated by perceptual stimulus features. When controlling the material for complexity, no clear advantage in core emotion regions was found for the pictorial

stimuli, while the verbal stimuli showed a valence effect in the AMY (see Figure 5.1 A). This was in contrast to earlier reports in the literature (Kensinger & Schacter, 2006) and supports the assumption of a high emotional potential of words (Jacobs et al., 2015). Furthermore, several domain-specific valence effects were revealed, mainly in visual regions for pictures and language regions for words (see Figure 5.1 B). As discussed in chapter 2, this involvement of domain-specific brain regions was interpreted in line with accounts of experience-based simulation, which assume a close connection of sensory processes and emotions (Niedenthal et al., 2009; Barrett & Lindquist, 2008; Kousta et al., 2011; Pessoa, 2008).
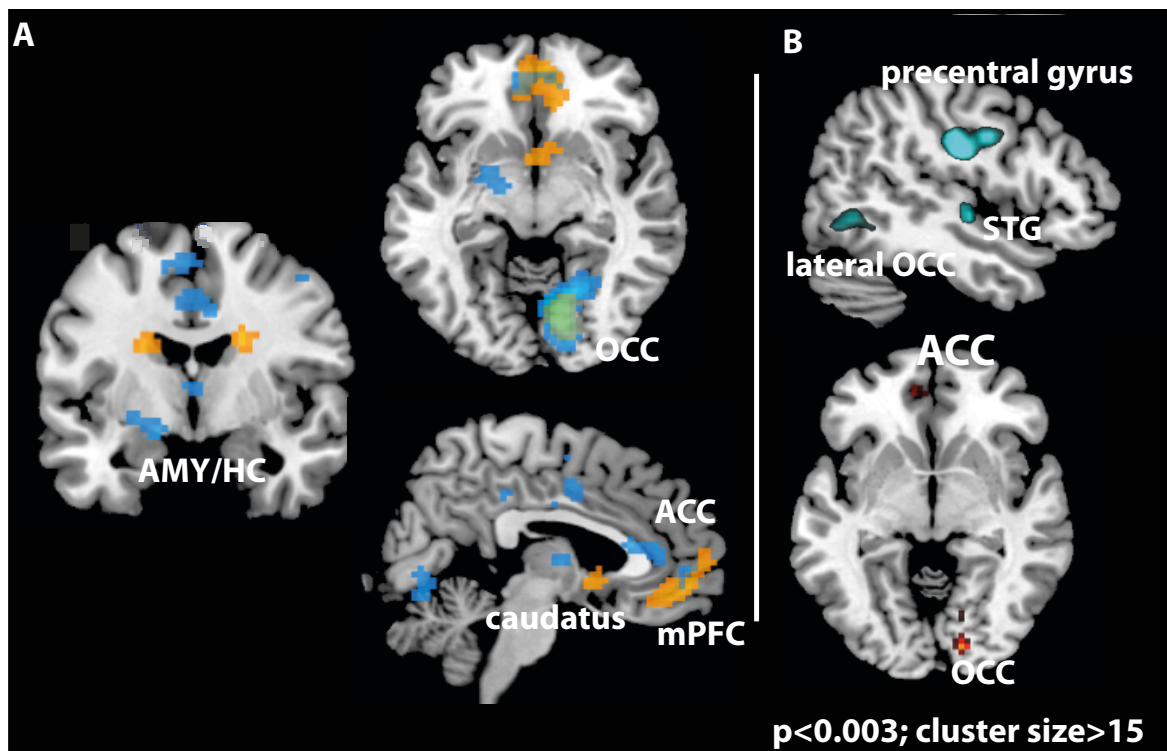

