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Attentional and Neural Mechanisms Underlying the Trade-Off Effects of Negative Emotion on Memory

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1. Introduction

1.1. Emotional Episodic Autobiographical Memory - What Do We Remember?

What we can recall from our daily life experiences signifies those experiences as more important, more meaningful or otherwise exceptional. But what kind of episodes do we remember? What makes an experience important, meaningful or otherwise exceptional? Research on episodic autobiographical memory discerning characteristics of experiences that lead to durable memories has ascertained that emotionality is a key determinant (e.g., Berntsen & Rubin, 2002; Rubin & Kozin, 1984; Wagenaar, 1986; White, 1982). But while the role of emotion for an episode to be remembered per se has been ascertained, it is more complex to give accounts on the actual content of remembered emotional real-life experiences i.e., given an episode was emotionally arousing and thus will be retained per se, how much and what kind of information will actually be remembered?

1.1.1. Canonical Aspects of Autobiographical Memory

Investigations on the accuracy of emotional episodic autobiographical memory have strongly focused on surprising and arousing public events (cf., Christianson, 1992; Holland & Kensinger, 2011; Kensinger, 2009; Phelps, 2006; Reisberg & Heuer, 2004). In a seminal study on "flashbulb" memories, Brown and Kulik (1977) analyzed reports of participants recalling the circumstances when they first heard of 9 different shocking news: deaths, assassinations, or assassination attempts of public figures (e.g., John F. Kennedy, Robert F. Kennedy, Ted Kennedy, Gerald Ford) and memory reports of one personal "unexpected shock" (p. 79). Based on inspections of participants' narrations, the authors identified "six classes of information reported in 50 percent or more of the accounts" (p. 79). With this criterion the authors determined, that *place, ongoing activity, source, aftermath* and *own affect*, were "canonical" categories for public and for private events, and *affect in others* was additionally identified as "canonical" for public events. These aspects most likely constituted participants' memory of hearing shocking news and in this sense were called *canonical aspects* of what people remember from such a moment. With regard to the assassination of John F. Kennedy, the authors reported that 99% of the participants remembered the circumstance when they first heard about it "with an almost perceptual clarity, where he was, when he heard, what he was doing at the time, who told him, what was the immediate aftermath (and) how he felt about it" (p. 73), even after 12 years had passed. The authors labeled this extraordinary kind of memory as "flashbulb" memories, to allude to the perceptual clarity and vividness, by liken it to a flashlight that illuminates a past experience, a few moments printed like photography into memory. (For critical considerations regarding the accuracy and generalizability of *canonical aspects*, please see Appendix 1)

In a very recent study Kızılöz & Tekcan (2013) elucidated the issue of remembered content of "flashbulb" memories in more detail. This study is the first to report on investigations primarily aimed at replicating the finding of *canonical aspects* (cf., Christianson, 1989). Participants "were asked to write in as much detail as possible" (p. 354) of of three different "flashbulb" memories. Results across about 400 narratives revealed that 4 of the 5 *canonical aspects* postulated by Brown and Kulik (1977) were confirmed to be very often part of such memories. Reports on "flashbulb" memories most often described aspects related to: *source* (64.4%), *place* (58.3%), *ongoing activity* (47.6%), *own affect* (42.0%) and *aftermath* (38.3%). Additional classifications found *thought* (25.7%) and *others present* (21.5%) also relatively often in participants' memory reports. Further categories frequently but much less often referred to were: *affect in others* (10.4%), *activity before* (9.9%), *time* (9.0%), *first thing heard after event* (6.9%), *day of week* (5.9%), *first thing said after event* (5.7%), *weather* (2.7%), *change in ongoing activity* (1.7%) and *clothes* (1.0%). These results replicated, that a few classes of information exist that are most probably part of "flashbulb" memories. Generally such memories comprise information regarding how someone heard about the shocking news, where he was, what he was doing at that moment, how his emotional reaction was and what he did after hearing the news. Often some thoughts are remembered as well but other aspects are much less often reported. Only 1% of about 400 detailed narrations on "flashbulb" memories that had passed 3 to 7 years described memories of clothing and only 2.7% mentioned information about the weather. It could be, that participants did not report those details although they remembered the weather and their clothing as good, as they remembered where they were. But the results seem to suggest rather, that information less essential to the core of an emotional event will less probably be part of future memory. Emotional events are more probably remembered and the content of such memories tends to be strongly restricted to a few classes of essential information. It could be that emotional processes are of central relevance for remembering information of a few *canonical aspects* and that they are involved in not remembering information more peripheral to the core of an emotional real-life experience. Findings of a study (Schmidt, 2004) on "flashbulb" memories that analyzed memory consistency as a function of the intensity of the emotional reaction partially support these assumptions. Participants with strong emotional reactions to the terrorist attack on 9/11 showed less consistent memory for more peripheral aspects (i.e., *clothing*, *weather* and what they had for breakfast and for lunch at that day) than participants with moderate emotional reactions, while participants did not differ in consistency for more central aspects (i.e., *source*, *place* and *ongoing activity*).

1.1.2. Autobiographical Memory for Specific Details

Though *canonical aspects* may reflect most essential classes of memory reports, personal memories also contain very specific sensory details. It is important, to clearly distinguish findings referring to classes or aspects of narrative reports and the very specific visual, audititory and feeling details of these memories.

An example event that a person could encounter in daily life might be to witness a quarrel while standing lined up at the check stand in a nearby supermarket. A male middle-aged salespersons approaches a younger female salesperson. Obviously he is agitated, they have a dispute. Quite suddenly he tears the woman out of the check stand and violently drags her to the entrance. Outside the store the woman is slowly walking away from the entrance, she seems to be crying. What would a person remember of such an episode? Such an experience would probably be remembered as an unfolding event, as a relatively coherent episode, yet it would also consist of some specific visual details. Maybe some bodily and facial expressions, maybe some concrete acoustic memory of what they said to each other. A person would remember where this event had happened but he probably would also have some very specific memories of the context, for example memory of the check stand or of the entrance door.

In a survey-based study by Christianson and Loftus (1990), university students were asked to think of the most traumatic event they had experienced in their life*. Among others, participants rated how many relevant details (defined as a detail "relevant and directly associated with the traumatic event per se" (p. 196)) and "how many peripheral details (they) remembered from this event - details which were not necessarily relevant or not directly associated with the traumatic event per se." (p. 196). Analyses showed, that relevant details were rated to be rememberd more comprehensively (M = 2.36; 1 = few, 2 = many, 3 = almost all) than peripheral (M = 1.85). These ratings represent subjective estimates of the amount of remembered relevant and irrelevant details and suggest that participants estimate to remember quite many relevant details but also noteably more than a few irrelevant details which are more peripheral to the core of an event. In a second survey participants were also asked to think of the most traumatic event they had experienced. Among others participants were then asked "if there was a specific detail that they remembered much better than other details from the traumatic event". If so, participants had to judge whether this detail was "naturally central or peripheral to the core of the traumatic event" (p. 2). 82% of the recalled events involved such a detail. Surprisingly, participants classified only 57% of those as being central to the core of the traumatic event, while 43% were classified as being peripheral, not central to the core of the traumatic event. "This detail was very concrete in 70.5% of the descriptions (e.g., "how the doors behind her were closing ... in slow motion"; "an average leather jacket"; "two large rocks"; "backs of their helmets"; "X's face just before she hit me"; "the Doberman's head and teeth"; "the first moment I stepped up to the coffin .... she wasn't wearing the wedding ring which she never took off") p. 197 (cf., Wessel & Merckelbach, 1994).

But experiences are manifold, and multiple manifold are possible details that could constitute memory of an emotional experience and it is apparently difficult to interpret memory values from these studies as indicators for an objective fraction of remembered relevant and irrelevant details.

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*It was optional to describe the event but 65% of the participants gave descriptions. 12% of the narrations related to a death of a relative, 9% related to a divorce of parents or close friend, further experiences related to traffic accidents (9%), an injury or accident involving a relative or a friend, with half of these involving the death of a friend (11%), other psychologically stressful events, e.g., discovery of unfaithfulness, arrest, or a fight involving a close person (15 %), miscellaneous traumatic memories, e.g., shootings, sexual assault or dead bodies (6%), and incidents of a more physical character, e.g., skiing accident, broken arm or an appendix operation (3%).

1.2. Ecological Validity of Experimental Designs

Convergent validation of survey-based findings on autobiographical memories, that negative emotion has an enhancing effect on memory, can be seen in results of laboratory studies, showing that the probability to remember a stimulus per se is enhanced when it is emotional. This effect has been confirmed using diverse kind of stimuli like pictures (e.g., Bradley, Greenwald, Petry, & Lang, 1992), words (e.g., Kensinger & Corkin, 2003) or short movie clips (e.g., Cahill et al., 1996). Moreover has laboratory research profoundly shown, that only specific information of stimuli are actually affected by emotional enhancement effects, clarifying that the beneficial effects of emotion on memory is conditional and does not pertain better memory for all kind of information of a given experimental experience (cf., Kensinger, 2009; Levine & Edelstein, 2009; Mather et al., 2006; Mather & Sutherland, 2011).

Research on negative emotional real-life experiences strongly indicates to differentiate effects of emotion on memory (e.g., the event itself; differences in *canonical aspects*; specific details; relvance of information). But survey-based research on the accuracy of episodic autobiographical memory is especially complicated when aiming to delineate emotional effects for specific details of such experiences. Memory accuracy of real-life events can only be tested by relying on reports and retesting, severely limiting the scope of information that can be analyzed. Experimental studies can prevent these problems by inducing controlled emotional experiences. However, when addressing the issue, which aspects and what kind of details we remember from emotional episodes of our lives, and when investigating factors that may generally impact what we remember from the past, it is necessary to reflect the generalizability of findings that are based on artificial experiences and it is important to stress that experimentally induced experiences are ecologically restricted.

Early laboratory research addressing the issue to deliniate emotional effects on memory was thrived by seemingly contradicting findings of exceptionally long lasting and vivid "flashbulb" memories (e.g., Brown & Kulik, 1977) and doubts regarding the accuracy of such memories (e.g., Neisser & Harsch, 1992), and also fueled by ascertainments from eyewitness research, revealing not enhancing, but diminishing effects of negative emotion on memory (cf., Loftus, 1979).

To investigate the effects of negative emotion on memory for specific information early research operationalized experiences in the laboratory, by showing participants narratives via short movie clips or picture stories which varied (or varied in part) regarding emotionality. But more recent behavioral (e.g., Libkuman & Stabler, 2004; Melcher, 2010; Nobata, Hakoda, & Ninose, 2010; Riggs, Mcquiggan, Farb, Anderson & Ryan, 2011; Yegiyan & Lang, 2010) and brain imaging studies in this domain (e.g., Kensinger, Garoff-Eaton, & Schacter, 2007; Kensinger & Schacter, 2006; Mather et al., 2006) did not focus on ecological validity. Most of these studies used a set of unrelated stimuli depicting diverse natural scenes (e.g., from the International Affective Picture System (IAPS), Lang, Bradley & Cuthbert, 2008). And these more recent, scene driven studies furthermore differed from the thematically driven early research, in that "central" test-items were for example the picture itself, the central one-third of the picture area or a letter superimposed on the stimulus material for a short time, while more "peripheral" test-items were objects that were placed outside-around the pictures, the peripheral two-third of the picture area or digits presented outside-around the pictures, respectively. In the imaging studies, neural activity of subsequently remembered emotional (vs. neutral) single, unrelated stimuli was for example compared with neural activity of other subsequently remembered contextual details from the encoding situation, like the location of the (emotional vs. neutral) stimulus on the computer screen or memory for a decision task concurrently performed while encoding the (emotional vs. neutral) stimulus.

Studies using different kind of designs clearly enrich the understanding of differential effects emotion can have on memory and the neural bases thereof. Importantly, studies based on more artificial and thus, more controlled stimuli can better establish an understanding of the differential effects of emotion on memory within a broader context of related findings and theories of experimental research (for reviews, see Kensinger, 2009; Levine & Edelstein, 2009; Mather, 2007; Mather & Sutherland, 2011). But from an ecological perspective it is important, to bear in mind, that such stimuli do not (or only in a very restricted fashion) reflect episodic information encountered in real-life. They don't encompass information about where and what event took place, the temporal ordering of what happened and the meaning of an event. Yet, such information empirically represent what is most often remembered from emotional autobiographical episodes.

An interesting approach for investigations on what may be retained of emotional experiences is the construct *narrative coherence.* This general factor subsumes the few information that are retained of an emotional experience. *Narrative coherence* is derived from story schema models (e.g., Stein & Glenn, 1975) and of linguistic analyses of personal narratives (e.g., Burling & Labov, 1975). It is constructed to measure coherence of a narration regarding when, where, and what event took place. Importantly, the construct also measures the meaning or *theme* of an event. The *theme* of a narrative is measured by high points and resolutions, which are assessed by affective and evaluative information given in a report. "The reference function of narrative is to provide information to the listener about 1) the participants, 2) where and when a specified event took place, and 3) what happened. Meaningful stories, however, must go beyond simply narrating event actions and placing them in context. The second function of narrative is that of evaluation, which includes nonverbal and verbal expressions of emotion, emphasis, perspective, and insight. Evaluations are the core of personal narratives because they convey the significance of the event for the teller" (Reese et al., 2011, p.428). *Narrative coherence* seems to be a critical concept across studies using narrations but the empirical basis to elucidate relationships of *narrative coherence* and autobiographical memory is only beginning to be established (Reese et al., 2011). A recent study by Peterson, Morris, Baker-Ward, and Flynn (2014) investigated possible predictors for the survivability of 4 to 13-years-old children's memory depending on the dimensions constituting *narrative coherence: context* (i.e., where), *chronology* (i.e., temporal ordering of the event), and *theme* (i.e., inclusion of high points and resolutions, as well as affective and evaluative information). The dimensions of *narrative coherence* were measured with the NaCCS*, and further variables, including references to emotion were assessed as well. The authors found, that narrations containing a reference to emotion were 2.5 times more likely to be remembered again after 2 years compared to narratives containing no reference to emotions. Additionally, all dimensions of *narrative coherence* also predicted survivability of children's memory. Especially the dimension *theme* was found to be a potent predictor for retention.

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* Since there seems to be no agreed upon definition, Reese et al. (2011) offered a working definition, proposing "that a coherent personal narrative is one that makes sense to a naïve listener – not just in terms of understanding when, where, and what event took place, but also with respect to understanding the meaning of that event to the narrator" (p. 425). Theoretically derived from the extant literature, the authors constructed a coding scheme (NaCCS, Narrative Coherence Coding Scheme) for *narrative coherence* and the utility of the NaCCS was demonstrated by its application to 498 autobiographical memory narratives from participants ranging in age from 3 years to adulthood.

This dimension was coded on a scale ranging from 1 to 3 and each unit increase in *theme* made an event 5 times more likely to be retained over 2 years.

Complementary findings were reported in a study that investigated "flashbulb" memories from the moment when hearing about the 9/11 attacks in the USA (Talarico & Rubin, 2003). Memory was collected one day after the terrorist attack and compared to a freely chosen everyday event that occurred three days before, at longest (e.g., parties, sporting events, studying). Among others, participants were asked whether their memory came in words or in “pictures as a coherent story or episode and not as an isolated fact, observation, or scene” (p. 456). Analyses revealed, that “flashbulb” memories came as more "coherent stories" than everyday memories, also emphasizing the importance between a superordinate dimension like *narrative coherence* and the probability that an exceptionally long lasting memory with perceptual clarity of it's sensory details, a "flashbulb" memory, will be formed (but see, Talarico & Rubin, 2007).

Memories are comprised of concrete sensory details. It can be assumed that such specific details often relate to: *source*, *place*, *ongoing activity*, *own affect* and other *canonical aspects* of an experience. However, such a specific detail in itself does not need to be naturally relevant to the core of the experience, it often is a seemingly arbitrary, irrelevant specific detail, even if it referrs to a *canonical aspect*, for example an entrance door of a supermarket or a sunny bright window behind a television where shocking news are reported. This is no contradiction but rather denotes the difference between specific details (e.g., bright window) and classes or aspects (e.g., *place*). And both characteristics of autobiographical memory seem fundamental. Firstly memories of our daily-life have structure. Narratives of past experiences clearly show that the information of a past episode is "structured" regarding essential dimensions like where and what event took place, the temporal ordering of what happened and the meaning of an event. Secondly memory is a reconstruction containing specific sensory details. Experimental understanding of what it is, that we remember and what the neural basis of our memories are may thus benefit from ecologically oriented experiments on both, memory for relevant information of more complex stimuli depicting narrative episodes and also on memory for specific sensory details of these stimuli.

1.3. Experimental Research on the Effects of Negative Emotion on Memory

1.3.1. Effects of Negative Emotion on Memory

In early experimental laboratory research Christianson (1984) and Christianson and Loftus (1987) used thematically driven picture stories and also revealed differential effects of negative emotion on memory for details. The authors found an enhancement effect of negative emotion on memory for essential information but they also found diminished recognition memory for the very specific pictures participants had been shown. A story about a mother and her son was presented, and in the middle section of the negative condition pictures showed them walking in the streets, the boy gets hit by a car and is bleeding strongly. The neutral version showed the same persons passing the same car but no accident happens. Participants who watched the negative picture story remembered the essence and the main features of the story better, but in a 4 alternative-forced-choice recognition test depicting one picture of the incidental encoding session with 3 similar pictures, no enhancement effect (Christianson, 1984) or even worse memory (Christianson & Loftus, 1987) was found, suggesting two effects of negative emotion on memory, an enhancing effect for essential information and no, respectively a diminishing effect for more specific details. Findings supporting the assumption that negative emotion has diminishing effects of memory was also found in further studies (Clifford & Hollin, 1981; Clifford & Scott, 1978; Loftus & Burns, 1982), and some researchers suggested, that negative emotion may overall reduce the ability to remember details of an event (for a review, see Christianson, 1992). Clifford and Scott (1978) for example used a neutral and a negative violent movie clip each of about 1 minute duration. The clips were identical in the beginning and the ending but differed in the middle part of the movies. Both movies showed policemen searching and finding a criminal. The neutral condition depicted a verbal exchange between the persons involved, while the negative condition showed an escalating situation involving a shooting. Recognition memory was tested using a 40 items questionnaire and analyses revealed, that participants had worse memory for details in the negative condition. Or in another study by Loftus and Burns (1982), two versions of a movie clip were shown, each depicting a bank robbery. In the negative condition the clip showed a violent sequence where a boy was shot in the face while the neutral condition did not show this sequence but instead showed the manager calming customers and employees after the robbers had left the bank. In this study peripheral memory was only tested regarding one critical item. This item asked for a number that was printed on a t-shirt of an actor and participants in the more negative condition showed worse memory for this detail.

In reviewing earlier findings of experimental studies on memory for details of narrative stimuli, Christianson (1992) suggested to post-hoc differentiate results of previous laboratory studies into those regarding memory for information of central relevance and those regarding memory for more irrelevant information. With this differentiation an emotional enhancement effect on memory seemed to exist, but only regarding memory for information of central relevance. Additionally the studies indicated that the benefit in memory for centrally relevant information came at the expense of memory for more peripheral information.

Applied research on eyewitness testimony also indicates that negative emotion can have differential effects on memory for details. The presence of a weapon in a crime scene, for example, seems to have a negative effect on the ability to identify the perpetrator (a peripheral detail), while the weapon itself (the central detail) is remembered well. This effect is referred to as “weapon-focus” effect, to describe the assumption that attention in an armed crime is strongly focused on the weapon, restricting encoding of other details of the scene thus causing witnesses and victims of an armed crime to have diminished memory for other details and reducing the probability to correctly identify suspects or accurately remember other information, like the clothing of suspects (e.g., Loftus, 1979; Loftus, Loftus & Messo, 1987). A meta-analytic review (Steblay, 1992) on experimental studies confirmed the presence of this effect across different study designs (e.g., “real-life” enactments, videos, slide presentations). Interestingly, the overall effect size was comparably small for lineup identification (Cohen’s $d = 0.13$), but the effect size for more peripheral information (e.g., other characteristics of the perpetrator, like his clothing) was considerably higher ($d = 0.55$). Corresponding findings were more recently obtained in a study using physiological methods to detect if a person has knowledge about details of a past event (e.g., a robbery). In the Concealed Information Test (CIT) subjects are presented a series of multiple-choice questions and physiological reactions are measured for comparisons (Lykken, 1959). For each question (e.g., "What was stolen?") one possible answer corresponds to the past event (e.g., "Jewelries"), while the other options are equally plausible but not accurate regarding the event (e.g., "Money"). In experimental studies on the validity of the CIT "guilty" participants typically execute a mock crime and are confronted with specific details of that episode in the CIT-phase. Gamer, Kosiol, & Vossel (2010) investigated differences in physiological reactions of "guilty" participants between the alternatives of the multiple-choice questions. Important to the issue of this thesis, test items were subdivided into objects central to executing the mock crime, ("items that must have been perceived in order to successfully accomplish the mock crime") and peripheral objects ("that might or might not have been perceived and encoded by the participant during the course of the mock theft", p. 102). Participants were divided into an immediate test group and a delayed test group (two weeks later). Analyses showed that "guilty" participants in the immediate and the delayed test group had good recognition memory for the central test items but the groups differed in recognition memory for the peripheral items. While the immediate "guilty" group showed good memory performance, memory of peripheral items was considerably reduced in the delayed "guilty" group.

Most thorough computer based experimental investigations using controlled narrative stimuli that aimed at discerning differential emotional effects on memory was conducted by (Burke, Heuer & Reisberg, 1992). The authors assessed memory after participants viewed a picture story either in a negative arousing version or a neutral one. The stories consisted of 12 slides with the first 3 and the final 4 being identical in the negative and the neutral version. In both versions a mother and son were going to visit the father at work. The arousal manipulation in the middle slides showed the father being a surgeon operating a patient. Internal organs were plainly visible and a child was shown with injured legs. In the neutral slides in contrast, the father was shown as a mechanic repairing a car. Test items were separated into those relevant to how the story unfolded and those items that were not relevant to the plot of the story. Plot-relevant items were essential information, "any fact or element that one would include when narrating the story of the slide material ...(e.g., that father is the chief surgeon and not a pediatrician)" as well, as brief descriptions of the various slides, "element(s) one would mention when describing what the slide showed... For example, that a slide showed (the) mother hailing a cab, and not walking, would be in this category" (p. 280). The plot-irrelevant items were subdivided, into central and peripheral irrelevant items. Central detail were those closely associated with the main figures of the stories, like the color of the mother's sweater, while peripheral details were not associated with the main characters but details of the surrounding background e.g., "whether a slide centrally depicting a broken car also contained other cars in the background" (p. 280). Findings confirmed that memory for the theme or "plot-relevant" information was enhanced in the negative condition. Moreover and in line with the assumption of differential effects on memory for specific details, the authors found that memory for plot-irrelevant information, but spatially associated with the central figures, was higher in the emotional compared to the neutral condition. On the other hand, memory for information that was plot-irrelevant and spatially not contiguous with the action of the central figures was undermined in the emotional negative condition.

However, only a limited amount of experimental studies used thematically driven picture stories to explicitly (a priori) test differential effects of negative emotion on memory for central vs. peripheral details (Adolphs, Tranel & Buchanan, 2005; Burke et al., 1992; Christianson, 1984; Christianson & Loftus, 1987; Heuer & Reisberg, 1990; Laney, Campbell, Heuer & Reisberg, 2004; Loftus et al., 1987; Wessel, van der Kooy & Merckelbach, 2000). Furthermore all of these studies are based on experimental comparisons between only one negative and one neutral narrative episode and more importantly, some of these studies did not confirm both effects (Laney et al., 2004; Loftus et al., 1987; Wessel et al., 2000). But taken together and considering related findings on eyewitness research (e.g., Loftus, 1979), research on the "weapon focus" effect (e.g., Steblay, 1992) and further more recent research using non-narrative single stimuli (e.g., Libkuman, Stabler, & Otani, 2004; Melcher, 2010; Nobata, Hakoda, & Ninose, 2009; Riggs, Mcquiggan, Farb, Anderson, & Ryan, 2011; Yegiyan & Lang, 2010), the pattern of findings seems to confirm that negative emotion has not only enhancement effects on memory but also diminishing effects on memory, specifically for more irrelevant, peripheral details (cf. for reviews, see Christianson, 1992; Kensinger, 2009; Levine & Edelstein, 2009; Reisberg & Heuer, 2004). Although an episode per se, the central theme and main features of the episode (e.g., picture story) are remembered better when an experience is emotional, irrelevant details seem to be less well retained, when compared to memory for details of neutral episodes.

In summary do findings of experimental studies correspond with findings of survey-based studies in that the probability to retain an emotional experience is grounded in the retention of essential or "plot-relevant" aspects. For real-life episodes these seem to comprise information regarding when, where, and what event took place (e.g., Brown & Kulik, 1977; Kızılöz & Tekcan, 2013) and also information conveying the meaning of an experience (e.g., Peterson et al., 2014; Reese et al., 2011). In experimental studies these aspects seem to be represented by the "plot-relevance" of narrative stimuli. Experimental findings that negative emotion seems to enhance also memory for plot-irrelevant central details while diminishing memory for plot-irrelevant peripheral details may also correspond with survey-based observations on autobiographical memories, that people estimate to remember a higher proportion of central details from their most traumatic event they had experienced when compared to the proportion of rememberd peripheral details (Christianson & Loftus, 1990), and that stronger emotional reactions were not affecting central aspects of "flashbulb" memories, while they had diminishing effects on memory for more peripheral information (Schmidt, 2004).

A distinction of central and peripheral relevance of information is not clear-cut but a question of continuum and of defining those terms (cf., Christianson, 1992; Kensinger, 2009; Levine & Edelstein, 2009; Reisberg & Heuer, 2004). Nevertheless, survey-based and experimental findings seem to suggest that emotional experiences are more probably remembered per se, and that they are remembered containing more information measured as "*canonical aspects*" or "*narrative cohesion*" or "*plot-relevance*". Emotional episodes are those we remember more probably and memory of these episodes seems to be characterized by a trade-off favoring "plot-relevant", "essential" or "central" aspects of an experience and specific details thereof.

1.3.2. Effects of Negative Emotion on Memory - The Role of Attention

Only a few studies so far investigated possible explanations of these effects. Regarding specific details, it is generally assumed, that attentional processes are mediating the effects of emotion on memory. With reference to Easterbrook (1959) it is assumed, that in negative emotional experiences attention is narrowed to the relevant information, this in turn would enhance memory for these information and would reduce memory for irrelevant information (e.g., Christianson, 1992; Adolphs et al., 2005; Kensinger, 2009; LaBar & Cabeza, 2006; Mather et al., 2006; Phelps, 2006). This explanation was initially given in eyewitness studies and in related investigations on the “weapon-focus” effect. In a real armed crime scene attention may be strongly focused on the weapon thus restricting attention for other details. But emotional experiences in real-life are manifold and may not always imply specific "attention magnets" or at least imply "attention magnets" of varying kind. This leads to skepticism on the sufficiency of an attentional explanations for the trade-off effects (cf., Laney et al., 2004; Levine & Edelstein, 2009; Reisberg & Heuer, 2004). However, only a few studies directly examined the general assumption that attentional processes underlie the trade-off effects regarding specific details by measuring or manipulating overt attention. Loftus and colleagues (1987) showed participants an emotional or a neutral version of a picture story while eye movements were recorded. The stories showed people standing in line of a fast-food restaurant and the four critical slides in the emotional version showed a person standing in front of the cashier, pulling a gun whereupon the cashier hands him money. The neutral story showed the same man handing the cashier a check to pay with, whereupon the cashier hands him back money. Analyses showed that participants made longer and more fixations to the weapon than to the check. However, memory for the relevant objects did not differ between both conditions. Memory for irrelevant details of the picture stories was diminished in the negative condition but only marginally significant. This study demonstrated that participants in the negative condition spent more attention to the object of central relevance but to draw conclusions on the assumption that attention mediates the emotional trade-off effects is difficult because memory for central items did not differ and attention to the peripheral details was not tested. Findings may rather disagree with the attention mediation hypothesis. If attention is driving the emotional enhancement effect for relevant information then why did memory for relevant details not differ though more attention was given to the relevant item in the emotional condition?

Objections can also be drawn from a study by Wessel and collegues (2000) that was set up to explicitly test the attention mediation hypothesis. In this study participants' eye movements were recorded while they were watching either an emotional, an unusual or a neutral version of a picture story. The conditions differed in one critical picture where a girl was lying on a pedestrian crossing and bleeding from a head injury in the emotional condition, while the neutral condition showed the girl walking on the pedestrian crossing. A pink bicycle at the edge of the picture was defined as the detail of peripheral relevance, while the girl and descriptions of the girl were considered as centrally relevant information. The authors found more overt attention to the girl and less to the bicycle in the negative, compared to the neutral condition. However, in this study the accordant differential recall-pattern was also not obtained. Participants in the emotional group did not show enhanced memory for centrally relevant information, nor did they display impaired memory for peripheral information. Moreover, correlational analyses did only reveal a modest relationship between fixation time and recall of peripheral items, and no correlational relationship was found for fixation time and recall of relevant items. This pattern of results give further indication, that the amount of attention given to a detail may not directly translate into identical effects on memory for that detail, again questioning that attention may mediate the trade-off effects. Further skepticism is indicated from results of another study by Christianson, Loftus, Hoffman and Loftus (1991). Participants were shown a similar picture story, as was used in the study by Wessel and collegues (2000) and memory for the relevant detail was tested by asking for the color of the protagonists' coat, while memory for the irrelevant detail was tested by asking for the color of a car in the background. In this study attention was controlled by showing a fixation cross directly before stimulus onset at the position of the subsequently presented relevant detail. The stimuli were shown for only 180 ms to prevent eye movements to other picture parts. Although attention to the relevant item was controlled by this means, participants in the emotional negative condition remembered the relevant detail better than those in the neutral condition. Further objections may be drawn from two methodologically different studies. Riggs and collegues (2011) used single, unrelated pictures as central test items and objects that were placed outside-around the pictures were used as peripheral test items. The authors found evidence in support for emotional trade-off effects in both, attention and memory. But importantly, attention only partially mediated memory enhancement for centrally presented negative pictures and it did not explain reduced memory for the peripheral information. And in a very recent study by Steinmetz and Kensinger (2013) participants were found to have better "selective" memory for single unrelated emotional items (i.e., concurrent forgetting of the associated background image). However, fixations were not increased on emotional vs. neutral items.

Taken together, two studies have observed increased attention to relevant details and one of those studies also reported decreased attention to the irrelevant detail of the negative condition. However, both studies did not observe the congruent pattern in memory. Another study controlled attention to relevant details and found better memory for the item of the negative emotional picture story. And the experiments using unrelated stimuli found emotional trade-off effects on memory but no (respectively only a partial) mediation of these effects by attention. These studies show a very inconclusive pattern regarding the assumption that attention is the underlying reason for the differential effects of negative emotion on memory for relevant vs. irrelevant details. If the amount of attentional processing is not or only partially related to later memory for details, then other reasons will be involved in the trade-off effects, which should be found in correspondence to an understanding of the neural basis of emotional memory.

1.3.3. Effects of Negative Emotion on Memory - Neural Basis

Emotional significance highlights what is important or meaningful to our lives and enhances the probability for experiences to be remembered. Findings of animal and human studies investigating the neural basis of emotional enhancements in memory have shown compelling evidence that the amygdala plays a key role in the beneficial effects of emotion for later remembering. Neural activity at encoding of later successfully remembered emotional (vs. neutral) stimuli per se has been investigated in many experiments using single emotional (vs. neutral) but otherwise unrelated stimuli like film clips (e.g., Cahill et al., 1996), pictures (e.g., Hamann, Ely, Grafton, & Kilts, 1999) or words (e.g., Hamann, 2001) and revealed the central role of the amygdala for enhancing the probability to remember emotional stimuli. Brain imaging studies in humans for example found that amygdala activity at incidental encoding of emotional but not of neutral film clips was correlated with the number of freely recalled clips 3 weeks later (Cahill et al., 1996), while hippocampal but not amygdala activity is generally found to be related to memory of nonemotional information (e.g., Alkire, Haier, Fallon, & Cahill, 1998). The amygdalae, bilateral almond shaped clusters of nuclei in the medial temporal lobes (MTL), are extensively connected with other cortical and subcortical regions (Young, 1993). The main mechanism, that has been investigated to elucidate the impact of emotion on memory is the influence of the amygdala on hippocampal consolidation (c.f., Cahill & McGaugh, 1998; Dolcos, Iordan, & Dolcos, 2011; McGaugh, 2004; Phelps, 2006). Physiological arousal at incidetanl encoding activates beta-adrenergic receptors of the amygdala which in turn modulates hippocampal processing resulting in enhanced consolidation of arousing experiences (c.f., McGaugh, 2004).

Studies investigating neural processes at retrieval also found that enhanced activity in the amygdala and the hippocampus were related to successful retrieval of emotional vs. neutral stimuli (e.g., Dolcos, LaBar, & Cabeza, 2005) and furthermore activity in the amygdala at incidental encoding has been shown to be related to hippocampal activity at retrieval (e.g., Strange & Dolan, 2004). Retrieval of emotional events can elicit brain activity similar to that during experiencing the original event (cf., Buchanan, 2007). Different regions seem to be involved in retrieval of autobiographical memory: the hippocampus, the medial and lateral prefrontal cortex, the medial and lateral parietal cortex, the amygdala, and sensory cortices (cf., Holland & Kensinger, 2011). However much less research has investigated the neural bases of emotional influences on retrieval of autobiographical memory. "Emotional intensity (...) affects the perceptual and phenomenological properties of autobiographical memories, such as the degree to which the memory is re-lived on retrieval, the vividness of memory and narrative detail. The neurobiology underlying these experiential influences (however) is not well characterized" (LaBar & Cabeza, 2006, p. 59).

Though research on the neural basis of emotional memory has mainly focused on amygdala modulations of MTL processing at (incidental) encoding, the rich literature on imaging studies also revealed areas across the whole brain to be related to emotional memory. In a meta-analysis of emotional memory, these additional areas were found to cluster in the ventral visual stream, the left lateral prefrontal cortex and the right ventral parietal cortex, indicating that emotional arousal may enhance memory for experiences through interacting processes of the amygdala with areas involved in perceptual processing, semantic elaboration and attention (Murty, Ritchey, Adcock, & Labar, 2010). These more recent notions of involvements of larger scaled networks across the whole brain in emotional memory is paralleled in current understanding of emotion processing. Consistent activation in multiple brain areas is found across a vast number of imaging studies investigating brain correlates of emotional processing. These areas include cortical regions within the medial, orbital, and inferior lateral frontal cortices and multiple subcortical areas including the amygdala, ventral striatum, thalamus, hypothalamus and periaqueductal gray (Kober et al., 2008).

There is much less understanding however on the neural basis of differential effects negative emotion can have on memory for central classes or aspects and details vs. peripheral details of narrative visual stimuli at incidental encoding. Experimental investigations on the neural basis of emotional trade-off effects on memory are restricted to artificial encoding situations in the laboratory and only a few studies addressed this issue (Adolphs et al., 2005; Adolphs, Denburg, & Tranel, 2001; Waring & Kensinger, 2011). Additionally, only one of these studies operationalized thematically driven experiences and tested emotional trade-off effects on memory for details of visual narratives (Adolphs et al., 2005), while both other studies addressed this issues using unrelated visual stimuli. Further imaging studies investigated some related issues: comparing neural activity of subsequently remembered emotional (vs. neutral) stimuli with neural activity of other subsequently remembered contextual details from the encoding situation like the location of the (emotional vs. neutral) stimulus on the computer screen or memory for a decision task concurrently performed while incidentally (Kensinger et al., 2007; Kensinger & Schacter, 2006) or even explicitly (Mather et al., 2006) encoding emotional vs. neutral stimuli. There is clearly a lack of ecologically more valid research on the neural basis of (differential) effects negative emotion can have on memory for specific information of an experience. Given the high impact of narrative structures on retention of real-life experiences, it is desirable to better understand the neural basis of negative emotion's effects on memory for central aspects and details vs. peripheral details from ecologically more valid experiences, both regarding incidental encoding and retrieval processes.

Seminal work on the role of the amygdala regarding memory for details of emotional negative narratives came from studies on brain lesion patients (Adolphs, Cahill, Schul, & Babinsky, 1997; Larry Cahill, Babinsky, Markowitsch, & McGaugh, 1995) – though differentiations dependent on the relevance of details were not addressed in these investigations. In both studies rare patients with selective bilateral amygdala damage encoded slightly modified versions of the emotional picture story utilized in the study by Burke et al. (1992), where a mother and son are visiting the father who is a surgeon at his work in a hospital. Recognition memory for the details of the emotional slides (the middle phase of the picture story) and for details of the neutral slides (the beginning and the ending of the picture story) were compared between patients and normal controls. Both studies revealed that the amygdala damaged patients – in contrast to normal controls – did not show an emotional enhancement for details of the emotional slides, while memory for details of the neutral phases did not differ between amygdala damaged patients and normal controls. This finding corresponds with results reported in a study by (Cahill, Prins, Weber, & McGaugh, 1994), showing that the ß-adrenergic system is involved in the enhancement effect of negative emotion on memory for details of complex narrative stimuli. Participants were either administered propanolol, a ß-adrenergic receptor antagonist, or a placebo and half of each group were shown either a negative or a neutral version of a narrative. The stimuli used were again variants of the emotional picture story utilized in the studies by Burke et al. (1992). In both conditions the picture story of the mother and son visiting the father who is a surgeon was shown. Emotionality was manipulated by audio-recorded narrations accompanying the slide presentations that varied only for the middle phase of the narrations. In the emotional negative condition the pictures of the middle phase were described to depict a real, critical surgery, while the audio descriptions in the neutral condition told that a surgical team was practicing with realistic-looking injuries on actors. Memory data clearly showed an enhancement effect for details of the middle phase of the negative condition but only in participants who had received the placebo treatment, while the enhancement effect was absent for the propanolol group and also absent in the propanolol and the placebo groups, who had encoded the neutral story version. Together these studies seem to suggest that the amygdala is not only involved in better memory for stimuli per se but also in better memory for specific details of more complex emotional narratives, probably via moderating effects on consolidation processes. However, while a relationship of amygdala activity and the ß-adrenergic system with enhanced memory for details of narrative visual stimuli was demonstrated, the studies did not investigate recognition results for details as a function of relevance (central vs. peripheral), thus omitting conclusions regarding the role of the amygdala for differential effects of negative emotion on more central aspects and details vs. peripheral details, as revealed in the psychological studies cited above.

Only one study (Adolphs et al., 2005) investigated the neural basis of trade-off effects in visual narratives. In this study patients with MTL brain lesions were compared with normal controls. Participants were shown either a neutral or an emotional picture story presented with a short sentence accompanying each picture. The neutral story depicted and described a story of parents taking a drive to the countryside for relaxation, while the negative story told of parents taking a drive to recover the remains of their dead children who were passengers in a plane that had crashed. In both versions neutral target pictures were embedded within an array of further pictures, either of an emotional negative valence (e.g., shocking pictures of dead bodies), or of neutral valence. The (neutral) target pictures were identical for the negative and the neutral version and a surprise recognition test asked for "gist" memory and memory for more peripheral details of the target pictures. "Gist" was defined as "information essential to the meaning of the picture", while questions regarding peripheral details asked for "background information that was irrelevant" (p. 517). Corresponding to previous findings of emotional trade-off effects, results revealed that normal controls had better memory for "gist" details (i.e., a higher proportion of gist details relative to the total score on all questions) in the negative (vs. neutral) condition. Importantly the authors found that damage to the MTL including the amygdala resulted in impaired proportional gist memory for scenes of the negative story version, while amygdala damaged patients in the neutral condition did not show impaired proportional "gist" memory. This amygdala dependent effect on proportional "gist" memory for negative picture stories was additionally substantiated by a correlation between proportional "gist" memory and volumetric amygdala damage. In contrast, other patients with damage to the MTL including the hippocampus but excluding the amygdala did not show a relationship of proportional "gist" memory with volumetric damage to the hippocampus.

Corresponding findings were reported in a previous study by (Adolphs et al., 2001) where memory of amygdala damaged patients and control groups were tested for "gist" and detail of emotional aversive and neutral scenes. In this study 10 unrelated pictures showing 5 neutral and 5 emotional negative scenes were presented accompanied by a verbal single-sentence description for each picture. Memory for "gist" tested "general information of the scene that was sufficient to distinguish that particular stimulus from all the other stimuli (e.g., that a dead person had been found in the forest) and that did not depend on remembering details of the scene." Memory for details was tested as "information which could only be accessed from detailed memory of the visual image (e.g., the particular type of surface - grass or dirt - that the dead person was lying on or the particular orientation of the body in the scene)" (p. 985). Findings of this study revealed that damage to the amygdala was related to both, diminished memory for "gist" and better memory for visual details. Together both brain lesion studies on emotional trade-off effects seem to indicate that the amygdala is involved in both, the enhancement effect negative emotion has specifically for central aspects and a concurrent effect diminishing specifically memory for peripheral details.

The involvement of the amygdala in the emotional trade-off effects is additionally substantiated by findings of brain imaging studies using the event-related subsequent memory paradigm. Neural activity at encoding is acquired and contrasted between those trials in which stimuli were presented that participants later remembered and those trials they did not remember in a subsequent surprise memory test (DM = due to memory effect). Emotion related activity at encoding specifically related to later remembering can then be isolated comparing DM within emotional trials and DM within neutral trials. Further distinctions can additionally be applied to extract differential activity at encoding exclusively related to subsequent memory for centrally relevant vs. peripheral details by contrasting corresponding trials or parametrically modulating encoding activity with regard to later memory performances of central and of peripheral details. This results in the statistical parametric images of activity specifically related to the influences of emotion on the differential effects between later memory for central and peripheral details respectively. Though no brain imaging study investigated emotional trade-off effects on memory for details of narrative stimuli, some findings of related research seem to give further indications to understand neural processes possibly underlying these effects. Waring and Kensinger (2011) utilized the subsequent memory paradigm to investigate neural correlates of incidental encoding emotional vs. neutral objects later remembered and incidental encoding emotional vs. neutral background information later remembered. Participants were shown a set of unrelated pictures, each depicting a neutral background scene (peripheral information) in which an item (central information) of emotional or neutral valence was incorporated in the foreground by photo-editing software (e.g., a snake by a river vs. a squirrel by a river, counterbalanced across subjects). Analyses of the subsequent recognition test revealed emotional memory trade-off effects for all four emotional categories (i.e., positive and negative, each of high and of low arousal) compared to the neutral condition. Brain images of encoding were back-sorted as a function of emotion, recognition and centrality, and an analysis contrasting neural activity specifically related to memory for all emotional (vs. neutral) central information with activity specifically related to memory for all emotional (vs. neutral) peripheral information revealed activity in bilateral amygdala. Additionally this analysis indicated that activity in further, wider spread areas of the brain reflected emotional effects of remembering central items and forgetting corresponding peripheral backgrounds. These areas included limbic, prefrontal, and also temporal regions, and were interpreted to indicate processing of emotional information and emotional memory. Further analyses were performed to determine neural activity related to the difference between remembering only the central information of emotional stimuli vs. remembering central and peripheral information of emotional stimuli to isolate more specifically neural activity related to the diminishing effect emotion can have on remembering background information. Analyses of this contrast were reported for each emotion category. For negative stimuli of high arousal this contrast revealed only significant activity in a visual processing area, the left fusiform gyrus (FFG). The analysis regarding stimuli of low negative arousal revealed activity in more wide spread areas located in the middle temporal gyrus and inferior parietal lobe, and were interpreted to indicate enhanced visual processing and enhanced demands for directed visual attention. Findings of further imaging studies seem to support the notion that the amygdala and visual processing areas might be involved in generating the emotional trade-off effects. These studies compared neural activity related to later memory for emotional (vs. neutral) stimuli with neural activity related to later memory for contextual information, such as memory for the location of the (emotional vs. neutral) stimulus on the computer screen or memory for a decision task performed during presentation of emotional vs. neutral stimuli. In an imaging study by Kensinger and Schacter (2006) participants were shown emotional and neutral stimuli and were instructed to answer for each object either whether it was a living being or to judge whether it was a common or an uncommon item. Analyses of a subsequent memory tasks revealed no behavioral effects of emotion on memory regarding which kind of judgments participants had made for the items but participants showed enhanced recognition memory for emotional stimuli. This dissociation between better memory for emotional items but no enhancement for the concurrent task performed was related to amygdala activity that predicted subsequent memory for emotional items but not for the task performed. This finding was replicated in a further study (Kensinger et al., 2007) where memory for the visual details of negative vs. neutral objects was tested in a surprise recognition task. Participants had to decide whether an object was the same object as previously seen in the incidental encoding session, a similar or a new one. Memory for which of two decisions about the objects were made during incidental encoding was also tested. Activity in the amygdala again corresponded with better memory for the emotional items (i.e., correct "same" responses) of negative but not neutral stimuli, and did not relate to memory for the task performed. Additionally amygdala activity of incidental encoding remembered negative items was correlated with activity in the FFG but not amygdala activity of incidental encoding subsequently forgotten negative items and neither did amygdala activity correlate with incidental encoding of remembered or forgotten neutral items. In a study by Mather et al. (2006), additional findings were reported confirming the assumption that brain areas known for visual processing might be involved in emotional trade-off effects on memory. In this study participants completed a trial-based working-memory task in which they had to remember the locations of four subsequently shown pictures. In each trial the four pictures were emotionally either of high, medium or low arousal. Behavioral findings showed that memory for the correct picture location was negatively related to increasing arousal levels of stimuli. In contrast however, memory for the items itself increased with increasing arousal levels of the stimuli and this relationship corresponded to increased activity in visual processing areas.

Brain imaging studies based on non-narrative stimuli seem to indicate complementary evidence for the assumption derived by the study on brain lesioned patients, that the amygdala is involved in driving the differential effects of negative emotion on memory for central vs. peripheral details. Findings of these studies seem to suggest additionally, that further brain areas could also be involved in these effects. Findings indicate, that the trade-off effects are driven by allocation of processing resources to specific areas including the amygdala and the FFG, but putatively further more wide spread areas in limbic, prefrontal, and temporal regions. It was suggested that incidental encoding of emotional stimuli is related to prioritized resources for visual processing and directed attention and that these processes may lead to better memory for centrally relevant information and worse memory for more peripheral information (cf., Adolphs et al., 2005; Kensinger, 2009; LaBar & Cabeza, 2006; Mather et al., 2006; Phelps, 2006).

However, studies on the neural basis of emotional trade-off effects are still sparse and brain imaging studies on this issue tested memory for unrelated single stimuli and contrasted them to memory for more artificial contextual details, possibly restricting generalizability due to lack of episodic or narrative dimensions of stimuli. As already noted, even only a few behavioral studies explicitly tested differential effects of negative emotion on memory for central vs. peripheral details relying on thematically driven picture stories and some of these studies did not confirm both effects. Furthermore only one brain lesion study and no imaging study so far investigated the biological basis of differential effects of negative emotion has on memory by using thematically driven picture stories. Much more research focusing on ecological validity is warranted to better delineate differential effects of negative emotion on memory, to better understand the putatively causal role of visual processing and directed attention in these effects and to better understand the neural implementation of differential emotional memory. To this end we aimed to replicate findings of negative emotional trade-off effects on memory for central aspects and details vs. peripheral details, to test the assumed attentional mediation of these effects and to investigate the neural basis thereof using a set of divers, thematically driven picture stories with central and peripheral test details appearing naturally within these stimuli.

1.4. Terminology

Based on the literature discussed so far, I will hereafter use the term *aspects* to refer to essential information of what is remembered from real-life episodes (when, where, what, meaning). This term corresponds to some degree with the terms "plot-relevant information" or "gist memory" as used in experimental research using narrative stimuli e.g., "any fact or element that one would include when narrating the story of the slide material" (Burke et al., 1992, p.280), or any "information essential to the meaning" (Adolphs et al., p.517). I will use the term (emotional enhancement for) *central details* referring to experimental research using narrative stimuli indicating that more specific "plot-relevant" details and also "plot-irrelevant" details closely associated with the main figures of emotional narratives, are better remembered and also referring to findings of survey-based studies indicating that very specific details of traumatic emotional real-life experiences seem to be rather central. Furthermore I will use the term (diminishing effect of negative emotions on memory) for *peripheral details* referring to findings of experimental research using narrative stimuli suggesting diminished memory for "plot-irrelevant" peripheral details and with regard to survey-based studies suggesting that stronger emotional reactions seem to have a diminishing effect on memory for more peripheral information of an emotional experience. With regard to the latter two findings – emotional enhancement effect for *central details* and diminishing effect for *peripheral details* – I will also jointly refer to trade-off effects of negative emotion on memory for central vs. peripheral details or in short: *trade-off effects*.

2. Development of Stimulus Material

2.1. Picture Stories

Similar to earlier studies, we used picture stories as stimulus material (for example picture stories and test items, see figure 1). However, instead of using only one story, we developed a larger set of stimuli to be able to examine the validity of emotional trade-off effects on memory across different story contexts. Essentially, we developed in both counts: on the one hand we aimed to generate as ecologically valid stimulus material as possible using thematically driven picture stories and recognition test objects which were naturally embedded within the incidental encoding material. On the other hand we tried to maximize experimental control. To this aim 13 negative and 13 neutral picture stories were constructed with each story consisting of 4 pictures. While the first picture introduced the setting and was always of neutral valence, from the second picture on negative stories illustrated incidents such as domestic violence, vandalism, burglary, a fight or a murder. The negative stories varied in the severity of the event but all depicted a plot that could be a matter of criminal law in real-life.