Figure 5.1: Effects of valence and interaction of valence and modality. A shows the BOLD responses for effects of positive valence for words and phrases in blue and photos and pictograms in orange; **B** shows the interaction of valence and modality, with verbal (positive > neutral) > pictorial (positive > neutral) in blue and pictorial (positive > neutral) > verbal (positive > neutral) in red.
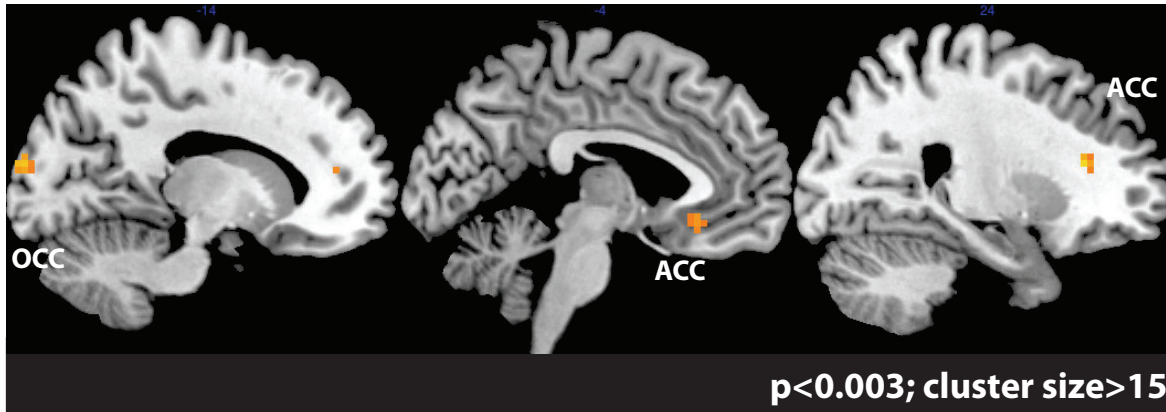
Figure 5.2: Interaction of complexity and valence. BOLD responses for photos (positive > neutral) > pictograms (positive > neutral) are shown.

To investigate the role of complexity for the emotional responses, interaction effects of complexity and valence were calculated, which were significant for the pictorial material, revealing activation differences in the prefrontal cortex (ACC) (photos versus pictograms, see Figure 5.2). This was interpreted in the sense that perceptual features such as visual complexity modulated the emotional impact of more realistic pictorial stimuli. The findings were in line with the results of another study conducted in our group. In an ERP-study using a similar paradigm, Tempel and colleagues (2013) report an emotional superiority effect for words compared to pictograms. The study used a valence-rating task to assess the emotional impact of pictograms and words, revealing comparable early ERP-responses. Later valence effects however were smaller for pictograms, while the effects of the words were characterized by a larger and more widespread scalp distribution. This was attributed to the potential of words to trigger the imagination, while perceptual information in pictograms is reduced, requiring additional processing effort. In a similar vein, the complexity effect of the pictures in the fMRI-study may be attributed to more realistic photos being processed more directly, facilitating the reactivation of experience-based emotional respresentations (Barsalou, 2008; Decety & Grèzes, 2006; Kousta et al., 2011), compared to pictograms. Potential mechanisms underlying the processing of symbolic and more realistic emotional information were further evaluated in the third study and will be discussed in section 5.4.