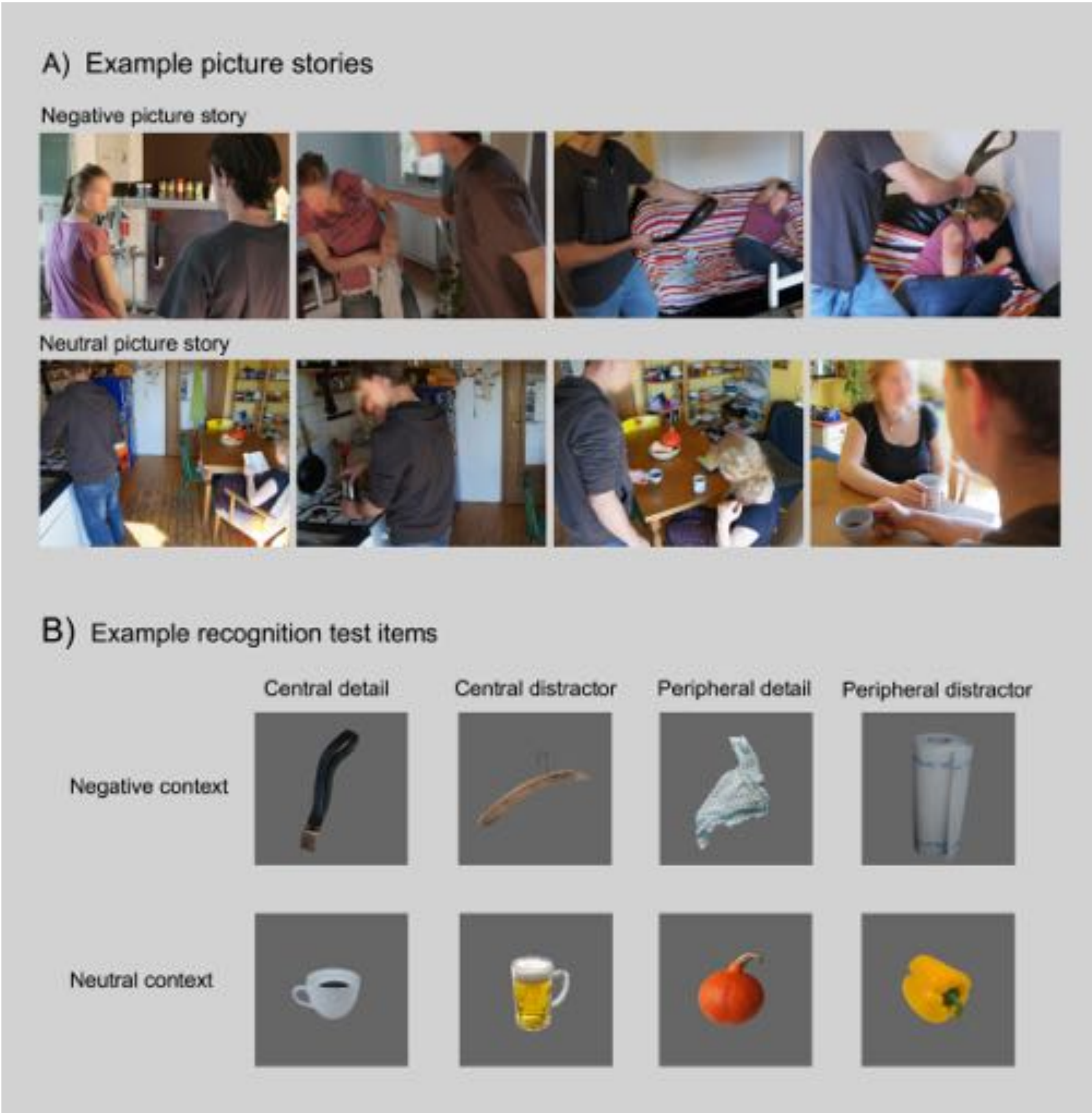

Figure 1. A) Negative and neutral example picture stories of the incidental encoding phase. B) Negative and neutral example items of the surprise recognition test. Note, to protect privacy, faces of persons depicted in the example picture stories were blurred for publication, but were clearly visible for participants in the study.

Neutral stories only depicted amateur actors in daily non-emotional activities, such as a couple having a cup of coffee, someone buying something in a shop, or a person eating an apple (for a complete list of the stories, see table 1). All stories were shot from the perspective of a male protagonist. Negative and neutral stories were balanced in regard to the number and sex of the persons involved and to the kind of location the story took place at (i.e., for each negative story involving a male protagonist and a female victim a neutral story was constructed that took place at a similar location and also involved a male and a female actor). In each picture story two relevant objects were naturally embedded in the scenes for a subsequent recognition test. One object was of central relevance for the plot while the other one was peripheral, irrelevant for the storyline. The object that was most closely related to the story always served as the central item (e.g., a belt someone used to beat up a woman or a cup of coffee someone serves a woman), while an object that was also present in the scene but completely irrelevant for the plot was chosen as peripheral item (e.g., a dishtowel in the middle-ground of a domestic violence scene or a pumpkin on the table at which a couple was sitting). Both, the centrally relevant and the peripheral object appeared clearly visible in two of the 4 pictures of a story and the picture number in which central and peripheral items occurred in (i.e., 1st to 4th picture) was balanced across contexts. None of the objects nor objects of a same category appeared in any of the other stories again. Most of the central test items and all peripheral test items were technically neutral regardless of the emotional context. However, 4 out of 26 central items could be considered to be arousing themselves (i.e., a pistol, a knife, an axe, a hammer) but these items were balanced between the emotional and the neutral context. We also controlled for the absolute spatial distance of items from the center of the pictures and the sizes of the regions of interest (ROI). Central items of negative picture stories had an average distance of 296 pixels from the screen center, which did not differ significantly from the neutral picture stories (M = 293 pixels distance), $t(50) = 0.07$, $p = .94$. Also the distance of peripheral items from the image center did not differ significantly between contexts (negative: M = 407 pixels, neutral: M = 491 pixels, $t(50) = 1.59$, $p = .12$). Importantly the difference of distances between central and peripheral items did not differ between negative and neutral picture stories, $t(50) = 1.20$, $p = .24$. Furthermore, none of the comparisons regarding the ROI sizes measured in pixels were significant (central negative: M = 56541, central neutral: M = 74933, $t(50) = 0.68$, $p = .50$;

peripheral negative: M = 36918, peripheral neutral: M = 42727, $t(50) = 0.49$, $p = .63$; negative [central – peripheral] vs. neutral [central – peripheral], $t(50) = 0.43$, $p = .67$).

Table 1. List of all negative and neutral picture stories

Negative picture stories	**Neutral picture stories**
Robbery (4x)	Eating an apple
Vandalism (2x)	Shopping
Murder (2x)	Losing gloves
Burglary	Chopping wood
Kidnapping	Drinking coffee
Theft	Opening the door for someone
Intimate partner violence	Finding something
Affray	Buying a parking ticket
	Putting something in the rear trunk
	Driving the son to the tennis club
	Asking the time
	Pottering about
	Buying cigarettes

2.2. Recognition Test Items

A picture of each central and peripheral item was taken individually for the surprise recognition test. Care was taken to portray each object from a similar perspective as they had appeared in the picture stories. Further, for each central and peripheral target item, three distractor test items were constructed. We decided to construct a larger set of distractor items to be able to use the same stimulus set in future studies involving the presentation of multiple distractors for each target item (e.g., studies using variants of the Concealed Information Test (Lykken, 1959)). However, since all results did not differ significantly between distractor sets, we decided to pool the data across sets for all statistical analyses. Distractor items were developed based on the following 3 criteria: First, a distractor object had to be as plausibly to appear in the story as the respective target item. Second, the picture of the distractor item was taken from a comparable perspective as the corresponding target item. Third, none of the distractor objects nor objects of a same category appeared in any of the other stories. With 13 negative and 13 neutral picture stories, each containing a central and a peripheral object, there were a total of 52 target items and 156 distractor items. In study 1 for each participant 52 target items and 52 items (one randomly drawn distractor set) were used in the recognition test, in study 2 each participant was given 52 target items and 104 distractor items (two distractor sets).

3. Study 1

3.1. Aims of the Study

A negative emotional context can have differential effects on memory for details. It can enhance memory for central aspects and details and impair memory for peripheral details. These trade-off effects are generally assumed to result from attentional processes: a negative context seems to narrow attention to centrally relevant information at the expense of processing more peripheral details, thus causing the corresponding effects in memory. However, the hypothesis that attention mediates the trade-off effects has rarely been tested and extant findings did not support the assumption. To examine the role of attention for the emotional trade-off effects on memory in an ecologically more valid but standardized setup, we used the previously developed 26 picture stories with either an emotionally negative or a neutral context (see section 2 for a detailed description of the stimulus material). In each story one centrally relevant and one detail of peripheral relevance was naturally embedded in the scenes. The spatial distance of central and peripheral objects between the two contexts were controlled, thus centrality of objects was primarily defined by the relevance objects had for the depicted storyline. The object that was most closely related to the story always served as the central item, while an object that was also present in the scene but irrelevant for the plot was chosen as peripheral item. Explicit memory for these details was tested in a surprise recognition test and was expected to show the trade-off effects of emotion on memory. Eye movements were acquired to examine the relationship between overt attention during incidental encoding and later recognition memory and explicit affective ratings and autonomic responses were measured to validate the induction of emotional arousal. Hierarchical logistic regression analysis was applied to further elucidate the relationship between arousal and attention at incidental encoding and later memory for details.

Hypotheses

Firstly we expected to replicate previous findings, that negative emotion would enhance memory for the most relevant details of our picture stories and that negative emotion would diminish memory for peripheral details completely irrelevant for the picture stories. To this aim, we further expected to validate the emotional manipulation with more negative affective ratings of, and stronger physiological reactions for the negative picture stories. Secondly, we were interested in analyzing the role of attention for the negative emotional trade-off effects on memory for details.

3.2. Methods

Ethics Statement

This study was approved by the local ethics committee of the Medical Association, Hamburg, Germany and conducted according to the principles expressed in the Declaration of Helsinki.

Participants

Sixty-five male subjects, most of them students from various faculties (89%), with normal or corrected to normal visual acuity participated in the study. Four participants were excluded from data analysis, two due to difficulties in obtaining stable eye-tracking data and two due to technical problems. The final sample (N = 61) had a mean age of 26.3 years (SD = 3.7 years). We examined only male participants because of two reasons: Firstly, to maximize comparability between the emotional conditions, all picture stories were shot from the perspective of a male protagonist. Thus both, the kind of stories presented and the sex of the protagonist could have differential effects on male vs. female individuals. Secondly we aimed to verify the emotional manipulation not only by explicit ratings but also using physiological measurements. Since findings of studies are inconclusive regarding sex differences in physiological responses to emotional stimuli (Chentsova-Dutton & Tsai, 2007), we decided to examine a homogeneous sample consisting only of males. Participants gave written informed consent and were paid for participation. After the experiment, they completed the Beck Depression Inventory, BDI (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) and the trait version of the Spielberger State Trait Anxiety Inventory, STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The BDI scores ranged from 0 to 27 (M = 4.73, SD = 4.50) and the STAI scores ranged from 21 to 53 (M = 33.97, SD = 6.17). The STAI scores were well comparable to published norms for this age group (M = 33, SD = 10). Additionally, all analyses were also rerun excluding one participant who had a BDI score greater 13 (i.e., 27), the cut-off value for no to minimal depression, and another one who had a STAI score higher than the 90^{th} percentile of the norm sample (i.e., 53). Results for this restricted sample were very similar compared to results based on all participants.

Apparatus

Physiological responses were recorded with a Biopac MP100 device (Biopac Systems, Inc.). Skin conductance was measured at the thenar and hypothenar eminences of the participant's non-dominant hand by a constant voltage system (0.5 V) using a bipolar recording with two Hellige Ag/AgCl electrodes (surface area = 1 cm^2) filled with 0.05 M NaCl electrolyte. An electrocardiogram (ECG) was recorded using 3M RedDot Ag/AgCl electrodes filled with electrode paste and attached to the manubrium sterni and the left lower rib cage, the reference electrode was placed at the right lower rib cage. Eye movements were monitored using a video-based eye-tracker (EyeLink 1000, SR Research, Ontario, Canada) with a spatial resolution of less than 0.01° and a spatial accuracy of 0.25° - 0.4° and were recorded during the incidental encoding phase with a sampling rate of 1000 Hz. The head location was fixed using a chin rest and a forehead bar. The Software Presentation (Neurobehavioral Systems) was used to present the stimuli on a 19" LCD monitor and to automate the recordings of the eye-tracker and the physiological data. Participants viewed the screen from a distance of 47 cm, and responded by using a standard keyboard. Measurements were conducted in a sound-attenuated room, all recording and programming equipment was located outside the room.

Procedure

Upon individual arrival at the laboratory, participants were told that they would be shown a set of picture stories and that the purpose of the experiment was to quantify the experience, physiological responses and visual interest when viewing these picture stories. They were told that the stories had been constructed for this purpose and asked to watch the pictures closely and to try to get engaged with the storyline. There was no indication that memory for objects appearing in the stories or memory for the stories themselves would be tested later. After applying the electrodes, participants were seated and the chin rest and forehead bar were adjusted. To get used to the valence and arousal rating-scales that were employed for measuring the affective quality of the picture stories, participants were given 6 practice trials each consisting of one picture. Pictures for the practice trials were collected from the Internet and depicted a scene with negative (3) or neutral (3) content. After adjustment of the eye-tracking camera, a 9-point calibration procedure was completed before presenting the picture stories. Each story started with a central fixation cross (see figure 2), shown for 6000 ms and an additional 0 – 2000 ms for a random delay. Participants were instructed to look at the fixation cross. Subsequently, the 4 pictures of a story were presented consecutively, each with a duration of 10 seconds and a size of 47.1° by 36.5° of visual angle. Picture presentation was terminated with another fixation cross lasting for 2000 ms. After every picture story, participants rated their emotional experience on a computerized version of the Self-Assessment Manikin (SAM; Lang, 1980), a non-verbal self-report measure consisting of two bipolar nine-point scales representing the affective dimensions valence and arousal. The eye-tracker was recalibrated after half of the trials and the order of the stories was randomly chosen for each participant. Picture stories were presented without any additional information, neither a title nor a narrative was given. Upon completion of the incidental encoding session participants performed a filler task completely unrelated to this experiment. Instruction and performance of the filler task took approximately 10 minutes. Then participants were instructed for the surprise recognition task. Objects were presented sequentially and participants were asked to indicate whether or not they had seen them in the picture stories before by pressing corresponding keys on a computer keyboard (see figure 3). The instruction emphasized on the correctness of the response instead of the response speed. Target and distractor items were presented in random order with a size of 18.6° by 18.6° of visual angle and a duration lasting until a response was given. Afterwards a fixation cross was shown during the intertrial interval that varied randomly between 5000 ms and 7000 ms.

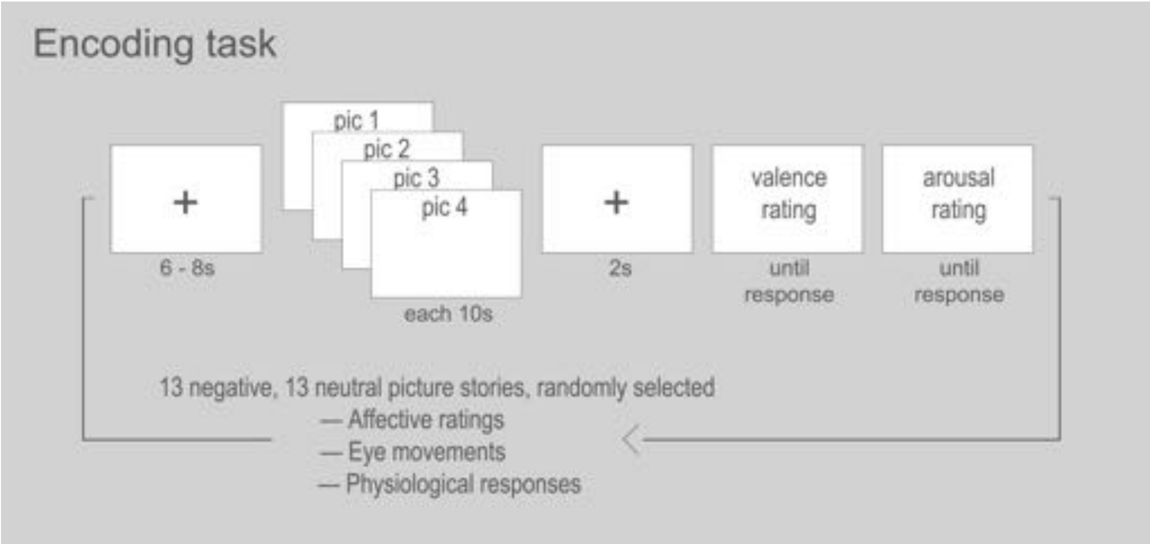

Figure 2. Incidental encoding task design of study 1

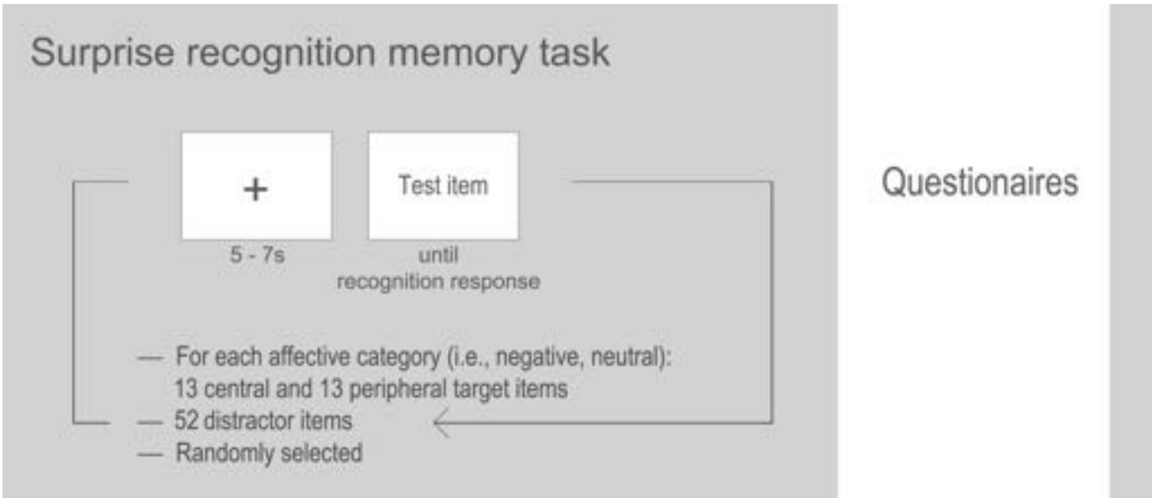

Figure 3. Recognition task design of study 1

Data Processing

Heart Rate

To quantify phasic stimulus related heart rate (HR) changes, R-waves were detected from the ECG data and R–R intervals were converted to HR (in beats per minute). Afterwards a real time scaling procedure was applied (Velden & Wölk, 1987) resulting in one HR value for each of the 40 seconds post picture story onset. The HR in the last second prior to story onset represented the prestimulus baseline. Poststimulus difference scores (ΔHR) were derived by subtracting the prestimulus baseline value from the HR-score of each poststimulus second.

Electrodermal Responses

Two measures were derived from the electrodermal recordings: Changes in the skin conductance level (SCL) and the number of nonspecific skin conductance responses (#NSRs) during story presentation. For SCL quantification, skin conductance recordings were low pass filtered using a cutoff frequency of 0.05 Hz. Afterwards the mean SCL value was obtained for each picture. The mean SCL of the last second prior the onset of each story represented the baseline and was subtracted from the SCL values of the 4 pictures of each story. The number of nonspecific skin conductance responses was determined for each picture of the stories by counting all responses occurring at least 1 sec after picture story onset. Skin conductance responses were required to exceed an amplitude of 0.02 μS.

Eye Movement Data

Eye movement data were parsed into saccades and fixations using Eyelink's standard parser configuration, which classifies an eye movement as a saccade when it exceeds 30°/sec velocity or 8000°/sec^2 acceleration. Subsequently x and y coordinates of fixations were drift corrected with reference to the central fixation cross at the start of each trial. For each central and peripheral item an outline was drawn around the ROI. Fixations were attributed to a target item when they were within the region's pixel coordinates. The first fixation that occurred after each picture onset was removed from the data to eliminate confounding effects of participants' previous attentional focus (e.g., fixation cross, fixation from a previous picture). Two attentional measures for central and peripheral items were derived from the eye movement recordings: The latency of the first fixation on the ROI measuring how fast a ROI was fixated for the first time after stimulus onset and the proportion of viewing-time spent on the ROI relative to the total fixation time during picture presentation (excluding blinks and saccades).

Statistical Analyses

All statistical analysis were accomplished with R, an open-source language for statistical computing (www.r-project.org). Parameter estimations and model fit evaluations for the hierarchical regression analyses were done using the R-package lme4 (Bates & Maechler, 2009). An a priori significance threshold of α = .05 was used but marginally significant effects (*p* <

.10) are also reported. Cohen's *d* and *f* are depicted as effect sizes for pair wise comparisons and analyses of variance (ANOVAs), respectively.

Affective Ratings

To compare the affective quality of negative and neutral picture stories, mean subjective ratings of valence and arousal were each analyzed by paired *t*-tests (negative vs. neutral).

Physiological Responses

Physiological responses between negative and neutral picture stories were compared using a series of 2 × 4 repeated measures ANOVAs with emotional context (negative, neutral) and picture number as within-subject factors.

Eye Movement Data

The latency of the first fixation and the proportion of viewing time on central and peripheral items were compared between negative and neutral stories in a 2 × 2 repeated measures ANOVA with emotional context (negative, neutral) and centrality (central, peripheral) as within-subject factors. To investigate possible differences in the proportion of viewing across time, a more explorative analysis was run as a 2 × 2 × 3 repeated measures ANOVA with emotional context (negative, neutral), centrality (central, peripheral) and time (1^{st} third, 2^{nd} third, 3^{rd} third of picture presentation times) as within-subject factors.

Recognition Memory

Recognition memory for central and peripheral details was determined by subtracting the proportion of false alarms (erroneous recognition of distractor items) from the proportion of hits (correct recognition of items) and analyzed in a 2 × 2 repeated measures ANOVA with emotional context (negative, neutral) and centrality (central, peripheral) as within-subject factors.

Hierarchical logistic regression analysis was used to examine the influence of affective context, item centrality, and overt attention on recognition memory. Based on individual trial level data, random intercept logistic regression models (cf., Wright & London, 2009) were estimated to analyze the assumed mediating role of attention for the emotional trade-off effects on memory. In model 1 centrality (i.e., peripheral [-0.5] vs. central [+0.5], mean centered) was entered as predictor of subsequent memory. In model 2.a.1 arousal (i.e., range -3.9 [low arousal] to +4.1 [high arousal], mean centered) was added and in model 2.a.2 the interaction of centrality × arousal was additionally taken into account. In model 2.b.1 analogously the estimates for centrality and proportion of viewing time of details (z-standardized values across all items, range: -0.87 to +5.24) and in model 2.b.2 additionally their interactions were used as predictors. In model 3 all parameters used in the models 2.a.2 and 2.b.2 were entered. Finally, the full model 4 comprised all main and interaction effects of centrality, arousal, and proportion of viewing time. We decided to restrict the regression analyses to arousal ratings as the measure of affective quality and proportion of viewing time as the index of overt attention since separate analyses using valence (instead of arousal) ratings or the latency of the first fixation (instead of the proportion of viewing time) revealed highly similar results due to (substantial) intercorrelations between measures (correlation between valence and arousal: $r = -0.83$; correlation between first fixation latency and proportion of viewing time: $r = -0.44$). Additionally, regressions were run with the physiological data but no significant effects were obtained. We furthermore checked whether the results of the regression models involving proportion of viewing time might have been driven by outliers (i.e., values outside M ± 2 *SD*) or trials where participants did not look at an item at all. Excluding the latter did not change the pattern of results and excluding both, the trials where items were not fixated at all and outliers (with separate cut-off values for central and peripheral items) did also not alter the pattern of results. In all models, correct recognitions of items that were depicted in the picture stories were estimated with individual (random) intercepts per subject to account for repeated measurements. All estimated regression coefficients of the predictor variables were modeled as fixed effects, since generalization of the results was emphasized as opposed to analyses of individual differences. Noticeably however, a model with all predictor variables of model 3 but with the coefficients of arousal, centrality and arousal × centrality varying by subject was estimated, too (random intercept random slope model). This model showed nearly identical effects and did not differ significantly from the random intercept only model. Overall, there were 3172 data points (i.e., 61 subjects × 26 stories × 2 levels of centrality) of memory responses (coded as 0 or 1, respectively). Comparison of model deviances, regression coefficients with their standard errors and average predictive probability are reported. Because of the non linearity of the logistic regression coefficients, a specific difference in one of the predictor variables does not correspond to a constant difference in predicted memory. The average predictive probability is a summary comparable to the linear regression coefficient and gives the expected probability to recognize an item corresponding to a specified value or difference of values in one (or more) of the predictor variables while simultaneously taking into account the varying values of all other (unspecified) predictors. These estimates were $logit^{-1}$ transformed and expressed as percent probability to recognize an item (Gelman & Hill, 2006, p. 101).

3.3. Results

Affective Ratings

Consistent with the a priori grouping of negative and neutral stories, results revealed significant differences in valence and arousal ratings between both contexts. Negative picture stories were rated as more unpleasant in valence ($M = 2.36$, $SD = 0.65$), than neutral stories ($M = 6.41$, $SD = 0.67$), $t(60) = 32.64$, $p < .001$, $d = 6.08$. Also, negative stories were rated as more arousing ($M = 7.03$, $SD = 0.81$), than neutral stories ($M = 2.87$, $SD = 0.86$), $t(60) = 30.35$, $p < .001$, $d = 4.98$. As depicted in figure 4, negative and neutral picture stories were clearly separable with respect to the affective ratings.

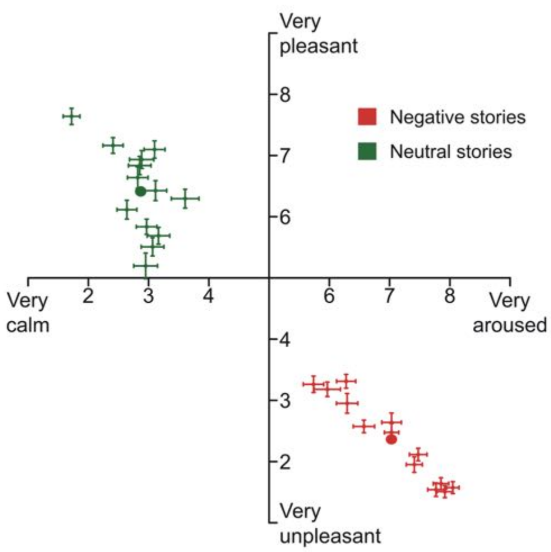

Figure 4. Affective ratings. Mean and standard error of the mean of valence and arousal ratings aggregated per story (crosses). Grand mean and standard error of the mean of valence and arousal ratings for negative and neutral picture stories (filled ellipses).

Physiology

The ANOVA on cardiac responses yielded a main effect of emotional context, $F(1, 60) = 4.65$, $p < .05$, $f = 0.13$, reflecting a stronger heart rate deceleration for negative picture stories (see figure 5A). A comparable main effect was neither found for SCL, $F(1, 60) = 1.82$, $p = .18$, $f = 0.04$, nor for #NSRs, $F(1, 60) = 2.78$, $p = .10$, $f = 0.05$ (see figure 5B and 5C). Additionally, the factor picture number was significant for heart rate, $F(1, 58) = 28.00$, $p < .001$, $f = 0.18$, and for SCL, $F(1, 58) = 32.92$, $p < .001$, $f = 0.44$, reflecting a general decrease across story presentation. No other main or interaction effect was significant.

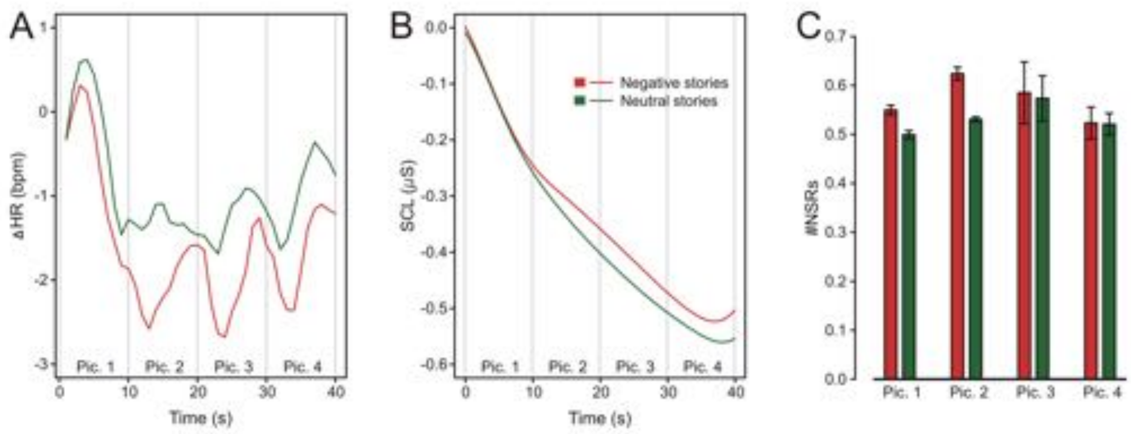

Figure 5. Physiological responses to negative and neutral picture stories as a function of time (picture 1 – picture 4). A) Phasic heart rate; B) Skin conductance level; C) Number of nonspecific skin conductance responses; Error bars indicate standard errors of the mean.

Eye Movement Data

Regarding latency of the first fixation, a significant main effect of centrality in relevance was obtained, $F(1, 60) = 862.47$, $p < .001$, $f = 1.43$ (see figure 6A). Central items were fixated much earlier than peripheral. A marginally significant main effect of emotional context, $F(1, 60) = 3.58$, $p = .06$, $f = 0.07$, indicated that items in negative contexts tended to be attended later. Importantly the interaction of emotional context and centrality was not significant, $F(1, 60) = 0.00$, $p = .99$, $f = 0.00$. The ANOVA on the proportion of viewing time also showed a main effect of centrality, $F(1, 60) = 883.27$, $p < .001$, $f = 1.76$, resulting from a reduced fixation duration on peripheral items. Moreover the significant main effect of emotional context, $F(1, 60)$

= 126.12, $p < .001$, $f = 0.23$, indicates that participants spent less time looking at the items while viewing negative picture stories.

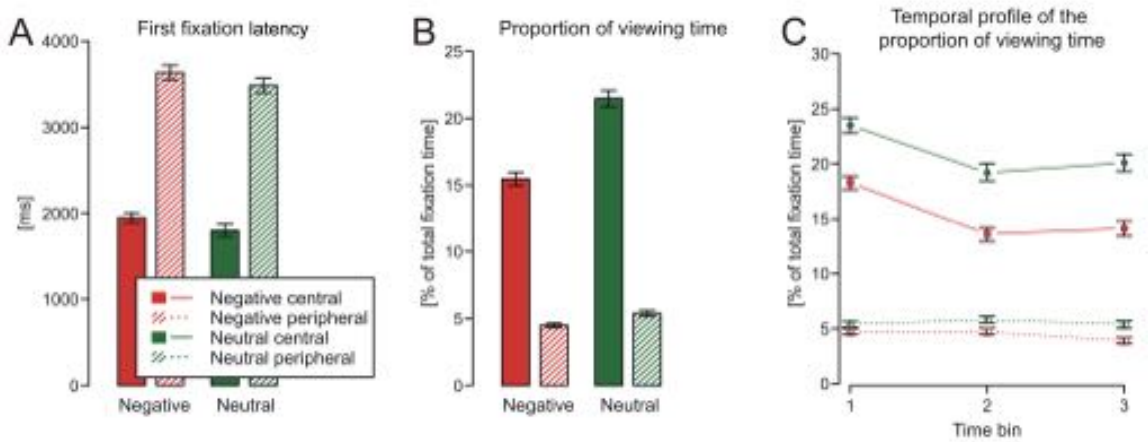

Figure 6. Fixation data of central and peripheral items from negative and neutral picture stories: A) First fixation latency; B) Proportion of viewing time; C) Temporal profile of the proportion of viewing time. Error bars indicate standard errors of the mean.

Crucially these main effects were qualified by an interaction between emotional context and centrality, $F(1, 60) = 71.39$, $p < .001$, $f = 0.17$ (see figure 6B). Though proportion of viewing time of central items was overall higher compared to peripheral items, this difference was much smaller in negative stories, foremost driven by a considerably shorter fixation on central items in negative (M = 15.5%, SD = 0.5%) compared to neutral stories (M = 21.5%, SD = 0.6%). The ANOVA on the proportion of viewing time with emotional context, importance and time as independent variables resulted in significant main effects of all three factors. Besides emotional context, $F(1, 60) = 120.55$, $p < .001$, $f = 0.21$, and importance, $F(1, 60) = 812.16$, $p < .001$, f = 1.36, there was also a significant difference across the three time bins, $F(2, 59) = 29.39$, $p < .001$, $f = 0.12$ (see figure 6C). Additionally, the two way interaction importance × time was significant $F(2, 59) = 28.78$, $p < .001$, $f = 0.12$, while the interaction emotional context × time was not significant. Most interestingly however, the significant interaction emotional context × importance, $F(1, 60) = 59.33$, $p < .001$, $f = 0.14$, showed a similar pattern as in the ANOVA without the factor time and importantly, the non significant three way interaction indicated no differences in the interaction of context × importance across the three time bins.

Recognition Memory

A significant main effect of centrality, $F(1, 60) = 643.67$, $p < .001$, $f = 1.36$, showed that central items were remembered more than twice as often as peripheral details. The main effect of emotional context was marginally significant $F(1, 60) = 3.63$, $p < .10$, $f = 0.05$. Importantly a significant interaction effect was obtained, $F(1, 60) = 9.25$, $p < .01$, $f = 0.10$, as assumed by the emotional trade-off effects. While recognition for central items (negative: $M = 0.81$, $SD = 0.12$; neutral: $M = 0.79$, $SD = 0.15$) was not modulated by the emotional context, $t(60) = 1.37$, $p = .17$, memory for peripheral items occurring in negative stories ($M = 0.35$, $SD = 0.15$) was considerably worse compared to neutral stories ($M = 0.43$, $SD = 0.18$), $t(60) = 3.15$, $p < .01$, $d = 0.49$ (see figure 7).

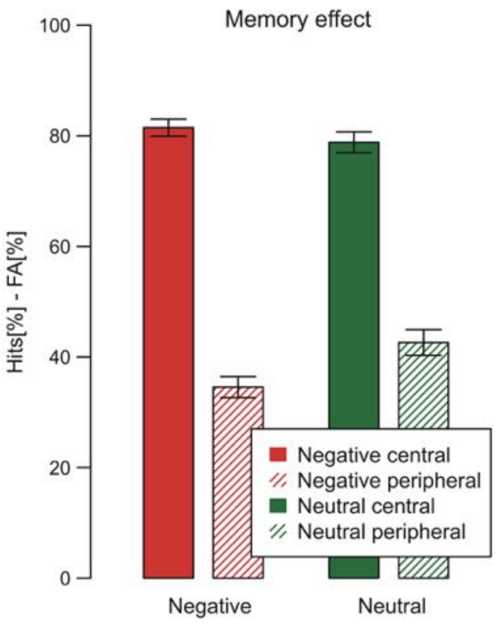

Figure 7. Recognition rates. Mean recognition rates for central and peripheral items of negative and neutral picture stories. Error bars indicate standard errors of the mean.

Hierarchical Regression Analyses

In model 1 only centrality was entered and the predicted average difference between recognition of central vs. peripheral items was significant (average predictive probability of central items: 86.3%, of peripheral items: 45.0%, for β-values and p-values, see table 2). In Model 2.a.1 the main effect of arousal was added and (significantly) predicted better memory for items appearing in a low arousing context compared to items of a high arousing context (see table 2).

That is, objects from a story rated 1 in arousal (mean centered: -3.9) were predicted to be recognized with 78.8% average probability while objects from a story rated 9 (mean centered: +4.1) were predicted to be recognized with 67.2% average probability. The effect of centrality did not change substantially. Model fit statistics showed that the model containing arousal as additional predictor (model 2.a.1) was a significant improvement over the centrality only model (model 1), χ^2 (1) = 26.43, $p < .001$.

In model 2.a.2 the interaction effect arousal × centrality was additionally added. The effects of centrality and arousal did not change substantially. Importantly the interaction effect arousal × centrality was significant as well (see table 2 and figure 8A). In line with the assumption of the emotional trade-off effects, the estimated model predicted increased differences in memory between central and peripheral items as a function of the arousal level. Central items from a low arousing context (-3.9) were estimated to be remembered with 87.8% probability and corresponding peripheral items with 56.4%, (average difference = 31.4%). By contrast, central items from a high arousing context (+4.1) were estimated with 84.9% and corresponding peripheral items with 33.7% (average difference = 51.2%). Correspondingly, comparison of model deviances suggested that the model including the interaction term arousal × centrality (model 2.a.2) was a significant improvement over the main effects only model (model 2.a.1), χ^2 (1) = 5.83, $p < .05$. Model 2.b.1 and model 2.b.2 with centrality, proportion of viewing time and their interaction as predictors, showed a divergent pattern. The effect of centrality decreased substantially from model 1 (average difference between central and peripheral items = 41.3%) to model 2.b.1 (average difference = 27.3%), where proportion of viewing time was added as a covariate. Thus, attention seemed to (partly) mediate the differential effect of central vs. peripheral details on memory. The effect of centrality decreased again in model 2.b.2 (average difference = 24.9%), where the interaction effect of proportion of viewing time × centrality was added. Correspondingly and in line with the assumption that proportion of viewing time would affect memory, the main effect of proportion of viewing time turned significant in model 2.b.1 (see table 2). Across centrality, items fixated for a relatively short duration (1^{st} quartile) were estimated to be recognized with 57.3% average probability and those fixated relatively long (3^{rd} quartile) were estimated with 76.1% probability to be recognized, an average difference of 18.7%. Comparisons of model deviances also suggested that adding the proportion of viewing time (model 2.b.1) was a strong improvement over the centrality only model (model 1), $\chi^2(1) = 154.63$, $p < .001$.

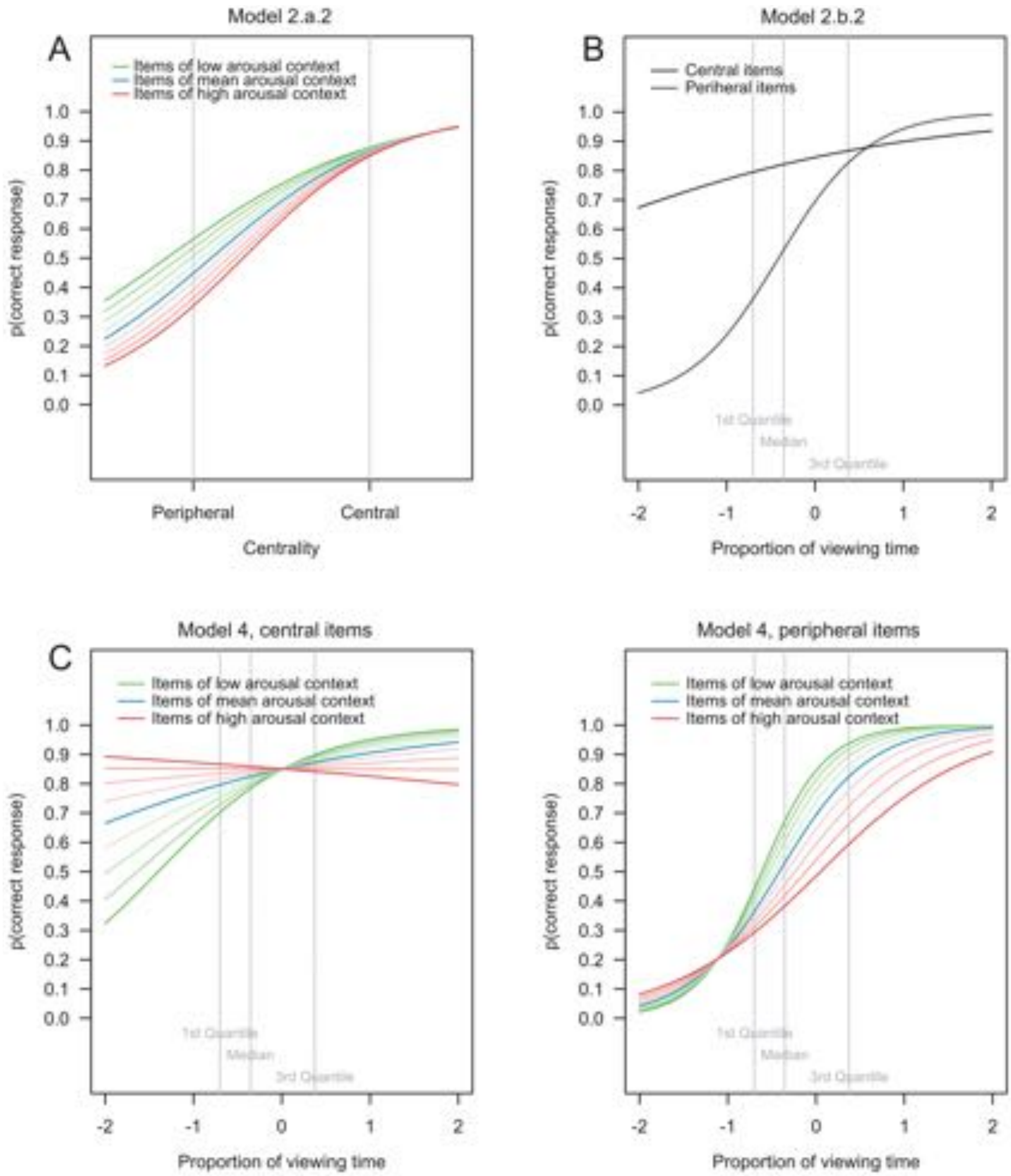

Figure 8. Estimated probabilities of hierarchical logistic regression models. A) Probability to recognize an item as a function of centrality, for the nine levels of arousal. B) Probability to recognize a central vs. peripheral item as a function of the proportion of viewing time. C) Probabilities to recognize a central (left) or a peripheral item (right) as a function of the proportion of viewing time, for the nine levels of arousal.

Table 2. Parameters and deviances of hierarchical logistic regression models predicting recognition memory from centrality, arousal and proportion of viewing time

	β	*SE*	*p*	*AIC*	*BIC*	*Deviance*	*df*
Model 1				3457	3475	3451	3
Intercept	0.82	0.07	<.001				
Centrality	2.04	0.09	<.001				
Model 2.a.1				3432	3456	3424	4
Intercept	0.83	0.08	<.001				
Centrality	2.06	0.09	<.001				
Arousal	-0.09	0.02	<.001				
Model 2.a.2				3428	3459	3418	5
Intercept	0.82	0.08	<.001				
Centrality	2.05	0.09	<.001				
Arousal	-0.07	0.02	<.001				
Centrality x arousal	0.09	0.04	<.05				
Model 2.b.1				3304	3328	3296	4
Intercept	0.96	0.08	<.001				
Centrality	1.42	0.10	<.001				
Proportion of viewing time	0.89	0.08	<.001				
Model 2.b.2				3236	3266	3226	5
Intercept	1.26	0.09	<.001				
Centrality	0.88	0.13	<.001				
Proportion of viewing time	1.23	0.09	<.001				
Centrality x Proportion of viewing time	-1.49	0.19	<.001				
Model 3				3215	3258	3201	7
Intercept	1.25	0.10	<.001				
Centrality	0.90	0.13	<.001				
Arousal	-0.06	0.02	<.01				
Proportion of viewing time	1.22	0.09	<.001				
Centrality x arousal	0.10	0.04	<.01				
Centrality x Proportion of viewing time	-1.46	0.19	<.001				
Model 4				3192	3247	3174	9
Intercept	1.26	0.10	<.001				
Centrality	0.91	0.13	<.001				
Arousal	-0.10	0.03	<.001				
Proportion of viewing time	1.22	0.10	<.001				
Centrality x arousal	0.23	0.05	<.001				
Centrality x Proportion of viewing time	-1.45	0.19	<.001				
Arousal x Proportion of viewing time	-0.17	0.04	<.001				
Centrality x arousal x Proportion of viewing time	0.03	0.08	.70				

Note. AIC = Akaike information criterion; BIC = Bayesian information criterion.

The main effect of proportion of viewing time increased in model 2.b.2. Items with small proportion of viewing time (57.9%) now differed to long durations (84.7%) by an average difference of 26.8%. Crucially the interaction effect was significant as well, suggesting that recognition of central vs. peripheral items are differentially affected by increased proportions of viewing time (see table 2 and figure 8B). Recognition of peripheral items was predicted to differ strongly dependent on attentional processing. Peripheral items that were fixated shortly (1st quartile) were estimated to be recognized with 36.3%, those fixated for a longer duration (3rd quartile) were estimated with 82.6%. For central items, however, these values were relatively similar and amounted to 79.5% (1st quartile) and 86.8% (3rd quartile), respectively. Correspondingly, adding proportion of viewing time contingent on centrality (model 2.b.2) showed a better fit than the main effects only model (model 2.b.1), $\chi^2(1) = 70.42$, $p < .001$. Taken together, comparisons of models 1, 2.b.1, and 2.b.2 showed that adding proportion of viewing time and the interaction of proportion of viewing time × centrality as covariates reduced the main effect of centrality thereby substantiating the mediating role of attention on memory for central vs. peripheral items. However, these results also showed that memory for central information depended much less on attentional processes during incidental encoding compared to memory for peripheral details.

In model 3 all parameters used in the models 2.a.2 and 2.b.2 were entered and comparisons of model deviances suggested model 3 to be an improvement over both models (model 3 vs. model 2.a.2, $\chi^2(2) = 217.32$, $p < .001$; model 3 vs. model 2.b.2, $\chi^2(2) = 24.54$, $p < .001$). The impact of the proportion of viewing time on memory and the proportion of viewing × centrality did not change substantially in the presence of the main effect of arousal and the interaction effect arousal × centrality (model 3 compared to 2.b.2). The effect of arousal did also not change substantially compared to model 2.a.2. Crucially however the effect of arousal × centrality was not affected by the presence of the covariates involving the proportion of viewing time (see table 2). Assuming that attention mediates the differential effects of arousal on memory for central vs. peripheral details, a reduced impact of arousal × centrality would have been expected, when controlling for attention. However, instead of a decrease, the impact of arousal × centrality on memory even increased slightly compared to model 2.a.2.

Interestingly, all effects of model 3 that were related to arousal increased in the presence of the additional predictors arousal × proportion of viewing time and the three way interaction of all factors in model 4. The effect of arousal × centrality even doubled in effect size (see table 2). All further effects did not change substantially (e.g., centrality, proportion of viewing time, and proportion of viewing time × centrality). Importantly, also the interaction between arousal and proportion of viewing time was significant and moreover, this effect was not significantly different for central vs. peripheral items (see table 2). The predictive power of the full model was significantly better than for model 3, $\chi^2(2) = 26.80$, $p < .001$. The pattern of results suggests that the amount of overt attention had a higher influence on memory for central and peripheral items appearing in a low arousing compared to a high arousing context (see figure 8C). Average predictive probability of a central item from a high arousing context was estimated to be comparably high when fixated shortly (86.6%), or long (84.8%). But for central items from a low arousing context the probability was estimated to be 70.6% if fixated shortly and increased to 88.8%, if fixated longer. Congruently, peripheral objects in a negative context improved much less, with longer fixation durations (1^{st} quartile: 28.9%, 3^{rd} quartile: 59.9%, average difference = 31.0%), compared to peripheral objects from a more neutral context (1^{st} quartile: 44.4%, 3^{rd} quartile: 93.3%, average difference = 48.9%).

3.4. Discussion

Early research on the effects of emotion on memory had a stronger methodological focus on ecological validity but revealed partly inconclusive results. It was then post-hoc suggested that the relevance of central vs. peripheral to-be-remembered information plays a crucial role, with central information being remembered better at the expense of memory for peripheral information, when appearing in an emotionally negative context (Christianson, 1992). Though more recent studies confirmed the hypothesis of the emotional trade-off effects on memory, these studies have used more artificial incidental encoding and test material. With a focus on ecological validity, the current study aimed to investigate the emotional trade-off effects on memory for central vs. peripheral details naturally appearing in thematically driven picture stories. Hypothesizing to find the emotional trade-off effects on memory using this kind of stimuli and test items we furthermore aimed to investigate the causes underlying the trade-off effects. Specifically we were interested in testing the common assumption, that attentional processes are mediating the emotional trade-off effects on memory (Burke, Heuer, & Reisberg, 1992; Christianson, 1992; Kensinger, 2009; Reisberg & Heuer, 2004). Furthermore we were interested in validating explicit emotional ratings of the stimulus material by physiological parameters and to explore the relationship of physiological reactions during incidental encoding with later recognition memory responses.

The difference found between explicit affective ratings of negative and neutral picture stories validated the a priori groupings of the stories. Picture stories were rated using the same scale and on the same affective dimensions as the IAPS picture set (Lang, 1980; Lang et al., 2008). On average, negative picture stories were rated as more unpleasant than 94.4 % and as more arousing than 96.7 % of the pictures of the complete IAPS set (relative to norms for male subjects), while neutral picture stories were rated on average as more unpleasant than 30.9 % and as more arousing than 20.1 % of the IAPS pictures.

Differences between negative and neutral picture stories were confirmed by a stronger heart rate deceleration for negative picture stories. This finding is consistent with (Burke et al., 1992), who also used picture stories as stimulus material and physiological measurements for validation and reported a decreased heart rate in the negative (vs. neutral) arousal group. A stronger heart rate deceleration for negative picture stories is also in line with findings of studies using IAPS pictures (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001) as stimulus material. Cardiac deceleration in an emotionally negative context seems to be an initial reaction to a threatening stimulus when preparation for an immediate reaction is not required (for a review, see Bradley et al., 2001). However the effect size of the heart rate measure was quite small in the current study and additionally we did not observe significant differences in the electrodermal data. These small (heart rate) and non-significant (skin conductance) physiological effects were not expected and indicate that physiological responses seem to depend on specific emotions and methods of induction. Though activity in the autonomic nervous system is an established variable to quantify responses to specific emotions, the pattern of findings is quite inconsistent. Importantly, physiological responses to emotions can be moderated by the method used for emotion-induction and seem to differ strongly for subgroups of negative and positive emotions (for reviews, see Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 1993; Kreibig, 2010; Larsen, Berntson, & Poehlmann, 2006; Mauss & Robinson, 2009). For example, other studies using stimuli from the IAPS did only find significantly enhanced electrodermal responding to highly arousing pictures (e.g., mutilation, animal attack, human attack; Bradley et al., 2001) or to threatening pictures (Bernat, Patrick, Benning, & Tellegen, 2006) whereas no such response amplification was evident for less arousing negative picture categories, or for victim scenes respectively.

The rather extreme explicit affective ratings obtained in the current study seem to be even more striking. It is important to emphasize, that not isolated pictures were presented in this study but instead sequential picture stories. It could be, that watching a story about a protagonist and often a second person (in the negative condition always a victim) generates more dynamic social cognitions including empathy and affective or moral judgments about the incident or the persons involved. This might have engaged a different subjective involvement of the participants causing these rather extreme ratings of valence and arousal, while strong affective physiological responses remained absent in the ANOVAs and also in the more explorative regressions of affective physiological responses at incidental encoding on subsequent memory.