5.2 Dynamic unfolding of emotional responses

Another main finding of this dissertation project was in relation to the psychological processes and neural mechanisms underlying the dynamic unfolding of affective information in movies. This was studied in the second study in chapter 3 of this dissertation project. It revealed temporal patterns of sadness ratings of emotional movie scenes as predicted by film analytic models, which assume that emotional responses to movies unfold within their aesthetic and plot composition (Kappelhoff & Bakels, 2011; Kuchinke et al., 2013). Against our prediction, sadness ratings of climax excerpts did not differ significantly between context conditions, which we attributed to the rating procedure and complexity of the stimulus material. As hypothesized, brain responses to the emotional film scenes were modulated by the dynamic movie context, in anterior and posterior cortical midline regions (see Figure 5.3) and their coupling with temporal and posterior (multi)-sensory regions as well as reward-related areas (see Figure 5.4). These findings supported the involvement of midline regions in contextual and socio-emotional processing in movies, as was previously reported in the literature (Hasson et al., 2008b; Nummenmaa et al., 2012; Kauppi et al., 2010). This is in line with the assumption that complex network dynamics are the functional basis for the integration of dynamic socio-emotional information.
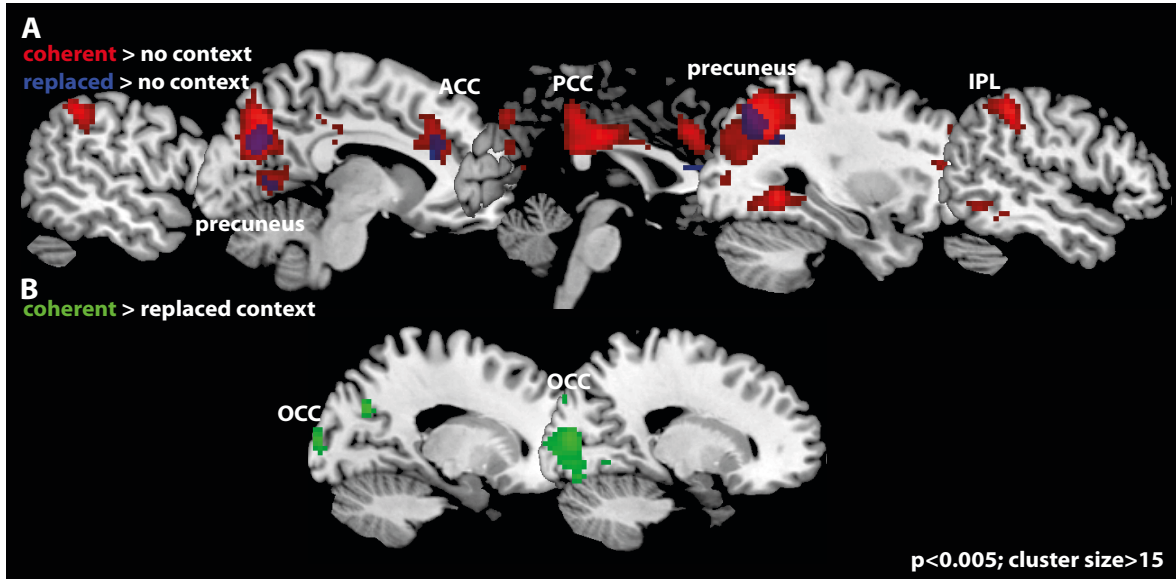
Figure 5.3: Effects of context for **A)** coherent versus no context and **B)** coherent versus replaced context.
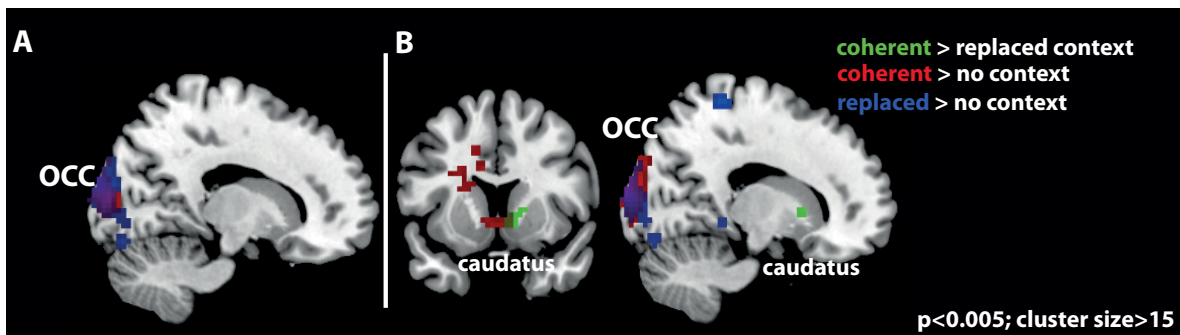

Figure 5.4: Psycho-physiological interactions (PPI) with seeds in **A)** PCC and **B)** ACC for coherent versus replaced context in green, coherent versus no context in red and replaced versus no context in blue.