Memory data from 13 negative and 13 neutral picture stories of the current study confirm the emotional trade-off effects on memory. We observed the expected interaction effect of emotional context × centrality on recognition data. Comparisons of grand means (see figure 7) indicated, that this effect was mainly driven by a reduced recognition rate for peripheral items presented in a negative (vs. neutral) emotional context and did not suggest an enhancement effect on memory for negative central items. However, the hierarchical regression models allowed for evaluating these effects in more detail. In the full model that incorporated influences of item centrality, arousal, and proportion of viewing time (model 4), the predictive probability of recognizing a central item that appeared in a highly arousing context was larger (85.4%) compared to a low arousing context (79.8%) and by contrast, an inverse pattern was obtained for peripheral items (high arousal: 46.3% vs. low arousal: 67.4%; see Figure 8 C and D). In conclusion, results from the present study using ecologically more valid stimuli and test items confirm the emotional trade-off effects, which assume enhanced memory for central information and reduced memory for more peripheral information when appearing in a negative compared to a neutral context.

To account for the emotional trade-off effects on memory, it is generally assumed, that negative emotional stimuli narrow attention to central information at the expense of attention for peripheral information. This in turn, so the assumption is the underlying cause for both, enhanced memory of central and for reduced memory of peripheral information in an emotional compared to a neutral context. In the current study, eye-tracking was used to test this hypothesis. Interestingly findings with both attentional measures, quantifying how fast and for how long participants attended to the details indicated that items appearing in a negative context were attentionally processed less (i.e. attended to later and for a shorter duration) regardless of centrality. Especially, central items in a negative context were fixated much shorter compared to a neutral one. Furthermore this result was also evident in an analysis of the temporal profile indicating, that less attentional processing of (even “central”) information in an emotionally negative context happens early and is maintained throughout the whole viewing period. This pattern of fixations did not reflect the memory results and contradicts the assumption that the emotional trade-off effects are mediated by attention. In contrast, these findings suggest, that in a negative context attention for objects is diminished even for central information closely connected to the thematic content, while eye movements seem to be directed more (and earlier) to other information, probably those establishing the emotionality of the negative context itself (e.g., faces / bodies). Moreover, the hierarchical models also suggest objection of the common hypothesis, that the trade-off effects of emotion on memory is caused by congruent differences in overt attention. Inclusion of fixation data into the regression models did not diminish the joint influence of centrality and arousal. By contrast, the effect sizes of the centrality × arousal term in the two models including attentional parameters as covariates increased partly substantially. Thus a necessary condition for a mediating role of this factor was not met (Baron & Kenny, 1986), ruling out the possibility that attention is mediating the trade-off effects of emotion on memory (see also Riggs et al., 2011; Steinmetz & Kensinger, 2013).

Furthermore, we obtained the following interesting relationships. Firstly, it seems that the effect of attention on memory differs between central and peripheral items. High recognition of objects that are important for the storyline (central items) seems to depend much less on overt attention than recognition of objects irrelevant for the plot (peripheral items). That is, central objects fixated shortly are recognized already relatively good, compared to objects fixated for a longer duration, while peripheral objects are recognized much better only when previously attended to for a longer duration. Secondly, the role of attention for recognition of objects from a high vs. low arousing context differs. Recognition of objects from a more negative context seems to depend less on the amount of overt attention, than recognition of objects from a more neutral context. Such effect was observed for both, central and peripheral details. These results suggest that processing of information of a negative context differs qualitatively from that of a neutral context. For the former, central information seems to be reliably encoded within a few fixations and even enhanced attention does not result in stable memories for peripheral information. In contrast, overt attention is a better predictor for the recognition of central and peripheral details that appeared in a neutral context. Taken together, results of study 1 confirmed the emotional trade-off effects on memory in an ecologically more valid stimulus set of picture stories, with either of an emotionally negative or a neutral context and a definition of central vs. peripheral details based of their relevance for the storyline. However, our results also indicate a strong objection of the common hypothesis, that the trade-off effect of emotion on memory is caused by corresponding differences in overt attention and moreover imply, that the role of attentional processing for later memory depends on centrality and emotional context but not their interaction. Both, the observed reduced effect of attentional processing on subsequent memory for any detailed information of a negative context and the negative emotional trade-off effects, which do not seem to be caused by attentional processing, indicate a qualitative difference in cognitive processing which might further be elucidated by examining the neural circuitry underlying these effects.

4. Study 2

4.1. Aims of the Study

Results of study 1 confirmed the expected differences in affective ratings between negative and neutral picture stories. Recognition results showed that the effect of a negative emotion differed for memory regarding central more plot-relevant details of the picture stories and peripheral details with no relevance for plot. However the expected enhancement effect of negative emotion for central relevant items was not pronounced indicating that a ceiling effect for plot-relevant details might have suppressed the expected difference in memory for central items of a negative vs. neutral context. To address this issue we tested participants memory for details after a longer retention delay of one day, since emotional enhancement effects on memory has been shown to be more pronounced after a longer consolidation period (e.g., LaBar & Cabeza, 2006).

Studies on the neural bases of the emotional trade-off effects indicate that it relates to allocation of processing resources to the amygdala, the FFG and to prefrontal, and temporal regions (Adolphs et al., 2005; Adolphs et al., 2001; Kensinger et al., 2007; Kensinger &

Schacter, 2006; Mather et al., 2006; Waring & Kensinger, 2011). Theses findings have been taken for indication that emotion prioritizes resources for visual processing of and directed attention to emotional information, leading to better memory for central information and worse memory for more peripheral information. However, there are only very few studies on the neural bases of emotional trade-off effects and extant imaging studies on this issue tested memory for unrelated single stimuli and contrasted them to memory for more artificial contextual details.

To investigate differences in neural activity related to differential effects of negative emotion on memory for central vs. peripheral details of thematically driven visual narratives and to investigate the assumption derived from study 1 that the role of attention in memory for negative vs. neutral details differs, with memory of negative details being less dependent on previous attentional processing, we measured brain blood oxygenation level dependent (BOLD) magnetic resonance imaging data, affective ratings (i.e., valence and arousal) and eye movements in study 2 (see figure 9).

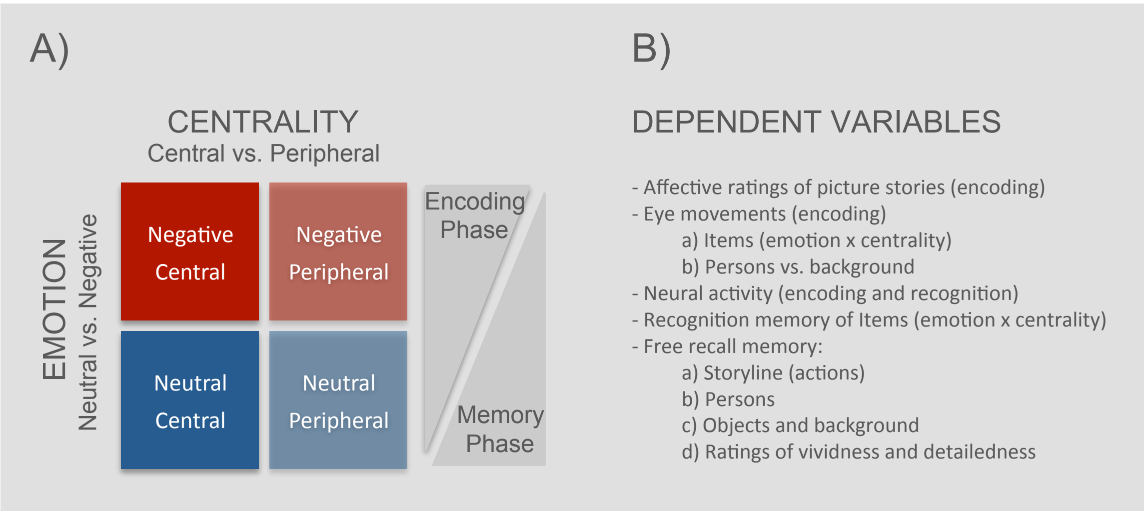

Figure 9. A) Study design of study 2; B) Dependent variables of study 2

One day later we tested recognition memory of the details. Simultaneously we acquired BOLD imaging data of the retrieval session to explore neural activity related to differential effects of negative emotion on memory for centrally relevant vs. peripheral details at retrieval. Additionally we assessed free recall memory (i.e., verbal descriptions of the picture stories) and ratings on how detailed and how vivid memory for each picture story was, to further explore effects of negative emotion on memory for specific content details.

Hypotheses

Effects of Emotion

We expected to replicate findings from the previous study of more negative ratings in valence and higher ratings of arousal for the negative picture stories. We also expected that these affective differences would be associated with differences in BOLD responses when contrasting incidental encoding of negative vs. neutral picture stories. Specifically we expected significantly stronger neural activation in the amygdala for negative picture stories (cf. e.g., McGaugh, 2004). Since divers, wide spread cortical and subcortical areas were found to be involved in processing of emotional stimuli (e.g., Murty et al., 2010), we also expected to find differences in various other areas of the whole brain (ventral visual stream, the left lateral prefrontal cortex and the right ventral parietal cortex).

Main Effects of Emotion on Memory

We expected to find effects of emotion in recall memory, ratings of vividness and ratings of detailedness. Specifically we expected to find higher ratings in vividness for negative picture stories (cf., Brown & Kulik, 1977) and higher ratings of detailedness for negative vs. neutral stories (e.g., Heuer & Reisberg, 1990), probably more recalled details regarding the actions of the storyline and (central) persons, and probably less recalled details regarding other objects or background details of the negative picture stories (e.g., Burke et al., 1992).

Main Effects of Emotion on Attention

Findings of study 1 revealed that participants deployed a considerably smaller amount of attention to central, plot-relevant details of negative picture stories indicating that attentional differences should be also evident for other information of the picture stories. We assumed that these would be the persons of the narrations who primarily conveyed the action and the emotional (vs. neutral) content of the picture stories. Correspondingly we expected to find prioritized attentional processing of persons and inversely less attentional processing of the remaining background. Additionally we intended to explore possible differences in attentional processing of negative vs. neutral picture stories regarding the total amount of fixations and the length of scan paths on pictures form negative vs. neutral stories.

Interaction Effects of Emotion and Centrality on Memory for Details

Investigating the influence of affective differences on later memory for central plot-relevant vs. peripheral plot-irrelevant details, we expected to replicate the emotional trade-off effects in recognition memory (e.g., Burke et al., 1992 for reviews, see Christianson, 1992; Kensinger, 2009; Levine & Edelstein, 2009; Reisberg & Heuer, 2004). More importantly, and as a main goal of this study, we expected to find subsequent memory effects with stronger BOLD responses at incidental encoding in a contrast corresponding to the differential effects negative emotion has on memory for central vs. peripheral details. By this means we intended to elucidate the neural basis of the trade-off effects, which seems not to be caused by the amount of (attentional) processing but by qualitative differences in neural processing. Specifically we expected to find those neural correlates in the amygdala (Adolphs et al., 2005; cf., Kensinger & Schacter, 2006) but putatively also in the FFG and limbic, prefrontal, and temporal regions (cf., Kensinger et al., 2007; Mather et al., 2006). Additionally we considered to find a difference when contrasting the emotional trade-off effects in BOLD responses at recognition, too. Thus, we expected to find more activation in the amygdala, when remembering central and forgetting peripheral details derived from a negative (vs. neutral) context, but maybe also in the FFG and limbic, prefrontal, and temporal regions, since such a finding would confirm assumptions, that a pattern of reactivation from incidental encoding can be found (cf., Buchanan, 2007).

The Role of Attention in Emotional Memory of Details

Since results of study 1 suggested that attention does not mediate the negative emotional trade-off effects in recognition memory for central vs. peripheral details, we expected to replicate the results in the present study. Additionally results of study 1 suggested a different relationship regarding the role of attention in memory for negative vs. neutral details: the relevance of attentional processing at incidental encoding for later recognition memory seems to be lower for details of a negative vs. neutral context. Central details in general, but those derived of a negative context specifically, were remembered very well even if they were attentionally processed only briefly. In contrast, does the probability to recognize a peripheral detail derived from a negative context not increase as much with more attentional processing compared to peripheral details derived from a neutral context. Accordingly we had furthermore the following hypotheses: we expected to replicate the effects in attentional parameters and investigated corresponding BOLD responses, both, at incidental encoding and at recognition. We expected to find corresponding differences in brain areas related to emotional memory.

4.2. Methods

Ethics Statement

This study was approved by the local ethics committee of the Medical Association, Hamburg, Germany and conducted according to the principles expressed in the Declaration of Helsinki.

Participants

Thirty-eight healthy young adults with normal or corrected to normal visual acuity took part in the study and were paid for participation. Four participants had to be excluded because one was very tired, two had massive movements while acquiring fMRI data and one due to technical problems during data collection. The final sample (N = 34, 21 women) had a mean age of 26.18 years (SD = 4.36 years). Stable eye-tracking data was only obtained from 24 participants and corresponding analyses involving eye movement parameters are restricted to this subsample. BOLD analyses involving recognition responses (correct, incorrect) were restricted to participants (N = 29) with variance in all four conditions of emotion (negative, neutral) and centrality (central, peripheral). Participants were told that they could withdraw from the experiment at any time and gave written informed consent. At the end of the experiment they completed the Beck Depression Inventory (Beck et al., 1961), and the trait version of the Spielberger State Trait Anxiety Inventory, (STAI; Spielberger et al., 1983). The BDI scores ranged from 0 to 12 (M = 3.68, SD = 3.18) and were all within the cut-off value for no to minimal depression (i.e., 13). The STAI scores ranged from 24 to 51 (M = 34.18, SD = 6.24) and were well comparable to published norms for this age group (M = 33, SD = 10).

Data Acquisition

Whole-brain fMRI data was collected on a 3 T Siemens Trio scanner using a 32-channel head coil. Echo-planar T2*-weighted images (TR: 2390 ms, TE: 25 ms, FOV: 216 × 216, flip angle: 80°) were acquired with 40 transversal oriented axial slices, a voxel size of 2 × 2 × 2 mm and a 1 mm gap between slices. A high-resolution (1 × 1 × 1 mm) T1-weighted anatomical image was recorded for each participant using an MPRAGE (magnetization-prepared, rapid acquisition gradient echo) sequence. Participants viewed the back-projected stimuli (10° × 15° field of view) via a 45° mirror placed atop the head coil. On the first day, eye movements were simultaneously recorded by a video-based eye-tracker [EyeLink 1000, SR Research, Ontario, Canada] using a sampling rate of 1000 Hz. The Software Presentation (NeuroBehavioral Systems, Inc.) was used to present the stimuli.

Procedure

Participants were scheduled on two consecutive days with a time lag of 24 hours. On the first day they were told that the aim of the study was to explore relationships between affective ratings, visual attention and brain activity while viewing pictorial narratives of different emotional valence. No indication for a memory task was given. Emphasis was made that eye movement recordings and scanner data acquisition would be only of sufficient quality when participants would lie comfortably in the scanner and would manage to avoid movements during data collection. They were told, that viewing and rating picture stories would take about 2 hours but that the experiment was divided into two sessions to ensure that taking part would not be unpleasant. However, in fact participants were shown all 26 picture stories on the first day while on the second day they were asked to do a surprise recognition test and a free recall test (see figures 10 and 11). Technical procedures were explained (i.e., calibration of the eye-tracker, affective rating scales, to look at fixation crosses) and participants were asked to try to get engaged with the picture stories they would see. Participants were then prepared for lying in the scanner, adjustments of the eye-tracking camera were made and a 9-point calibration procedure was completed. Then 6 practice trials were given to get participants used to the valence and arousal rating-scales (i.e., a computerized version of the (SAM; Lang, 1980), a non-verbal self-report measure consisting of two bipolar nine-point scales representing the affective dimensions valence and arousal). Pictures for the practice trials were collected from the internet and depicted a scene with negative (3) or neutral (3) content. After the practice trials the actual experiment started. Each picture story began with a central fixation cross, shown for 5 - 7 seconds. Then a picture story, consisting of four subsequently shown pictures, was randomly drawn. Each picture had a duration of 7 seconds. After the picture story, a fixation cross showed up briefly followed by the presentation of the valence and the arousal rating scales each lasting until the response was finally terminated.

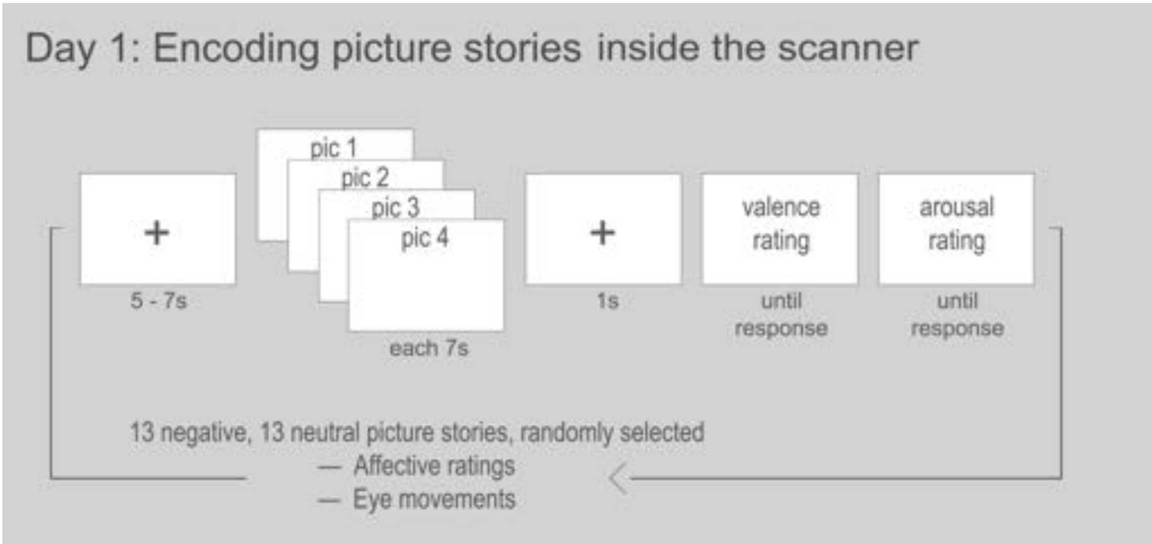

Figure 10. Incidental Encoding task design of study 2

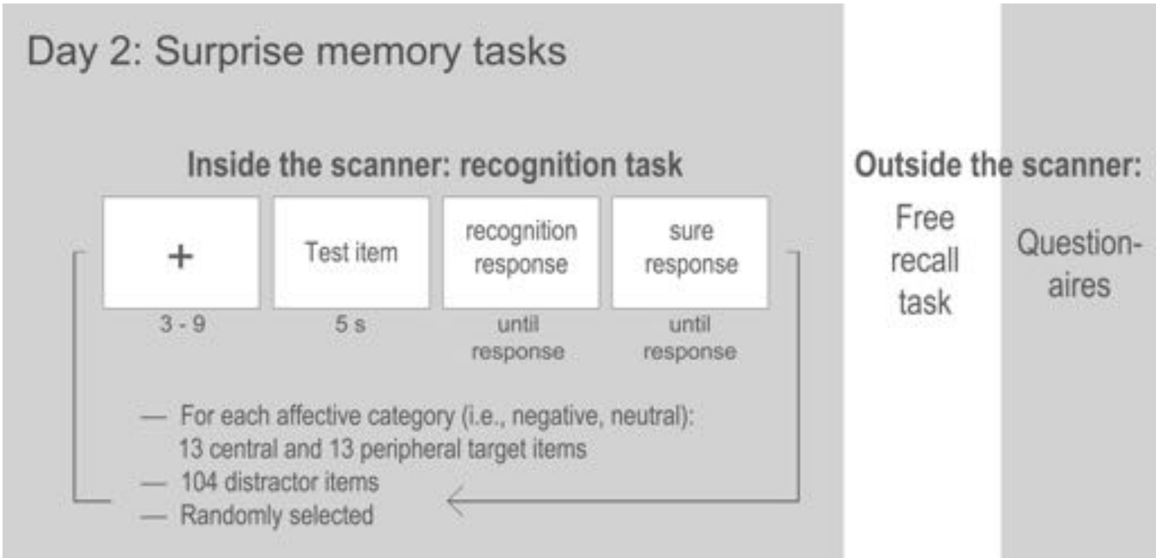

Figure 11. Recognition task design of study 2

After half of the trials the eye-tracker was recalibrated and at the end of the incidental encoding session the T1- weighted structural image was acquired. On day 2 participants were informed that - beside the relationships between visual attention, affective ratings and neural activity while incidental encoding picture stories - further aims would also be to investigate the interactions of those variables with later encoding related memory for details. Participants were informed about the upcoming recognition memory task that would take place in the scanner and the free recall task that would be administered afterwards. In the recognition task each trial started with a fixation cross shown for 3 - 9 seconds followed by a randomly drawn test item (i.e., 52 target items and 104 distractor times) presented for 5 seconds. After stimulus offset participants indicated whether they recognized the item as an object that had appeared in one of the picture stories or not by pressing the corresponding button of a response box. Additionally they were asked to indicate how confident they were about the recognition response just given by choosing one of the three options: very confident / rather confident / unconfident. After the recognition task participants left the scanner room and were instructed for the free recall task. In the computer based free recall task each trial began with a sentence that described a picture story. The descriptions did not mention the central nor the peripheral object, to minimize influences of the previous testing session and were held as short as possible (e.g., "a man is beating up his girlfriend"). Care was taken, that each description was an unambiguous cue for only one of the picture stories. After pressing the space bar on a standard computer keyboard a tone indicated that verbal responses would be recorded. Participants then reported their memories of the picture story with the instruction to be as detailed, as possible. They were asked to report the actions they remembered, to describe the persons and the location and to name all the objects they brought to mind when they tried to recall the picture stories. Participants indicated to be done with recording by pressing the space bar again. Then screens appeared where participants had to rate on two scales, each ranging from 1 to 6, how precise (i.e., no memory: 1; very precise memory: 6) and how vivid (i.e., no memory: 1; very vivid memory: 6) their memory of the picture story was overall. After finishing the free recall task participants were given the BDI and the STAI and they were notified that those forms were standard questionnaires to control for variations in trait measures.

Data Processing

Eye Movement Data

Eye Movement Data were parsed into saccades and fixations using Eyelink's standard parser configuration, which classifies an eye movement as a saccade when it exceeds 30°/sec velocity or 8000°/sec^2 acceleration. Subsequently × and y coordinates of fixations were drift corrected with reference to the central fixation cross at the start of each trial. The first fixation that occurred after each picture onset was removed from the data to eliminate confounding effects of participants' previous attentional focus (e.g., fixation cross, fixation from a previous picture). Around each item (i.e., central, peripheral) and each person (i.e., body, head and face) an outline was drawn to define the ROI. Fixations were attributed to a ROI when they were within the region's pixel coordinates. Additionally, all fixations made outside the ROI of persons were summarized as fixations to the background. For each ROI, two attentional measures were derived from the eye movement recordings: The latency of the first fixation (*latency*), measuring how fast a ROI was fixated for the first time after stimulus onset and the proportion of *viewing-time* spent on a ROI relative to the total fixation time during picture presentation (excluding blinks and saccades). In addition to ROI related parameters, the *scanpath length* and the *total number of fixations* were summarized for each picture of each story, to quantify overall eye movement behavior.

Free Recall

Aggregated data of the free recall task relates to only those picture stories participants could remember. Categories were a priori defined to quantify recorded responses of the free recall memory task. Data was separated into person, action and object related memory. *Person related memories* included physical characteristics, mimics and clothing. Thus objects that were part of the appearance of a person were allocated to *person related memories*. Furthermore, if such an object was not only named (e.g., "skirt") but also described in more detail (e.g., "blue skirt"), this was quantified using the same category. While the category *person related memories* comprised all aspects of the physical appearance of the persons involved in the picture stories, the category *action related memories* was specified to quantify memories regarding the plot of the stories. All memories describing the location or objects not directly related to a person were allocated to object related memories (e.g., "a man *stood* in a *stairway* and *watched* a woman *come in*" was quantified as three *action related memories* and one *object related* memory). *Object related memories* were scored when correctly named (e.g., "apple" or "road") and additionally when an attribute was correctly recalled (e.g., "red (apple)" or "small (road)"). For each category of correct memories another category was defined to quantify false memories of that category. To summarize correct and false memory, two further categories were generated: the mean score of correctly recalled details and the mean score of falsely recalled details. Besides ratings of *preciseness* and *vividness*, there were in total eight categories quantifying aspects of recall memory: Correct and false *person related memories,* correct and false *action related memories,* correct and false *object related memory*, mean correctly recalled and mean falsely recalled details. Recorded responses of the free recall memory test were transcribed and transcriptions of three participants who had to be excluded from the final sample (see above) were used to train raters and to specify rules how to allocate transcribed free recall memories to the categories. Reliability of ratings were good and amount to an intraclass correlation of *ICC* = .85 (95% confidence interval = .84 – .86).

BOLD Responses

Image processing and statistical analysis of fMRI data was performed using SPM8 (www.fil.ion.ucl.ac.uk/spm/). After removing the first five volumes of each session to compensate for T1 saturation effects, scans of the three incidental encoding sessions and scans of the two recognition sessions were concatenated for each participant separately. Then T1 structural images and fMRI data from incidental encoding and recognition were preprocessed for each individual as follows. First, fMRI images were slice-time corrected to the onset of the middle slice to account for the assumption, that all slices of a scan are acquired at the same time. Second, images were coregistered to the high-resolution anatomical T1 images and realigned and unwarped to compensate effects of subject movements. The DARTEL toolbox was used to create a structural template across subjects as well as individual flow fields which in turn were used for spatial normalization of the functional images (Ashburner, 2007). Finally functional images were smoothed with a Gaussian kernel of 6 mm full-width at half-maximum to account for the spatial dispersion of BOLD effects as well as to meet the assumptions for a random field theory-based correction for multiple comparisons.

Statistical Analyses

All statistical analyses of behavioral data were accomplished with R, an open-source language for statistical computing (www.r-project.org), Statistical testing of event-related blood oxygen level-dependent (BOLD) images were realized with Matlab R2009a (Math-Works, Natick, MA, USA). For analyses regarding behavioral data, an a priori significance threshold of $\alpha = .05$ was used but marginally significant effects ($p < .10$) are also reported. Cohen's *d* and *f* are depicted as effect sizes for pairwise comparisons and analyses of variance (ANOVAs), respectively. BOLD responses were analyzed using the general linear model approach as implemented in SPM8 (Wellcome Trust Centre for Neuroimaging, London). All analyses were performed on statistical parametric images, voxel-wise thresholded at $p < .005$ uncorrected, cluster extent > 30 voxels. Regarding the amygdalae and the hippocampi, we corrected for multiple comparisons using familiywise error corrected p-values ($p_{FWE} < .05$) in ROI-masks from the Harvard–Oxford subcortical structural atlas (Smith et al., 2004) thresholded with a probability of 0.5. In exploratory whole brain analyses, the multiple comparison problem was addressed by relying on cluster level inference ($p_{FWE} < .05$).

Affective Ratings

To compare the affective quality of negative and neutral picture stories, mean subjective ratings of valence and arousal were each analyzed by paired t-tests (negative vs. neutral).

Eye Movement Data

Latency and *viewing-time* regarding central and peripheral items were compared between negative and neutral stories in 2 × 2 repeated measures ANOVAs with emotional context (negative, neutral) and centrality (central, peripheral) as within-subject factors. Differences between negative and neutral stories in *latency of first fixation* and *proportion of viewing-time* of persons (and inversely backgrounds) were analyzed using paired t-tests (negative vs. neutral). Affective differences in *scanpath length* and in *total number of fixations* were compared in 2 × 4 repeated measures ANOVAs with emotional context (negative, neutral) and picture number (1st, 2nd, 3rd, 4th) as within-subject factors.

Recognition Memory

Differences in recognition memory for central and peripheral details was determined by subtracting the proportion of false alarms (erroneous recognition of distractor items) from the proportion of hits (correct recognition of items) and analyzed in a 2 × 2 repeated measures ANOVA with emotional context (negative, neutral) and centrality (central, peripheral) as within-subject factors.

Free Recall Memory and Ratings of Memory Vividness and Detailedness

Affective differences in ratings of memory *vividness* and *detailedness* and affective differences in free recall memory of correct and false *person, action* and *object related memory* and of correct and false mean scores were each analyzed using paired t-tests. Furthermore the proportion of negative vs. neutral picture stories participants could not remember at all were also analyzed using a paired t-test and valence and arousal ratings of remembered vs. forgotten picture stories were compared pairwise for neutral and negative contexts separately.

BOLD Responses

Six hypotheses were a priori postulated and analyzed in separate models. To test the expected differences in neural activity related to incidental encoding negative vs. neutral picture stories a model was set up with eight explanatory regressors on 1st level. This model contained the event-trains of onsets and durations from the 1st, 2nd, 3rd and the 4th picture of negative and of neutral picture stories. The model additionally contained a regressor of no interest modeling the event-train of affective story ratings. Estimated single-subject beta weights of the explanatory regressors were then entered on 2nd level into a 2 (negative context, neutral context) × 4 (1st, 2nd, 3rd, 4th picture) flexible factorial analysis.

A main goal of this study was to investigate effects in BOLD responses at incidental encoding related to the emotional trade-off effects on memory for central vs. peripheral details. This subsequent memory analysis was implemented by setting up a regressor containing the onsets and durations of negative and another containing the onsets and durations of neutral picture stories. Two orthogonal parametric modulators were entered to each of the negative and neutral onset regressors. One modulator coded subsequent memory (1 = recognized, -1 = not recognized) for central details, the other coded subsequent memory for peripheral details. A regressor of no interest was set up for the affective ratings. On the second level the four parametric modulators were entered into a 2 (negative context vs. neutral context) × 2 (central vs. peripheral) flexible factorial analysis.

To explore neural correlates of the emotional trade-off effects in BOLD responses at recognition, two analyses were carried out. First, to investigate whether differences in neural activity corresponding to the emotional trade-off effects on recognition memory in BOLD responses at retrieval can be demonstrated, a 1st level model was set up reflecting the event-train of negative central, negative peripheral, neutral central and neutral peripheral items in separate regressors. Additionally for each regressor of interest a parametric modulator coding correct (i.e., 1) and incorrect (i.e., -1) recognition responses was added to extract BOLD responses due to correct recognition. Four regressors (of no interest) were entered containing the onsets and durations of the corresponding distractors and a ninth regressor (of no interest) coded the trial phases of memory responses. On the second level the four parametric modulators were entered into a 2 (negative context vs. neutral context) × 2 (central vs. peripheral) flexible factorial analysis, contrasting [negative-central > negative-peripheral] > [neutral-central > neutral-peripheral].

Second, since this analysis did not reveal any significant results a second analysis was carried out to compare differences in BOLD responses of processing central vs. peripheral items that were derived from a negative vs. neutral context independent of correct recognition scores. Thus a 1st level model was set up reflecting the event-train of negative central, negative peripheral, neutral central and neutral peripheral items in separate regressors. Additionally four regressors (of no interest) were entered containing the onsets and durations of the corresponding distractors and a ninth regressor (of no interest) coded the trial phases of memory responses. On the second level the four regressors of interest were entered into a 2 (emotional context) × 2 (centrality) flexible factorial analysis, again contrasting [negative-central > negative-peripheral] > [neutral-central > neutral-peripheral].

In order to investigate BOLD responses corresponding to the main effect of attention in emotional memory, two models were set up, one dedicated to BOLD responses at incidental encoding, one dedicated to BOLD responses at recognition. The first analysis was implemented by setting up two 1st level regressors, one containing the onsets and durations of negative, the other those of neutral picture stories. Two orthogonal parametric modulators were entered to each of the regressors. One modulator contained subsequent memory (i.e., 1 vs. -1) multiplied with the corresponding proportion of viewing time for central details, the other contained analogous data for the peripheral details. A regressor of no interest was added to account for the affective ratings made in each trail. On second level the four parametric modulators were entered into a 2 (context) × 2 (centrality) flexible factorial analysis, contrasting [negative-central + negative-peripheral] < [neutral-central + neutral-peripheral].

The effect of attention in emotional memory at recognition was analyzed using a 1st level model with four regressors coding the event-trains of negative central, negative peripheral, neutral central and neutral peripheral items. For each regressor a parametric modulator was added, again coding the interaction effect of recognition × proportion of viewing time. Additionally four regressors of no interest (context × centrality) contained the onsets and durations of the distractors. A ninth regressor (of no interest) was added to account for the memory responses in each trial. On the second level the four regressors of interest were entered into a into a 2 (centrality) × 2 (context) flexible factorial analysis, contrasting [negative-central + negative-peripheral] < [neutral-central + neutral-peripheral].

Regressors on the individual level (1st level) were convolved with the canonical hemodynamic response function and corrected for baseline drifts by applying a high-pass frequency filter (128 s). On group level (2nd level) the estimated single-subject beta weights of regressors of interest or orthogonal parametric modulators of those were entered as explanatory variables into random-effects, within-subject flexible factorial analyses.

4.3. Results

Affective Ratings

As expected, affective ratings of the picture stories were clearly distinct in valence and arousal ratings (see figure 12). Negative picture stories were rated as more unpleasant (M = 2.18, SD = 0.47), than neutral stories (M = 6.22, SD = 0.49), t(33) = 28.70, p < .001, d = 8.35. Also negative stories were rated as more arousing (M = 7.46, SD = 0.62) than neutral stories (M = 3.27, SD = 0.89), t(33) = 19.90, p < .001, d = 5.44.

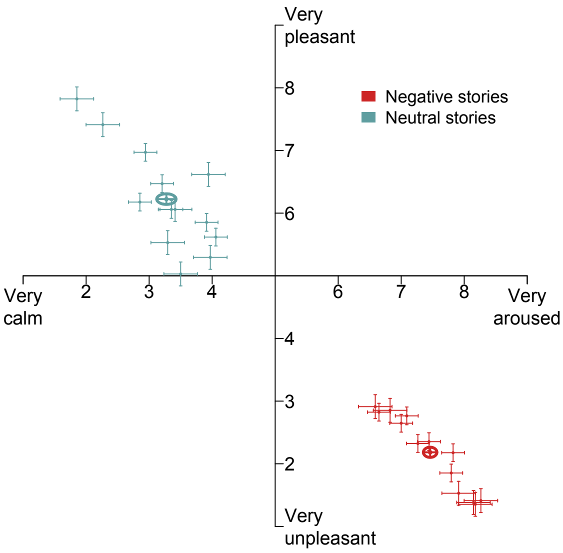

Figure 12. Affective Ratings: Mean and standard error of the mean of valence and arousal ratings aggregated per story (crosses); Grand mean and standard error of the means of valence and arousal ratings for negative and neutral picture stories (ellipses).

Eye Movement Data

The analysis of first fixation latency showed a significant main effect of centrality, F(1, 23) = 95.55, p < .001, f = 0.97 (see figure 13A). Central items were fixated much earlier (M = 1662 ms, SD = 506 ms) than peripheral items (M = 2730 ms, SD = 587 ms). The main effect of emotional context, F(1, 23) = 2.78, p = .11, f = 0.11, and more importantly, the interaction effect of emotional context and centrality did not turn significant, F(1, 23) = 0.03, p = .85, f = 0.01. The ANOVA on the proportion of viewing time also yielded a main effect of centrality, F(1, 23) = 239.20, p < .001, f = 1.48 (see figure 13B), driven by a much higher proportion of viewing time of central vs. peripheral items (central: M = 19.8 %, SD = 5.0 %; peripheral: M = 5.6 %, SD = 2.2 %). Additionally, we obtained a significant main effect of emotional context, F(1, 23) = 61.13, p < .001, f = 0.27, indicating that participants spent less time looking at central and peripheral items when viewing negative (*M* = 10.4 %, *SD* = 3.5 %) vs. neutral picture stories (*M* = 14.9 %, *SD* = 3.7 %). Most importantly, the interaction effect between emotional context and centrality was significant as well, $F(1, 23) = 65.61$, $p < .001$, $f = 0.23$. The difference in proportion of viewing time between central and peripheral items was much smaller in negative stories, driven by considerably shorter viewing time of central items in negative (*M* = 15.6%, *SD* = 4.8%) than neutral stories (*M* = 24.0%, *SD* = 5.2%), $t(23) = 9.64$, $p < .001$, $d = 4.98$. The difference for peripheral items was not significant between contexts in post-hoc pairwise comparisons, $t(23) = 1.04$, $p = .31$, $d = 0.29$.

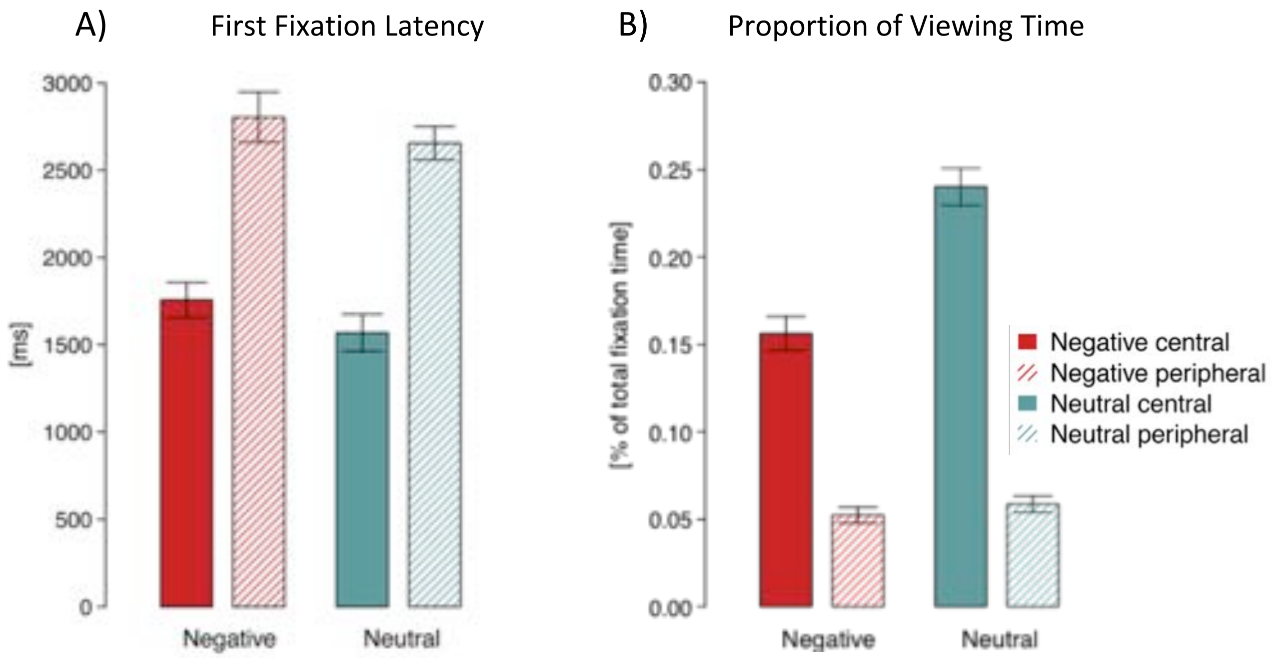

Figure 13. A) First Fixation Latency and B) Proportion of Viewing Time of central and peripheral items in negative and neutral picture stories. Error bars indicate standard errors of the mean.

The Analysis of attentional processing of bodies yielded differences in proportion of viewing time, $t(23) = 5.00$, $p < .001$, $d = 0.70$, with participants looking longer at persons depicted in negative (*M* = 36.4 %, *SD* = 5.1 %) compared to neutral picture stories (*M* = 32.6 % , *SD* = 5.9 %). Since the ROIs of backgrounds were defined as the whole picture, but excluding the ROIs of persons, the analysis regarding proportion of viewing time of the backgrounds corresponds inversely to the analysis of viewing time of bodies. The difference in the latency of first fixations on bodies (and inversely on the background) was not significant, $t(23) = 0.59$, $p = .56$, $d = .09$. The ANOVA of fixation count data showed a significant main effect of emotional context, $F(23) = 4.90$, $p < .05$, $f = .09$. Participants made more fixations when viewing neutral ($M = 27.10$, $SD = 5.85$) vs. negative ($M = 26.04$, $SD = 6.26$) stories (see figure 14 A). Additionally the main effect of picture number turned significant, $F(21) = 6.37$, $p < .01$, $f = .08$, suggesting that the number of fixations decreased while picture stories unfolded. However the interaction effect of emotional context and number of picture did not show differences in fixation count data over time, $F(21) = 2.21$, $p = .12$, $f = .04$. In the analysis of the scan path length only a significant main effect of picture number was obtained, $F(21) = 10.12$, $p < .01$, $f = .17$, indicating that scan path length decreased while picture stories unfolded over time (see figure 14 B).

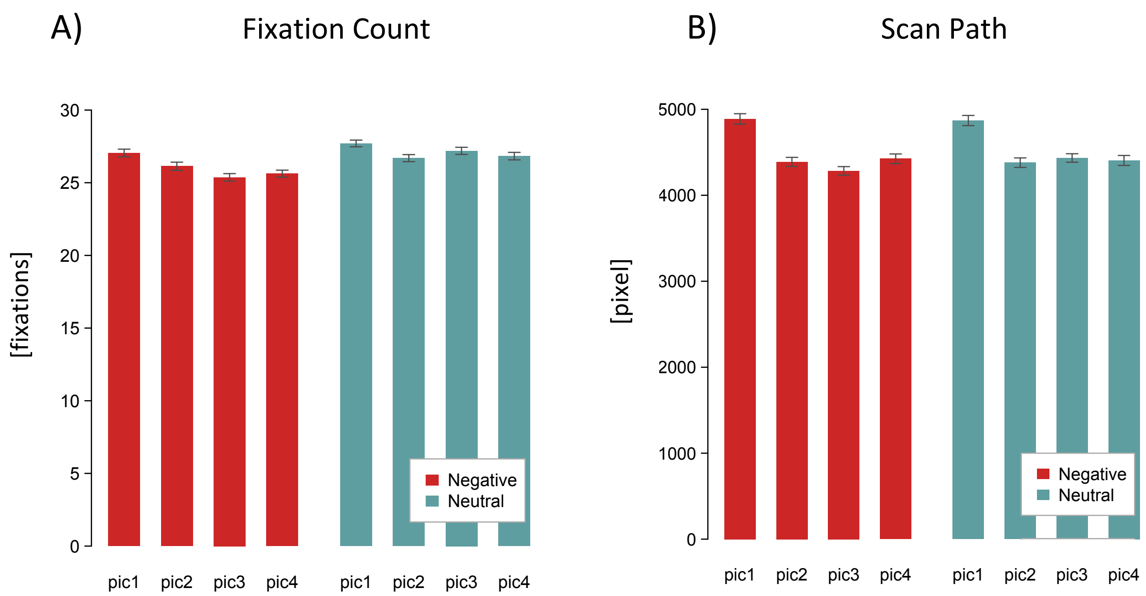

Figure 14. A) Fixation Count and B) Scan Path of negative and neutral picture stories. Error bars indicate standard errors of the mean.

Recognition Memory

A significant main effect of centrality, $F(1, 33) = 151.18$, $p < .001$, $f = 1.00$, was obtained showing that central items were recognized better than peripheral items (see figure 15). The main effect of emotional context was not significant, $F(1, 33) = 0.36$, $p = .551$, $f = 0.03$.

Importantly, and in line with the assumption of the emotional trade-off effects, the interaction effect was significant, $F(1, 33) = 4.70$, $p = .037$, $f = 0.12$, driven by a stronger difference between recognition of central vs. peripheral items in a negative compared to a neutral context. However, a post-hoc pair wise comparison between central items of a negative (M = 55.1 %, SD = 18.1 %) vs. neutral context (M = 51.1 %, SD = 14.5 %) did not turn significant, $t(33) = 1.13$, $p = .27$, $d = 0.21$, and the corresponding comparison between peripheral items of a negative (M = 19.2 %, SD = 14.5 %) vs. neutral context (M = 25.6 %, SD = 13.2 %) was only marginally significant, $t(33) = 1.97$, $p = .06$, $d = 0.46$.

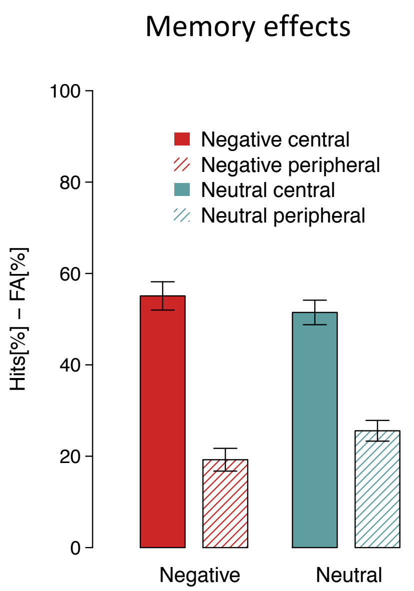

Figure 15. Recognition rates. Mean recognition rates of central and peripheral items occurring in negative and neutral picture stories. Error bars indicate standard errors of the mean.

Free Recall Memory and Ratings of Memory Vividness and Detailedness

In the cued free recall task participant responded in average to 4.18 (SD = 2.29) of the 26 picture stories, that they had no memory of them at all. Interestingly, the vast majority were neutral picture stories (M = 3.50, SD = 1.89), while negative picture stories were barely affected (M = 0.68, SD = 0.84), $t(33) = 8.98$, $p < .001$, $d = 1.93$. Further analyses revealed differences in valence and arousal ratings between neutral picture stories with no memory vs. those stories participants could recall. Recalled neutral picture stories were rated as more pleasant on the valence scale (M = 6.37, SD = 0.53) than forgotten neutral picture stories (M = 5.85, SD = 0.82), $t(33) = 4.05$, $p < .001$, $d = 0.77$. The differences in arousal ratings were marginally significant as well, indicating that remembered neutral picture stories were rated as more calm (M = 3.18, SD

= 0.91) than forgotten neutral stories (*M* = 3.48, *SD* = 1.25), *t*(33) = 1.94, *p* = .061, *d* = 0.27). Significant differences between forgotten vs. recalled negative picture stories in valence (forgotten: *M* = 2.04, *SD* = 0.90; recalled: *M* = 2.20, *SD* = 0.49; *t*(16) = 0.43, *p* = .67, *d* = 0.21) and arousal ratings (forgotten: *M* = 7.69, *SD* = 0.96; recalled: *M* = 7.44, *SD* = 0.65; *t*(16) = 0.71, *p* = .49, *d* = 0.30) were both not obtained. Please note, in the latter two analyses power was considerably lower due to the smaller sample size of participants who had forgotten at least one negative picture story.

Table 3: Means and grand means of correctly and falsely recalled details of persons, actions and objects and means of preciseness and vividness ratings as a function of emotional context of picture stories; Note: Means and test statistics refer only to picture stories participants could remember in the cued free recall task.

		negative		neutral		negative vs. neutral		
		M	***SD***	***M***	***SD***	***t*(33)**	***p***	***d***
correct	*person related memory*	1.54	0.82	0.92	0.65	6.85	< .001	0.84
	action related memory	2.95	1.0	2.29	0.90	6.3	< .001	0.69
	object related memory	3.52	1.0	3.87	1.44	2.37	< .05	0.29
	mean score	2.67	0.76	2.36	0.86	4.39	< .001	0.38
false	*person related memory*	0.27	0.28	0.18	0.22	2.06	< .05	0.32
	action related memory	0.42	0.25	0.39	0.28	0.70	= .49	0.11
	object related memory	0.35	0.24	0.41	0.23	1.55	= .13	0.25
	mean score	0.35	0.20	0.33	0.20	0.67	= .51	0.08
	preciseness	4.10	0.63	3.79	0.66	3.33	< .01	0.48
	vividness	4.20	0.60	3.67	0.60	5.64	< .001	0.90

Analyses of cued free recall data of those picture stories participant could remember revealed interesting differences between memory of negative vs. neutral stories (see table 3). Strong effects were obtained for *person* and *action related memory* with participants recalling more information of negative vs. neutral picture stories. The difference regarding *object related memory* was inverse. Participants recalled more object related information of neutral vs.

negative picture stories; however, the effect size was smaller. Differences in false memory were only obtained for *person related memory* showing that participants recalled not only more correct but also more false *person attributes.* Additionally analyses showed that participants rated their memory as much more vivid and also as more precise if they were referring to a negative compared to a neutral picture story (see table 3).

BOLD Responses

Incidental Encoding of Negative vs. Neutral Picture Stories

Comparing neural activity while incidental encoding negative vs. neutral picture stories, we found stronger activation in the left and the right amygdala (for details, see figure 16). Additionally wide spread areas on a whole brain cluster level showed that an extensive network of brain areas was more activated while participants viewed negative compared to neutral picture stories (for details, see figure 17 and table 4).

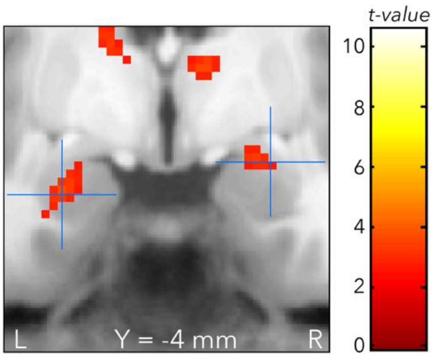

Figure 16: Brain responses in the amygdalae to incidental encoding picture stories: negative > neutral. Statistical map is voxel-wise thresholded at $p < .005$ uncorrected, cluster size > 30 voxels. Map depicts clusters in the left (x = -26 y = -4, z = -22 mm, t231 = 3.64, p < 0.01, FWE corrected) and right (x = 24 y = -2, z = -16, t= 3.34, p < 0.05, FWE corrected) amygdala (coronal plane). Map is overlaid on the mean DARTEL-normalized structural image.

Two large clusters were located bilaterally at the temporo-occipital junction, extending from the lateral middle and inferior occipital gyri in dorso-medial direction to superior parts of the occipital lobes. In ventro-rostral direction the clusters extended over the inferior temporal gyri to the fusiform gyri. In the right hemisphere the cluster also extended in dorso-lateral direction over the middle and the superior temporal gyrus to the angular and the supra marginal gyrus (SMG) thus covering the whole temporo-parietal junction (TPJ) and was connected to a large cluster comprising the right superior parietal lobe and medial adjacent the precuneus. The anterior part of the left SMG was part of another cluster that also included parts of the left superior parietal lobe. Two further clusters showed significantly more activation for incidental encoding negative (vs. neutral) picture stories, bilaterally at the inferior frontal gyrus (IFG) pars opercularis and adjacent parts of the intersection between the precentral gyrus and the middle frontal gyrus. The cluster in the right hemisphere was considerably larger, extending dorsally to the intersection of the (middle and superior) frontal gyri and the precentral gyrus, and extending ventrally to the IFG pars triangularis. Also in the right hemisphere, a cluster comprising large areas of the superior frontal gyrus medialis and furthermore another cluster comprising bilaterally the superior colliculi and parts of the thalami also showed stronger BOLD responses for negative (vs. neutral) stories.