The contextually modulated interplay of midline, visual and reward-related brain regions demonstrated the pivotal role of intrinsic, midline structures and their interaction with extrinsic, perceptual and reward areas in processing contextually embedded socio-emotional information in movies. Co-activations of intrinsic and extrinsic processes have been suggested in the context of immersive experiences (Golland et al., 2008; Christoff, 2012), real-life social experiences (Pehrs et al., 2015) or immersion in imaginative social scenarios (Wilson-Mendenhall et al., 2013). By co-

occurrence and dynamic interplay of perceptual, midline and reward areas, viewers empathize and feel with the contextually embedded emotional scenery as if they were in a real social situation. Relating this to Balázs words (1938), it could be said, that by involving brain networks similar to real life scenarios, the viewers are able to perceive the events of the movie through the eyes of the actors. As predicted by models of film reception, (Kappelhoff & Bakels, 2011; Kuchinke et al., 2013), we concluded that the narrative, aesthetic and kinetic content in movies is dynamically composed to create an emotional viewing experience and a sense of reality (Gallese & Guerra, 2012; Curtis, 2008; Curtis & Voss, 2008).

5.3 Mechanisms and modulating factors of processing emotional information in different media types

The third chapter focused on summarizing the emotional impact of different types of media. It reviewed recent neuroimaging findings in order to illustrate differences in emotion processing between media types and the development toward more complex and realistic materials. The literature research was able to provide an overview of a vast range of brain processes activated by emotional information in different media types. Beside core emotion regions, language, visual, auditory or multisensory, as well as reward, mentalizing and mirroring regions were reported. It also found several studies that reported advantages for more complex materials, and an increase in emotional brain responses for multimodal or dynamic stimuli. In the context of embodied or constructivist accounts of emotional responding (e.g., Barrett & Lindquist, 2008; Wilson-Mendenhall et al., 2013) we concluded that the different emotional stimulus materials recruit distributed modal systems including the perception of the external environment, internal bodily sensations, and mentalizing. The involvement of language regions we interpreted in line with the Quartet theory of emotion (Kölsch et al., 2015), which suggests a close connection and interaction of emotional and symbolic information. Advantages of more complex, dynamic or multimodal materials were usually interpreted by the literature in the sense that if an

emotional experience includes more than one modality (Klasen et al., 2012; 2014; Zaki, 2013) or movement (Krumhuber et al., 2013), it involves additional neural processes, while responses in core emotion regions may be facilitated. In a similar vein, additional information gained from interaction and the further spatial dimension in virtual settings has been suggested to facilitate and modulate the understanding of other people and emotional responding (Schilbach et al., 2013; de Gelder, 2009). This was explained in the context of a social cue integration account (Zaki, 2013), which predicts that the emotional information from the different sources is integrated in specific hub regions of the brain, leading to additive emotional effects. Regarding realism, the summarized findings were far from clear-cut. Some advantages for more realistic material are reported, while there are also indications of advantages for fictional (Altmann et al., 2012) or aesthetically composed stimuli (Gallese & Guerra, 2012; Hasson et al., 2004). In this line we proposed that rather than objective realism, the potential of a medium to create a sense of reality is a crucial moderator for responses to emotional content in complex media.

5.4 A crucial role for immersive processes in emotional media reception

In the general introduction of this dissertation project I discussed humans using different types of media, pictures, symbols, written stories, plays and movies, to communicate their thoughts and feelings. The different types of media all have in common that they make the recipients dive into artificial worlds as if they were real. In chapter 4 we propose that this phenomenon is crucial for emotional responses to media stimuli. It has been framed in the context of immersion, a psychological state that is related to processes like absorption, flow or suspense (Jacobs, 2015a,b). Jacob's dual-route model distinguishes between immersive and aesthetic processes, which are based on foregrounding and backgrounding text elements, respectively (Jacobs, 2015a,b). In his film theory, Balázs (1938) has termed the movie viewing experience, of seeing a movie through the movie character's eyes, as immersion. As described in