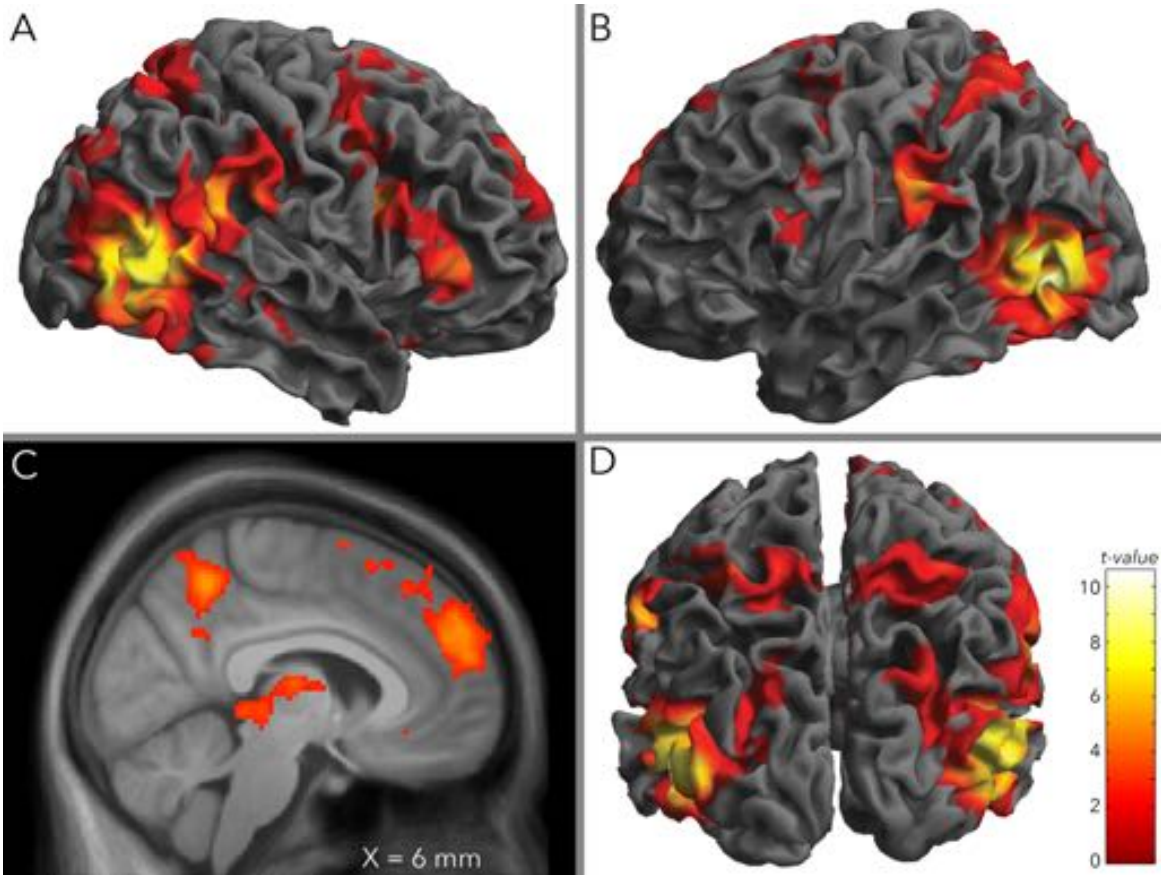

Figure 17: Brain responses to incidental encoding picture stories: negative > neutral. Statistical maps are voxel-wise thresholded at $p < .005$ uncorrected, cluster size > 30 voxels. For FWE corrected statistics on cluster level, see table 4. (A) right hemisphere, (B) left hemisphere, (C) right hemisphere (saggital plane), (D) posterior view of the brain; (A, B, D): Maps are overlaid on canonical 3D renderings as implemented in SPM8; (C): Map is overlaid on the mean DARTEL-normalized structural image.

Table 4: Significant clusters of brain responses to incidental encoding picture stories: negative > neutral. Statistical maps were voxel-wise threshold at $p < .005$ uncorrected, cluster size > 30 voxels. Significance values refer to whole brain FWE corrected statistics on the cluster level. Clusters are listed according to the appearance in the main text.

Brain regions	**Side**	***p* (FWE)**	**Cluster size (voxels)**	**Peak voxel MNI-coordinates**
Occipital lobe (lateral parts) Fusiform gyrus Temporal lobe (inferior and posterior parts) Supra marginal gyrus Superior parietal lobe Precuneus	R	< .001	9113	x = 52, y = -56, z = 6
Occipital lobe (lateral parts) Fusiform gyrus Temporal lobe (inferior and posterior parts)	L	< .001	5338	x = -50, y = -74, z = 4
Supra marginal gyrus Superior parietal lobe	L	< .001	4700	x = -58, y = -34, z = 34
Dorso medial PFC Inferior frontal gyrus Superior frontal gyrus (posterior parts)	R	< .001	3486	x = 40, y = 8, z = 24
Inferior frontal gyrus (pars opercularis)	L	< .01	411	x = -50, y = 4, z = 34
Superior frontal gyrus (medial parts)	R	< .001	1077	x = 10, y = 52, z = 36
Superior colliculi Thalami	R, L	< .001	934	x = 10, y = -28, z = -4

Emotional Trade-Off Effects on Memory

The analysis regarding neural activity at incidental encoding related to subsequent memory for central and for peripheral details did not reveal significant differences in the amygdalae nor in the hippocampi. However, on a whole brain level, the analysis yielded two significant clusters reflecting the emotional trade-off effects on memory (for details, see figure 18 and table 5).

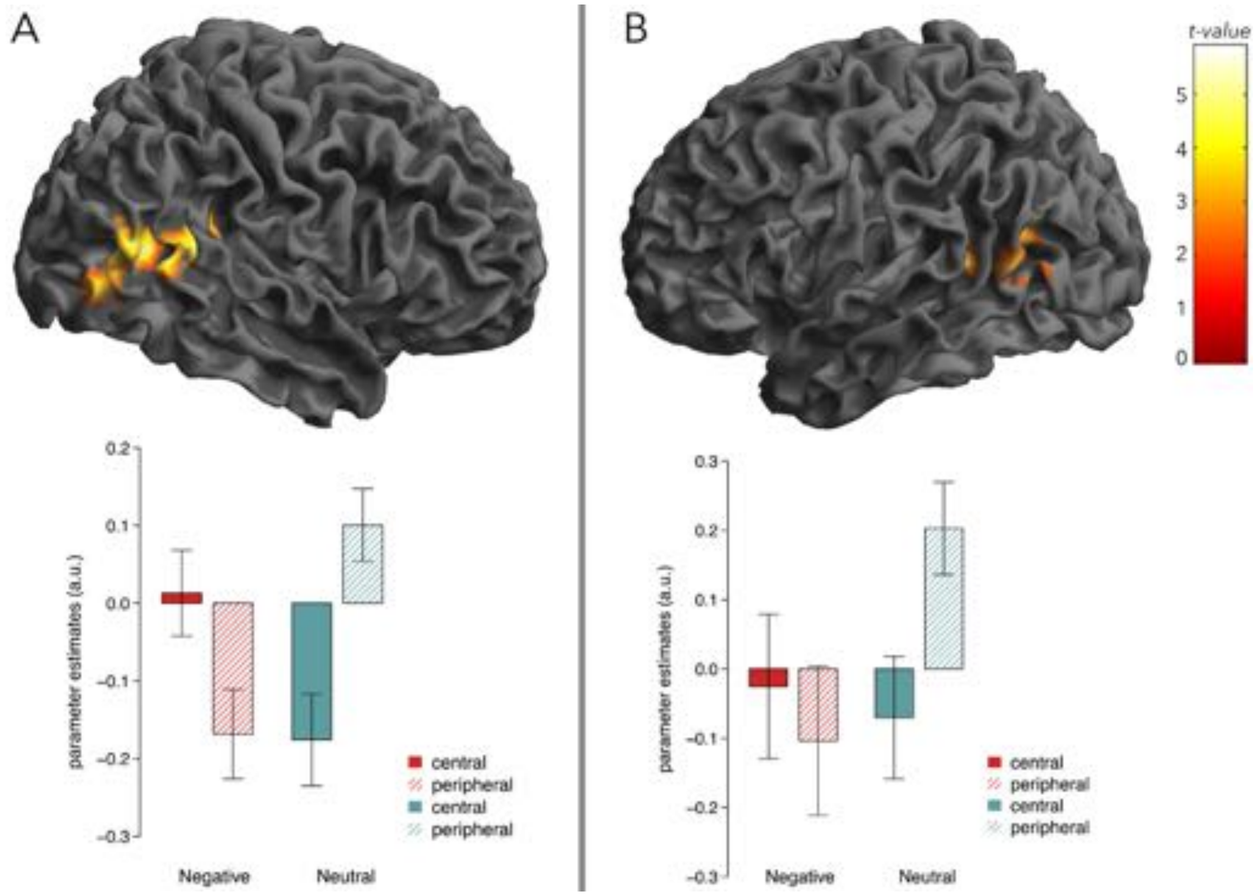

Figure 18: Significant clusters of brain responses at incidental encoding in the right (A) and left (B) hemisphere related to subsequent memory for central and peripheral details: [negative central > negative peripheral] > [neutral central > neutral peripheral]. Statistical maps are voxel-wise thresholded at $p < .005$ uncorrected, cluster size > 30 voxels. For FWE corrected statistics on cluster level, please see table 5. Maps are overlaid on canonical 3D renderings as implemented in SPM8. Parameter estimates of significant clusters are displayed below. Bar graphs show estimates extracted from the respective peak voxels with error bars representing SEMs (a.u., arbitrary unit).

That is, the difference between: a) the relationship of neural activity at incidental encoding and subsequent recognition (i.e., 1 = recognized; -1 = not recognized) of central details and b) the relationship of neural activity at incidental encoding and subsequent recognition of peripheral details was positive for negative picture stories while a negative difference was obtained for neutral picture stories. The clusters were located along the temporal junction to the occipital and the parietal lobes. Descriptively, there seems to be a lateralization with the larger sized cluster in the right hemisphere showing stronger neural activity related to the emotional trade-off effects on memory at incidental encoding.

Table 5: Significant clusters of brain responses at incidental encoding related to subsequent memory for central and peripheral details: [negative central > negative peripheral] > [neutral central > neutral peripheral]. Statistical maps are voxel-wise thresholded at $p < .005$ uncorrected, cluster size > 30 voxels. Significance values refer to whole brain analysis FWE corrected statistics on cluster level.

Brain regions	Side	*p* (FWE)	Cluster size (voxels)	Peak voxel MNI-coordinates
Occipital lobe (lateral parts) Temporal lobe (posterior parts)	R	< .001	1456	x = 52, y = -52, z = 14
Occipital lobe (lateral parts) Temporal lobe (posterior parts)	L	< .05	336	x = -50, y = -52, z = 14

Emotional Trade-Off Effects on Memory at Retrieval

Analysis of BOLD responses contrasting the emotional trade-off effects on memory for details at recognition did neither reveal any significant differences in the amygdalae or the hippocampi nor on a whole brain cluster level. Therefore we further analyzed data of neural activity of the recognition task session without parametrically modulating memory performance.

Effects of Viewing Recognition Test Items

This analysis yielded significant results in the right amygdala and the right hippocampus (for details, see figure 19 and table 6). Viewing central items caused relatively stronger activation in those areas than viewing peripheral items when they were derived from negative picture stories compared to the differential effects of viewing central vs. peripheral items derived from neutral picture stories. This interaction effect between emotional context and centrality was also evident in two clusters in the whole brain analysis. One cluster covered large parts of the occipital lobes, extending from the extrastriate cortex bilaterally posterior to the cunei and the superior occipital lobes and medially extending across the whole lingual gyri to the posterior parts of the fusiform gyri. In lateral direction the cluster extended bilaterally - but more prominently in the left hemisphere - to posterior parts of the inferior and middle temporal gyri. A second cluster was located bilaterally in the superior parts of the thalami.

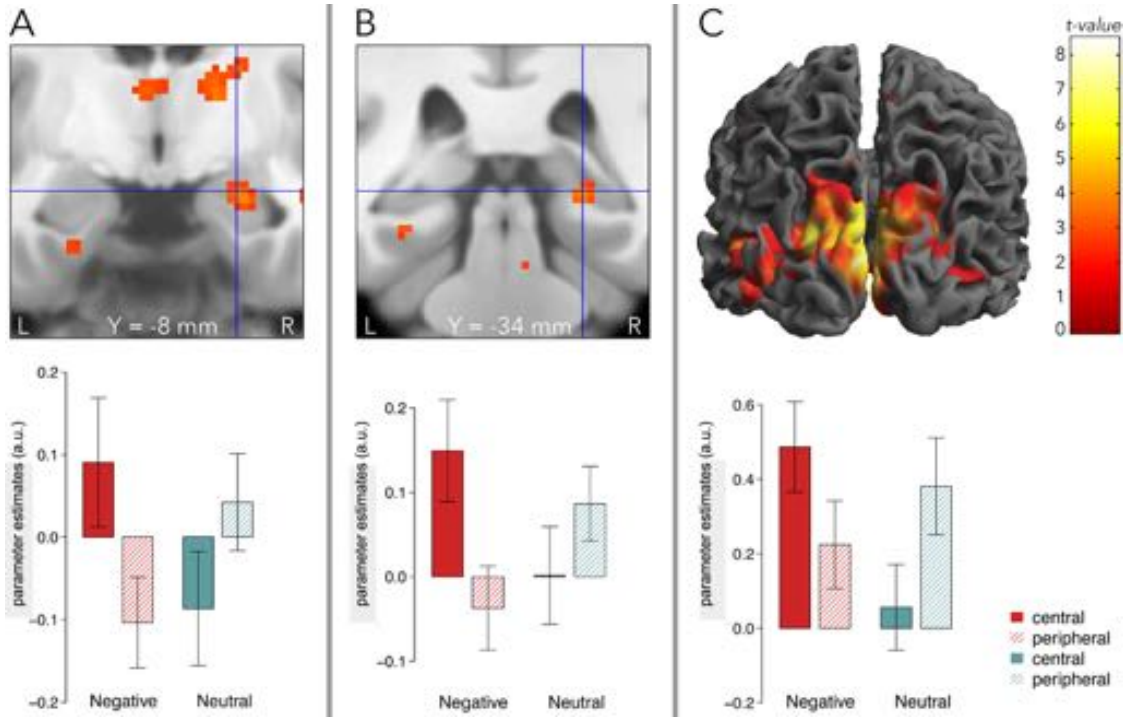

Figure 19: Brain responses at retireval related to viewing details: [negative central > negative peripheral] > [neutral central > neutral peripheral]. Parameter estimates of significant clusters are displayed below. Bar graphs show estimates extracted from the respective peak voxels with error bars representing SEMs (a.u., arbitrary unit). Statistical maps are voxel-wise thresholded at $p < .005$ uncorrected, cluster size > 30 voxels. (A) Right amygdala (x = 22 y = -8, z = -18, t = 3.89, p < 0.01, FWE corrected); (B) Right hippocampus (x = 22 y = -34, z = -4, t = 4.02, p < 0.05, FWE corrected). Maps (coronal planes) are overlaid on the mean DARTEL-normalized structural image. (C) Posterior view on the brain, for FWE corrected statistics on cluster level, please see table 6. Map is overlaid on canonical 3D renderings as implemented in SPM8.

Table 6: Significant clusters of brain responses at retireval related to viewing details: [negative central > negative peripheral] > [neutral central > neutral peripheral]. Statistical maps are voxel-wise thresholded at $p < .005$ uncorrected, cluster size > 30 voxels. Significance values refer to whole brain analysis FWE corrected statistics on cluster level.

Brain regions	**Side**	***p* (FWE)**	**Cluster size (voxels)**	**Peak voxel MNI-coordinates**
Occipital lobe	R, L	< .001	11107	x = -4, y = -92, z = 16
Thalamus	R, L	< .01	449	x = -2, y = -4, z = 10

Effects of Attention in Emotional Memory at Retrieval

The analysis regarding BOLD responses at incidental encoding corresponding to effects of attention on memory for central *and* peripheral details of a negative vs. a neutral context did not reveal any significant results.

However, investigating the influence of attention on memory for details of a negative vs. a neutral context in BOLD responses of the recognition phase did reveal stronger neural responses in the left and the right hippocampus (for details, see figure 20). Regarding items of a neutral context, stronger hippocampal activity at recognition was related to a positive relationship between viewing the details during incidental encoding and later recognition memory. For items of a negative context, stronger hippocampal activity at recognition was related to successful memory more independent of attentional processing at incidental encoding.

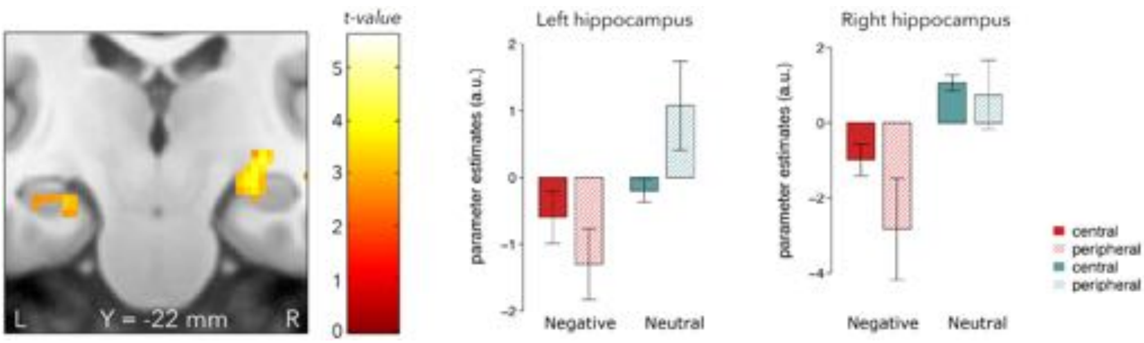

Figure 20: Brain responses at retireval related to attentional dependence of memory: [negative central + negative peripheral] > [neutral central + neutral peripheral]. Statistical map is voxel-wise thresholded at $p < .005$ uncorrected, cluster size > 30 voxels. Left hippocampus (x = -34 y = -30, z = -12, $t = 3.82$, $p < 0.05$, FWE corrected); Right hippocampus (x = 26 y = -22, z = -12, $t = 3.88$, $p < 0.05$, FWE corrected). Map (coronal plane) is overlaid on the mean DARTEL-normalized structural image. Parameter estimates of significant clusters are displayed below. Bar graphs show estimates extracted from the respective peak voxels with error bars representing SEMs (a.u., arbitrary unit).

4.4. Discussion

Affective Ratings

Affective ratings confirmed results of study 1: negative picture stories were rated as much more unpleasant and arousing than neutral stories.

Recognition Memory

Analyses of recognition memory of centrally relevant and peripheral details revealed that memory for details was overall diminished compared to results of study 1. Contrary to our expectations (e.g., LaBar & Cabeza, 2006), the extended retention delay of 1 day (vs. 15 minutes) did not affect differences in memory for central items encoded in a negative vs. neutral context. Grand mean values seem to suggest that possible differences were not covered by a ceiling effect. Instead, results rather indicate that the affective context had no or only a very small effect on recognition memory for central items of our visual narratives. We have tested recognition memory for inherently neutral objects that were naturally embedded in complex daily-life scenarios but controlled for size, position and presentation time. Central items were always very closely related to the actions of the persons, they always represented the key object of the narrations. Centrality was thus defined with high significance to plot-relevance. The null result is thus not in line with assumptions derived from survey-based studies, indicating that details of private most traumatic experiences are rather central to the core of the remembered event (Christianson & Loftus, 1990) and do not replicate those experimental findings reporting enhancements of negative emotion on memory for plot-relevant information and plot-irrelevant details closely associated with the central figures of picture stories (e.g., Burke et al., 1992; cf., Christianson, 1992; Kensinger, 2009; Levine & Edelstein, 2009; Reisberg & Heuer, 2004).

The assumption of better memory for "central" information regarding real-life episodes is largely unexplored and, as discussed in the introduction, detailed understanding of the effects of negative emotion on memory for "central aspects and details vs. peripheral details" from experimental studies is not given. However, when considering that emotionally arousing autobiographical episodes have a much higher probability of being retained, we can infer that emotion also enhances the probability to remember some kind of details or associated information of the retained emotional events. It could be speculated, that no emotional enhancement exists in comparing the most relevant objects of negative vs. neutral picture stories, or that we could not reveal this effect in a test where memory was measured after one day delay in a recognition test (showing the critical objects again). Results of the free recall memory reports showed that much more neutral stories could not be brought to mind and that participants freely recalled more information regarding the action and the persons of the negative stories. When assuming that emotionally arousing episodes imply retention of information for the most relevant object of that episode, our null results may rather suggest, that we did not find a corresponding effect due to the retention delay (e.g., 1 day vs. 1 or more years) and / or due to the kind of memory test we used (e.g., recognition test vs. free recall test). But a definite conclusion in favor for the explanation, that we have missed to reveal an existing effect for the central items or in favor for assuming that no effect of negative emotion on memory for the most relevant objects of picture stories exists, can not be drawn on the basis of the current data.

Importantly however, we again obtained a significant interaction effect showing a more distinct trade-off (central vs. peripheral details) in memory for the negative compared to the neutral picture stories. This effect was more driven by diminished memory for peripheral details from negative picture stories. It can be discussed, whether the trade-off effects should be primarily understood as two independent effects or if they should be primarily understood as a differential, but joined effect of negative emotion on memory for details. From the latter perspective the significant interaction effect can be further explored by assuming mutual underlying processes (e.g., neural bases or the role of attention) for the differential effects regarding central and peripheral details. Since I do not focus on possible independent underlying processes for the emotional effects on central vs. peripheral details, I will still use the terminology "trade-off effects" further on – since we found a more pronounced difference between memory for centrally relevant vs. peripheral details of the negative compared to the neutral picture stories.

Free Recall

Analyses of free recall data revealed a pattern of results that confirmed all expectations derived from previous survey-based studies and previous experimental studies: Participants could not bring to mind on average 4.18 out of 26 picture stories in the cued free recall task, of which the vast majority was neutral. Additionally, remembered and forgotten neutral stories differed in their affective ratings at incidental encoding. Remembered neutral picture stories were those participants rated marginally as more calm and significantly as more positive, again confirming the emotional effect for better memory of episodes per se (e.g., Brown & Kulik, 1977). Strong effects were obtained for the amount of freely recalled information regarding persons and actions and a medium sized effect for object related memory. The instructions participants had received clearly emphasized to report any detail they could remember and analyses showed that they reported specifically more person and plot related information but less information regarding "any other" detail of the negative picture stories (e.g., Burke et al., 1992). Further hypotheses were confirmed regarding ratings of memory vividness and preciseness, memories of negative picture stories were rated to be more vivid and more precise than memory of neutral picture stories (e.g., Brown & Kulik, 1977; Heuer & Reisberg, 1990). Considering the survey-based studies discussed in the introduction, this pattern of results seems to indicate that experimental studies using emotional and neutral picture stories can reproduce most relevant properties of emotional episodic autobiographical memory, i.e., better remembering emotional episodes per se, as well as enhanced memory for information regarding what the persons in an enfolding social situation are doing / how they interact. Regarding real-life events, information about where something happened, what happened, the temporal ordering thereof, and importantly emotional and evaluative information ("high-points" and "resolutions") of evolving social experiences represent what will be remembered, and especially emotional and evaluative information strongly predict durable retention of these events (cf., Brown & Kulik, 1977; Christianson & Loftus, 1990; Kızılöz & Tekcan, 2013; Peterson et al., 2014; Reese et al., 2011; Wessel & Merckelbach, 1994). We may infer, that differences in person and action related information found in free recall memory may not "only" reflect differences regarding what the persons in the picture stories are doing as purely descriptive knowledge but may moreover indicate differences regarding further inferences between negative and neutral picture stories derived from these person and action related information: possibly differences in perception of (and inferences on) how the persons are feeling (and why they do so) and possibly also differences in moral evaluations and further higher social cognitive processes; it can be assumed, that these differences in higher social cognitions were most critical for understanding and subsequent enhanced memory of the (emotional) episodic information given, leading to more remembered negative stories and more freely recalled action and person related information of negative picture stories.

Eye Movement Data

Attentional parameters for central and peripheral details replicated essentially findings of study 1, again showing that the amount of attentional processing is not mediating trade-off effects of negative emotion on memory for relevant vs. irrelevant information, as it is generally assumed in current research (Adolphs et al., 2005; Christianson, 1992; Kensinger, 2009; LaBar & Cabeza, 2006; Mather et al., 2006; Phelps, 2006; but see, Laney et al., 2004; Levine & Edelstein, 2009; Reisberg & Heuer, 2004; Steinmetz & Kensinger, 2013). Regarding the latency of the first fixation, no significant interaction effect between emotion and centrality was obtained and regarding proportional viewing time an interaction with opposed direction as would be expected from the attention mediation hypothesis was revealed. The latter effect was again mainly driven by much shorter viewing time of central items appearing in negative picture stories. No differences could be revealed as a function of emotional context in total fixation counts and in total scan path lengths.