chapter 4, immersion has since been defined as the psychological state of constructing a mental picture of and being transported into and being absorbed by a story world (e.g., Appel & Richter, 2010; Hakemulder, 2013; Ryan, 2001; Schrott & Jacobs, 2011; Jacobs, 2015a). The potential of a medium to induce immersive processes is often referred to as immersion potential (Ryan, 2001; Jacobs, 2015a,b). Defining immersion in the context of virtual reality, Slater (2003) takes a slightly different position and states that immersion should refer to the technological property of a medium to make an artificial setting seem real. The psychological response should accordingly be referred to as *feeling of presence*.

The chapter also discussed several mechanisms that underlie immersive processes in different media types. In reading immersion has been suggested to rely on theory of mind (Ryan, 2001). It is further suggested to rely on symbol grounding, the grounding of language in sensory-motor brain areas (Barsalou et al., 2003) or the closely related concept of neuronal re-use (Anderson, 2010; Ponz et al., 2014), the functional re-use of brain areas, originally related to face, pattern and object recognition, for language (Schrott & Jacobs, 2011). Immersion in movies has been proposed to rely on kinetic effects which create a somatic involvement as well as on imaginative effects of transfering the disembodied self into the filmic world (Curtis & Voss, 2008; Curtis, 2008). Gallese and Guerra (2012) suggest that the "reality effect" of movies relies mainly on embodied simulation, or mirroring. Presence in immersive virtual settings is similarly proposed to be based on embodiment processes (Costa et al., 2013), which here may lead to multisensory body ownership illusions, the belief that virtual body parts are one's own (Slater & Sanchez-Vives, 2014). The neural correlates of the subjective feeling of being immersed has so far only been studied in reading of fearful texts, where it was correlated with activity in the medial ACC (Hsu et al., 2014). In regard to virtual settings, Clemente and colleagues (2013) report a correlation of the postcentral parietal cortex and the insula with sense of presence. We further discussed a range of stimulus features that may increase the immersion potential of different media types, by facilitating embodied cognition, mentalizing and

sensory-motor simulation processes. In virtual environments, sensory enrichment, visual scale or haptic feedback, have been proposed to increase the sense of presence by facilitating embodiment processes (Costa et al., 2013). In literature, inducing fiction feelings like empathy, sympathy, identification, suspense, or vicarious fear or joy facilitate immersion (Jacobs, 2015b), as evidenced by activations in mentalizing regions being enhanced by fictional rather than realistic contextual knowledge (Altmann et al., 2014) and suspenseful plot (Hakemulder, 2013; Jacobs, 2015a,b; Lehne et al., 2015). Backgrounding elements of a story or poem, such as familiarity or situational embedding also facilitate immersion in reading (Lüdtke et al., 2014). In movies, compositional features may enhance immersive processes by facilitating embodiment (Gallese & Guerra, 2012). Attractive faces for instance capture visual attention (Leder et al., 2010) and close-ups of tools engage motor simulation (Hasson et al., 2004). Prototypical facial expressions or close-ups of faces may enhance facial emotional processing (Krumhuber et al., 2013; Hasson et al., 2004). On a more basic perceptual level, Bakels (2014) suggests that lighting, frequency of cuts, or changes in camera angle modulate embodiment processes dynamically during movie viewing.

5.5 Conclusions and future directions

This dissertation project provided new insights on emotional media reception on several levels. The first fMRI study confirmed the assumption that simple words, although highly symbolic, can evoke powerful emotion effects (Schrott & Jacobs, 2011; Jacobs, 2015a,b) comparable to more realistic pictorial stimuli. It further showed that domain-specific perceptual stimulus features, such as visual complexity, modulate emotional brain responses. It hence emphasizes the emotional and imaginative power of language (Ryan, 2001; Jacobs & Schrott, 2015) as well as a potential emotional advantage of more realistic and complex photos as compared to simple pictograms. The second fMRI study emphasizes the modulatory input of compositional context dynamics and the unfolding of emotions in response to dynamically composed audiovisual stimuli. The revealed co-occurrence and dynamic interplay of perceptual,

midline and reward areas in response to contextually embedded emotional movies may make viewers' immerse (Christoff, 2012), empathize and feel as if they were in a real social situation (Pehrs et al., 2015). The results provide support for predictions made by models of film reception (Kuchinke et al., 2013; Kappelhoff & Bakels, 2011; Gallese & Guerra, 2012), which assume that the dynamic unfolding of emotional responses to movies is based on fictional and aesthetic processes during viewing (Kuchinke et al., 2013; Kappelhoff & Bakels, 2011) and that they are composed to create a sense of reality (Gallese & Guerra, 2012; Balász, 1938). By summarizing the empirical literature, the third study described the modulating role of factors, such as complexity, for emotional responses to different media types. This provides a basis for the formulation of predictions regarding the impact of domain-specific or perceptual features for the emotional impact of a medium. By highlighting the role of multimodal and dynamic processes, it supports the relevance of integrating the dynamic interaction of components of mental activity into emotion models (Jacobs, 2012). In line with models of media reception (Schrott & Jacobs, 2011; Jacobs & Schrott, 2015; Jacobs, 2015a,b; Balász, 1938; Curtis, 2008), it provides further support for the crucial role of immersive processes when engaging in emotional content in media stimuli. These were discussed to be moderated by compositional features and rely on mechanisms related to mentalizing and embodied simulation. In all, the results may help specify predictions regarding

A) the emotional impact and dynamic interaction of narrative, aesthetic and domain-specific features of a medium

B) the resulting dynamic interplay of (multi-) sensory, core affect, reward, mirror and mentalizing systems on neural level as well as

C) immersive and aesthetic processes on psychological level.

The aim of this dissertation was to investigate mechanisms of emotional media reception. Considering that a big part of our present-day lives takes place in emotional media contexts their emotional impact in itself is of high interest. Insights into the emotional impact of media is however also of great value in regard to therapeutic

interventions, which make use of immersive media settings for exposure therapy (e.g., Morina et al., 2015; Gonçalves et al., 2012) or aim to promote an individual's socio-emotional abilities (Delano & Snell, 2006; Litras et al., 2010). Beside beneficial effects for therapeutic or educative interventions, knowledge about media-related immersive and emotional processes is highly relevant for problematic media use, for example in Internet or gaming addiction. With the recent development of new immersive media environments (Brown & Bobkowski, 2011) they have become a growing social issue (Cash et al., 2012; Kuss et al., 2014). The rewarding nature of interactions (Schilbach et al., 2013; Cole & Griffiths, 2007) in gaming and the simulation of alternative anonymous realities in passive media environments or the Internet have been discussed as main reasons for the addictive power of immersive media settings (Cole & Griffiths, 2007).

While providing useful insights for a range of research fields, another merit of this dissertation project was to open the ground for several new questions. To better understand the human emotion system, it pointed to the importance of studying different mechanisms underlying the processing of emotional information in symbolic, imaginative as compared to more realistic materials. Furthermore, to understand how emotional responses may evolve within complex socio-emotional events, future research may continue investigating how movies or other complex media input recruits brain regions dynamically, and modulate switching and interactions between intrinsic and extrinsic networks. The inclusion of effective connectivity analyses and inter-subject correlation analyses would provide insights into interactions of brain regions and specific network dynamics. To further explore beneficial as well as detrimental effects of media usage, the immersion potential of different media types and factors that modulate their immersive potential as well as neural correlates of the psychological state of immersion should be further studied. Regarding the plea for a second person perspective in social neuroscience (Schilbach et al., 2013), as discussed in chapter 4, another important aim of future emotion research should be to focus on virtual and interactive settings.

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Appendices

A   List of films used for the stimulus material in study 2

Film	Begin (h:min:sec)	End (h:min:sec)	Director	Actors
1. 4 Christmases (2008)	1:03:48	1:05:04	Seth Gordon	Reese Witherspoon, Vince Vaughn
2. The accidental husband (2008)	1:05:20	1:06:34	Griffin Dunne	Uma Thurman, Jeffrey Dean Morgan
3. Because I said so (2007)	1:09:54	1:11:21	Michael Lehmann	Mandy Moore, Gabriel Macht
4. Blonde ambition (2007)	0:57:15	0:58:59	Scott Marshall	Jessica Simpson, Luke Wilson
5. Letters to Juliet (2010)	1:22:48	1:24:20	Gary Wineck	Amanda Seyfried, Christopher Egan
6. Cinderella Story (2004)	1:17:01	1:18:26	Mark Rosman	Hilary Duff, Chad Michael Murray
7. Failure to Launch (2006)	1:01:44	1:02:56	Tom Dey	Sarah Jessica Parker, Matthew Mcconaughey
8. Going the Distance (2010)	1:19:39	1:21:08	Nanette Burstein	Drew Barrymore, Justin Long
9. Good luck chuck (2007)	1:14:10	1:15:09	Mark Helfrich	Jessica Alba, Dane Cook
10. Hitch (2005)	1:42:40	1:43:49	Andy Tennant	Eva Mendes, Will Smith
11. How do you know (2010)	1:47:37	1:49:09	Roger Ebert	Reese Witherspoon, Paul Rudd
12. How to lose a guy in 10 days (2003)	1:35:11	1:36:33	Donald Petrie	Kate Hudson, Matthew Mcconaughey
13. Intolerable cruelty (2003)	1:14:47	1:15:58	Ethan Coen, Joel Coen	Catherine Zeta-Jones, George Clooney
14. Jerry Maguire (1996)	1:47:37	1:49:18	Cameron Crowe	Renée Zellweger, Tom Cruise
15. He's just not that into you (2009)	1:22:20	1:24:02	Ken Kwapis	Ginnifer Goodwin, Justin Long
16. Life as we know it (2010)	1:26:42	1:28:07	Greg Berlanti	Katerine Heigl, Josh Duhamel
17. Maid in Manhattan (2002)	1:21:53	1:23:05	Wayne Wang	Jennifer Lopez, Ralph Fiennes
18. Management (2008)	1:06:56	1:08:08	Stephen Belber	Jennifer Aniston, Steve Zahn
19. Post Grad (2009)	1:04:04	1:05:28	Vicky Jenson	Alexis Bledel, Zach Gilford
20. Sex and the City (2008)	0:48:43	0:49:54	Michael Patrick King	Sarah Jessica Parker, Chris Noth
21. The Bounty Hunter (2010)	1:39:26	1:40:26	Andy Tennant	Jennifer Aniston, Gerard Butler
22. The Ugly Truth (2009)	1:14:08	1:15:36	Robert Luketic	Katherine Heigl, Gerard Butler
23. Wedding Planner (2001)	1:12:35	1:13:48	Adam Shankman	Jennifer Lopez, Matthew Mcconaughey
24. Yes Man (2008)	1:13:49	1:14:51	Peyton Reed	Jim Carrey, Zooey Deschanel

B Curriculum Vitae

[Aus Gründen des Datenschutzes ist der Lebenslauf in der Online-Version nicht enthalten.]

144

C   Eidesstattliche Erklärung

Hiermit erkläre ich von Eides statt, dass ich für die Entstehung der Arbeiten hauptverantwortlich war und die Arbeit selbstständig und ohne unerlaubte Hifle verfasst habe.

Die Studien dieser Dissertationsschrift wurden in marginal modifizierten Versionen in internationalen Fachzeitschriften veröffentlicht oder befinden sich im Reviewprozess.

Zudem versichere ich hiermit, dass ich mich nicht bereits anderwärts um einen Doktorgrad beworben habe und die Arbeit in keinem früheren Promotionsverfahren angenommen oder abgelehnt worden.

Berlin, den 26.01.2016   Lorna Schlochtermeier