But differences were revealed regarding attentional processing of persons in negative vs. neutral picture stories. Participants deployed more attention to persons and less to "any other" details of negative vs. neutral stories, showing a corresponding pattern between attentional processing and free recall in both, social information and "any other" details. Grand mean values showed enhanced attentional processing of persons in negative stories and enhanced freely reported memory about persons and their actions and an inversed relationship regarding "any other" information. In negative stories reduced attentional processing and reduced freely reported information was obtained for "any other" information. But though we found "trade-off effects" in attention and in free recall memory regarding social vs. "any other" information and though this pattern could seemingly explain free recall data and suggest a mediative role of attentional processing on corresponding memory, such a conclusion can not be drawn firmly. Instead, our results highlight the importance of further differentiations when analyzing the role of attention for later memory of details from negative vs. neutral experiences. Person and action related information were more attended to and were more reported in the free recall task, possibly indicating mediative effects. In contrast, attention to "any other" information was diminished in negative stories but this difference in attentional processing was not related to memory performance: Analyses of study 2 and especially of study 1 have evidenced, that diminished attention to "any other" information in negative picture stories is foremost driven by central, highly plot-relevant details. And though predominantly plot-relevant information were affected by less allocation of attentional resources, we could show that they were not remembered worse. Our data further showed no significant difference in attentional processing of peripheral background information from negative vs. neutral stories, yet peripheral background information derived from negative stories were less well recognized.

Less clear conclusions however can be drawn regarding the role of attention on memory specifically for person and action related information. Participants attended more to persons and this might have (partly) driven corresponding effects in free recall memory. Further research is needed to investigate to what extent enhanced person and action related memory depends on the amount of attentional processing.

BOLD Responses

Incidental Encoding of Negative vs. Neutral Picture Stories

Analyses of BOLD imaging data revealed pronounced differences of neural activity related to incidental encoding 13 different negative vs. 13 different neutral picture stories. As expected and corresponding to the affective ratings, we found more activity in bilateral amygdala related to incidental encoding negative picture stories. The difference however was also highly significant in several widespread right lateralized but largely bilateral clusters. The topography of brain areas involved seems to reflect that experiencing picture stories depicting negative narrative episodes differs from experiencing picture stories with a less arousing and more neutral storyline in allocation of extensive neural resources related to divers aspects of information processing.

These brain areas can be linked in large parts to meta-analytic findings of emotion processing (Kober et al., 2008) showing consistent activation in corresponding areas, i.e.: amygdala, thalamus, visual processing areas, TPJ, superior temporal sulcus (STS), IFG and dmPFC. Enhanced allocation of visual processing resources for emotional stimuli is a robust finding (e.g., Morris et al., 1998) and reflects the significance of affective information (Phelps, Ling, & Carrasco, 2006). Correspondingly, we found emotional enhancement of neural activity in the thalamus, indicating increased attentional demands (Guillery & Sherman, 2002) and the superior colliculi, indicating increased directed attention (Pierrot-Deseilligny, Müri, Ploner, Gaymard, & Rivaud-Péchoux, 2003). These attentional demands were accompanied with differences in late visual processing areas of the inferior temporal cortex and the occipital complex (within clusters exteniding to STS and TPJ). Functionally these extended areas included occipitotemporal regions found to be category-selective regions for processing of faces and bodies (Haxby, Hoffman, & Gobbini, 2000; Rossion et al., 2003; Ungerleider & Bell, 2011), i.e., the middle fusiform face areas, the occipital face areas (Kanwisher & Yovel, 2006) and the extrastriate body-areas (Downing, Jiang, Shuman, & Kanwisher, 2001). These areas are not only interpreted to be selective for processing isolated images of human body-parts but also for interpreting goal-directed movements (Astafiev, Stanley, Shulman, & Corbetta, 2004). Corresponding with this interpretation, we also found activity in the IFG, an area known to be important for action observation and imitation (Koski et al., 2002; Molnar-Szakacs, Iacoboni, Koski, & Mazziotta, 2005).

Our findings moreover showed that incidental encoding negative picture stories additionally involved enhanced activity in the STS, the TPJ, the medial PFC and the precuneus. Research in social cognitive and affective neuroscience – in part using cartoon based stimuli – has consistently found activity in these regions to be related to theory of mind, moral reasoning and empathy (cf., Mar, 2011; Van Overwalle, 2009; Zaki & Ochsner, 2012). Moreover, these regions are strongly correspond to meta-analytically found regions of emotion processing (Kober et al., 2008). From this perspective, our findings regarding activity in areas of higher order cognitive processes may reflect more engagement of evaluative resources to understand the emotional content of the unfolding narrations, specifically suggesting enhanced processes related to observations of the persons' motor intentions, their emotional states and to inferences or judgments about their thoughts, intentions and feelings.

Another alternative but not mutually exclusive interpretation may also account for the pattern revealed in the contrast of incidental encoding negative vs. neutral picture stories. Studies investigating the neural bases of focused attention and of reorienting attention have delineated two interacting networks to subserve these processes. A dorsal system is assumed to reflect top-down allocation of voluntary attention, selecting sensory stimuli based on internal goals, while a ventral system is assumed to be involved in processing salient unexpected stimuli and in initializing bottom-up driven shifts of attention. These two systems are thought to permanently interact during normal perception thus enabling both, focused goal-driven attention and dynamic disengagement and allocation of attention to unexpected, significant internal and external information (Corbetta, Patel, & Shulman, 2008; Corbetta & Shulman, 2002). Top-down processes are assumed to be processed in a dorsal network, mainly located bilaterally in areas extending from the intra parietal sulcus to the superior parietal lobe (SPL), the postcentral sulcus and the intersection of the precentral and superior frontal sulcus, while the ventral network is assumed to be located right lateralized in extended areas at the TPJ and the IFG (Corbetta & Shulman, 2002). In light of studies supporting these theories, our findings of activity related to incidental encoding of negative (vs. neutral) picture stories in bilateral superior parietal lobe, right superior frontal gyrus, bilateral TPJ and right IFG may be interpreted as enhanced allocation of resource for attentional processes to encode and understand the meaning of negative vs. neutral narratives. The progression of subsequently shown pictures disclosing the narrative content in an enfolding manner may engage both, more bottom-up reorienting caused by the emotional content (e.g., facial expressions and body postures), but also enhanced focused, expectation driven top-down attention, reflecting more engagement in directed attention to infer the meaning and verify assumptions or beliefs through rather controlled eye movements, while trying to develop an understanding of the negative picture stories.

We did not expect differences between incidental encoding of negative vs. neutral picture stories in wide spread areas of the brain on this scale. However, reconciling literature with corresponding findings offers a coherent post-hoc interpretation of the extensive differences found. Considering results obtained from analyses of the free recall data, these findings seem to give suggestive evidence, that incidental encoding of the negative picture stories differs from incidental encoding of the neutral stories in enhanced allocation of resources to process person and action related information. Moreover our findings seem to suggest that incidental encoding of the negative picture stories additionally involved enhanced allocation of resources for higher order cognitive functions related to inferring information about the intentions of the persons and their internal states, possibly reflecting the process of understanding the emotional and moral meaning of the narrative material. Findings may furthermore complementarily suggest that incidental encoding of the negative picture stories might also involve enhanced processes of top-down attention to develop and verify beliefs or expectations interacting with bottom-up driven shifts of attention to emotional salient information.

Emotional Trade-Off Effects on Memory

Statistical maps did not confirm our expectations to find a modulation of activity in the amygdala related to the trade-off effects of emotion on memory for relevant vs. irrelevant information. The null finding in this key region of emotion processing is thus at odds with the assumption that negative emotion has trade-off effects on memory for details. Moreover does it not correspond to the finding showing that amygdala lesioned patients had impaired proportional "gist" memory for scenes of negative picture stories (Adolphs et al., 2005) and to findings demonstrating that amygdala lesioned patients had impaired proportional "gist" memory for unrelated visual stimuli (Adolphs et al., 2001). Furthermore, brain imaging studies investigating related issues revealed neural activity in the amygdala corresponding to memory for emotional central information, when compared to activity related to memory for more peripheral information (Kensinger & Schacter, 2006; Waring & Kensinger, 2011). One explanation for our null finding might be insufficient power, especially due to the nonexistent emotional effect on remembering central items. This may indicate, that corresponding differences in amygdala activity computed on a trial based level also lacked power to reveal the trade-off effects (see also discussion of recognition results). A further reason could also underlie the null finding and is related to the issue of defining what can be regarded as centrally relevant (cf., Christianson, 1992; Kensinger, 2009; Levine & Edelstein, 2009; Reisberg & Heuer, 2004). To investigate the activity specifically related to the effects negative emotion has on memory for central vs. peripheral information, we computed two factors to extract variance in neural activity specifically related to a) later remembering vs. forgetting of central items and b) later forgetting vs. remembering of peripheral items. These factors were orthogonal extracted to incidental encoding negative and neutral picture stories and contrasted to each other, to delineate differential neural activity specifically related to the negative condition. Thus neural activity related to forgotten negative central objects had a negative impact on the statistical maps of this analysis. It could be that some negative central objects were forgotten, *because* the context was negative and that in those cases emotionally prioritized processing did not include memory for those "relevant" items, while in the other cases remembering central objects *was* related to emotional processes. It could also be, that activity in the amygdala was involved in both, memory for relevant objects derived of negative contexts but also of neutral contexts. This possibility in turn would rather indicate that the amygdala is not directly related to processing emotional information but more generally involved in evaluating biological and social relevance (cf., Markowitsch & Staniloiu, 2011; Pessoa & Adolphs, 2010).

Interestingly, orthogonal parametric modulation related to remembering central and forgetting peripheral items of negative vs. neutral picture stories, revealed significant clusters in both hemispheres along the TPJ including parts of the parietal and occipital lobes, with a considerably larger cluster in the right hemisphere. Parameter estimates indicated, that the differential effects were driven in larger parts by differences in memory for peripheral negative vs. neutral details, suggesting that activity in these clusters tended to originate from the diminishing effect of negative emotions on memory for peripheral information. As reported, BOLD imaging analyses of incidental encoding negative vs. neutral picture stories also revealed extensive (and also strongly right lateralized) differences in activity along the TPJ. Activity in this brain area could indicate both, enhanced bottom-up driven shifts of attention to emotional salient information (i.e., persons in the stories) and / or enhanced activity related to higher order social cognitions (e.g., intentions, emotional states, moral judgments). Neural activity in contrasting incidental encoding of negative (vs. neutral) stories also yielded enhanced activity in the thalamus, the superior colliculi and in late visual processing areas including regions for processing faces and bodies. But in contrast, parametric modulation of incidental encoding negative vs. neutral picture stories specifically related to remembering central and forgetting peripheral items did not reveal related activity in these areas. Activity along the TPJ may thus suggest, that the emotional trade-off effects on memory for central vs. peripheral details of picture stories was rather related to increased allocation of resources to higher order social cognitions, than to increased bottom-up driven attentional demands. Brain imaging studies based on non-narrative stimuli found that the trade-off effects were driven by allocation of processing resources to the amygdala, the FFG, and possibly further more wide spread areas in limbic, prefrontal, and temporal regions, suggesting that incidental encoding of emotional stimuli is related to prioritized resources for visual processing and directed attention (Kensinger et al., 2007; Kensinger & Schacter, 2006; Mather et al., 2006; Waring & Kensinger, 2011). In line with the attention mediation hypotheses for the trade-off effects, inferences were made, that these corresponding neural processes underlie better memory for centrally relevant information and worse memory for more peripheral information (cf., Adolphs et al., 2005; Kensinger, 2009; LaBar & Cabeza, 2006; Mather et al., 2006; Phelps, 2006). Our study is the first to investigate neural activity related to memory for central vs. peripheral details using thematically driven negative vs. neutral visual narratives and alludes to a different explanation. In the presence of the results we obtained in free recall memory and in neural activity related to incidental encoding negative vs. neutral picture stories, our findings along bilateral TPJ seem to indicate that enhanced allocation of resources for higher-order social cognitions may be an important factor in driving differential effects of negative emotion on memory for centrally relevant vs. irrelevant information – especially when using narrative stimuli with more ecological validity to autobiographical memories of real-life events.

Effects of Viewing Recognition Test Items

Analysis of BOLD responses contrasting the emotional trade-off effects on memory for details at recognition did not reveal any significant effects, neither at a ROI based level nor in exploratory whole brain analyses. But analyses of neural activity at recognition, without taking memory performance into account, showed that "viewing" central items derived from previously encoded negative stories caused relatively stronger activation in different brain areas, than "viewing" peripheral items - compared to differences in activity related to viewing central vs. peripheral items derived from neutral stories. Only conditional conclusions can be inferred regarding the effect found in the hippocampus, considering that no significant differences were revealed in the analysis specifically extracting activity related to recognition responses, orthogonally modulated to "viewing" the items. The null result finding might again be due to insufficient power to reveal an existing effect, foremost driven by lack of emotional differences in remembering central items. However, if activity in the hippocampus related to the trade-off effects in "viewing" items is not a false positive finding, then it seems to reveal both, firstly, stronger memory related processes while "viewing" central objects vs. "viewing" peripheral objects derived from negative picture stories, when compared to the difference regarding objects derived from a neutral picture story (cf., Dolcos, LaBar, & Cabeza, 2005; Strange & Dolan, 2004); and it secondly would suggest that activity in the hippocampus related to the interaction effect (emotion × centrality) in "viewing" items includes explained variance that is not related to conscious recognition processes. Viewing central (vs. peripheral) items from a negative (vs. neutral) context furthermore clearly differed in activity in the right amygdala, the thalami and in a highly significant cluster (bilaterally along large parts of later visual processing areas of the striate cortex in ventral occipital lobes, medial at the lingual gyri, at posterior parts of the fusiform gyri and left lateral extending to posterior parts of the inferior and middle temporal gyri), mainly encompassing areas involved in visual processing, but also found to be related to processing emotional information, indicating more allocation to emotion processing resources (cf., Dolcos et al., 2005) and enhanced visual processing areas (cf., Kober et al., 2008).

Since test objects were inherently neutral everyday objects, these profound differences can be assumed to be caused either by visual properties of the stimuli themselves or – more plausibly – by differences in the incidental encoding context where these test objects initially occurred. At incidental encoding items did not differ in presentation time, ROI size or ROI position. They thus differed substantially in two dimensions, the emotional context they were embedded in, and in their informational relevance for the contextual input. Results of brain activity at retrieval again show that assumptions about emotional effects on retention of information of naturalistic narratives crucially depend on how important an (emotional) object is for the context it is embedded in; and more specifically, how important a detail is for the essence of a story. In coherence with the above discussed results, we additionally found differences in neural activity during "viewing" details at retrieval as a function of negative emotion and plot-relevance. We could show that more resources were allocated to an emotion processing region, a memory related area and to wide spread visual processing regions, specifically when participants were viewing information of central (vs. peripheral) relevance, derived from an emotional negative context.

Effects of Attention in Emotional Memory at Recognition

The analysis regarding BOLD responses at incidental encoding corresponding to the differential effect of attention on memory for (central and peripheral) details derived from a negative, compared to a neutral context did not reveal any significant results. But, we found effects in BOLD responses from the recognition phase, showing that the impact of attention to neutral (central and peripheral) details at incidental encoding on later recognition, was related to stronger neural responses in bilateral hippocampus at retrieval.

Though only a few studies directly examined the assumption that attentional processes underlie emotional trade-off effects on memory, extant findings do rather not provide support for the attention mediation hypothesis. It is nonetheless generally assumed that negative emotional stimuli narrow attention to central information, causing enhanced memory for these details and diminished memory for more peripheral information (e.g., Christianson, 1992; Adolphs et al., 2005; Kensinger, 2009; LaBar & Cabeza, 2006; Mather et al., 2006; Phelps, 2006). Based on behavioral results of study 1 we suggested (Kim, Vossel, & Gamer, 2013), that attentional processing is not mediating differential effects of negative emotion on memory for central information vs. peripheral information of picture stories. Based on our findings we instead suggested, that central most plot-relevant information is reliably encoded even with considerably less attentional processing and that enhanced attention does less strongly affect more stable memories for peripheral background information of negative picture stories. Corresponding BOLD analysis of the retrieval phase additionally support this assumption, with corresponding bilateral hippocampal activity related to a positive relationship between viewing neutral details during incidental encoding and later recognition memory, and related to more independent retention from attentional processing at incidental encoding for details from a negative picture story.

5. General Discussion

In our studies we aimed to replicate enhancing effects negative emotion has on memory for an experience per se, for plot-relevant information and for central details, as well, as for diminishing effects negative emotion has on memory for details irrelevant to the plot of picture stories (cf., Christianson, 1992; Kensinger, 2009; Levine & Edelstein, 2009; Mather & Sutherland, 2011; Reisberg & Heuer, 2004). We furthermore aimed to investigate the role of attentional processing and the neural bases of these effects. Not many previous experimental studies have used narrative stimuli to explicitly test effects of negative emotion on memory for different kind of information (Adolphs et al., 2005; Burke et al., 1992; Christianson, 1984; Christianson & Loftus, 1987; Heuer & Reisberg, 1990; Laney, Campbell, Heuer & Reisberg, 2004; Loftus et al., 1987; Wessel, van der Kooy & Merckelbach, 2000) and some of these studies did not confirm both effects (Laney et al., 2004; Loftus et al., 1987; Wessel et al., 2000).

Moreover, the neural basis of these effects is largely unexplored especially regarding ecologically more complex stimuli with a narrative structure. We developed a set of divers, thematically driven picture stories with relevant and irrelevant test details appearing naturally within these stimuli and analyzed affective ratings, physiological responses, eye movements, recognition memory, free recall memory and neural activity of incidental encoding these picture stories, as well, as neural activity during the recognition memory test.

13 Negative and 13 neutral picture stories differed distinctly in participants' ratings regarding valence and arousal and explicit affective ratings corresponded to pronounced differences in neural activity. More activity for negative picture stories was found in emotion processing areas and we found increased allocation of resources to areas known to be involved in bottom-up and top-down driven allocation of attention, processing of faces and bodies, interpreting goal-directed movements, action observation and in areas known to be involved in processing higher order social cognitions, like empathy, theory of mind and moral judgments. In light of the notion, that narrative coherent structures of experiences and especially the dimension "meaning" strongly predict whether a real-life experience will be remembered after many years (cf., Brown & Kulik, 1977; Kızılöz & Tekcan, 2013; Peterson et al., 2014; Reese et al., 2011), our results in neural activity of viewing picture stories suggest that the differences substantially reflect enhanced allocation of resources "to make sense" of given visual input with regard to those aspects or dimensions. Affective ratings and the complex differences in neural processing of social information were correspondingly related to findings in free recall data. We could show that stimuli per se were more probably remembered after a retention delay of one day, when they depicted emotionally negative narrations. Free recall memory data moreover revealed that negative picture stories were reported with more information regarding persons and their actions but less information were reported regarding "any other" information. Additionally memories of negative picture stories were rated to be more detailed and more vivid.

We furthermore investigated differential effects of negative emotion on memory for specific details of differing relevance and the assumed mediative role of attentional processing. By measuring eye-movements we could analyze the impact of relevance on attentinoal processing of narrative stimuli and we could show that the above described differences between viewing negative vs. neutral picture stories (in affective ratings, neural processing and free recall memory) were related to emotion specific pattern in attentional processing of stimuli.

Participants spent more than 30% of the duration looking at the persons of the picture stories but participants showed more proportional viewing time of people from negative stories. However, this difference amounted only to about 4% of the total proportional viewing time. Interesting to memory for specific details, attentional processing of relevant vs. irrelevant objects varied as a function of centrality and of emotion × centrality. Objects of central relevance were fixated for much longer, than comparable objects that were not relevant for the stories. About 20% of proportional viewing time was given to attentional processing of the most important object of the picture stories, while only 5% of the duration was given to the irrelevant objects. Emotional context was additionally affecting processing of central items. While 24% of the duration was given to the relevant objects when they were part of a neutral picture-story (e.g., a cup, an apple, a tennis-racket), were plot-relevant item of negative stories (e.g., a belt, a set of keys, a skate-roller) attended to for a much shorter duration (16%). But, although central relevant items of negative contexts were less looked at, they were nevertheless remembered equally well in the recognition task. And with smaller effects, we found that although peripheral objects of negative and neutral stories were attended to for about the same time, negative peripheral objects were remembered worse. Thus, we found that the pattern of results regarding attentional processing did not correspond to the pattern of results in recognition memory. Trail based hierarchical regression analyses additionally suggested that the amount of attentional processing was not mediating the differential effects of negative emotion on memory. Regression analyses instead suggested the following effects of negative emotion and of relevance on the relationship of attention and later memory of naturally embedded objects derived from visual narratives: the role of attentional processing for later memory depends on relevance and on emotional context but not on their interaction. Memory for non-human but very relevant information seems to depend less on attentional processing at incidental encoding compared to more attention-dependent memory regarding irrelevant information. And driven by effects of negative emotion, recognition memory of relevant objects is ensured well and recognition memory of irrelevant objects is diminished, both more independent of proportional viewing time at incidental encoding. These assumptions about the role of attention for memory as a function of relevance and of emotion were additionally supported by corresponding differences in neural processing at retrieval. We obtained significantly enhanced bilateral hippocampal activity at retrieval related to more attention-independent successful incidental encoding of details derived from negative picture stories and related to attentionally more dependent successful incidental encoding of details derived from neutral picture stories.

That attention is driving the effects of negative emotion on memory for relevant vs. irrelevant information has been a prominent explanation in discussions about differential effects of emotion on memory and was initially assumed regarding findings on eyewitness testimonies and on the so called “weapon-focus” effect (Loftus et al., 1987). Research on sensory processing as an interaction of the environment and the observer has accumulated detailed understanding about how we process information given limited capacity to deal with the amount of permanently emerging information. Attention is a primary characteristic within the competitive process to select the most relevant information at any point in time (Desimone & Duncan, 1995). This results in the familiar experience of daily life, dealing with information in a serial nature, consciously processing only a restricted fraction of available information. In attention research the serial nature of visual scene analysis is often likened by a “spotlight” metaphor (A. Treisman G. & Gelade, 1980). This behaviorally crucial role of attention to selectively allocate cognitive resources to be consciously accessed is generally understood to be driven by a top-down system reflecting executive control over deployment of attention and a bottom-up system compressing and filtering sensory information for saliency (Itti & Koch, 2001). Salient stimuli are infrequent or of instinctive or learned importance. Within this framework an understanding has been established regarding the role of emotion in biasing the processing of incoming sensory information (e.g., Pourtois, Schettino, & Vuilleumier, 2013). Based on more specific research on the differential effects of negative emotion regarding memory for details, some theories (Kensinger, 2009; Levine & Edelstein, 2009; Mather & Sutherland, 2011) have been proposed to integrate findings of enhanced memory for central details and reduced memory for peripheral information, when the context of incidental encoding is negative. In the ABC theory, a framework about "arousal-biased competition in perception and memory", Mather & Sutherland (2011) explain divergent findings of enhanced memory for central details and reduced memory for peripheral information into fundamental assumptions of basic research. Arousal is understood as a factor increasing both, top-down and bottom-up processes to selectively allocate cognitive resources to (internal and external) information of relevance. Thus arousal affects the competition between different information by increased processing of high priority information and decreased processing of low priority information.

Importantly however, distinctions have to be drawn between attentional processes and further processes when explaining arousal related increased prioritizing of (relevant vs. irrelevant) information and the effects on subsequent memory. We could show that neural processes linked to processing information of social relevance – and not proportional viewing time – were involved in arousal induced increased prioritization regarding later memory. Results of previous brain lesion studies (Adolphs et al., 2005; Adolphs et al., 2001) suggested the involvement of the amygdala in driving the trade-off effects of negative emotion on memory for details of picture-stories. Imaging studies using more artificial stimuli also suggested differences in neural processes of the amygdala and furthermore differences in neural processes related to regions for focused attention and visual processing (Kensinger et al., 2007; Kensinger & Schacter, 2006; Mather et al., 2006; Waring & Kensinger, 2011). Experimental research may consider more the ecological validity of findings on emotional memory by inducing experiences based on stimuli where social information is embedded in a complex but coherently related narrative structure. With reference to findings based on narrative stimuli, Mather & Sutherland (2011) point out, that events which "have an overarching theme or narrative, the gist or schema is likely to be more salient and have more relevance than the details" (p. 124), thus strengthening representation of those information which are more related to a narration including enhanced memory for details of central relevance and reduced memory for peripheral information. In light of these assumptions, it seems essential to determine what the relevance of stimuli is and to consider differences between controlled stimuli and real-life events (cf., Levine & Edelstein, 2009). Our findings in brain imaging data related to processing negative vs. neutral, thematically driven picture stories suggest, that ecologically valid reasons for the differential effects of negative emotion on memory for relevant vs. irrelevant details are rather to be found in enhanced allocation of resources to process higher-order social cognitions.

6. Conclusions

Of all the experiences we encounter in everyday life, those events we encounter with emotional reactions are more meaningful to us. They are kept available in memory to think and talk about. Such experiences are often emotional episodes, for example a young woman suffering that her husband is beating her. Or the moment a person receives some terrible news, or even a picture story telling of parents who lost their children in a plane accident. Memory of such moments will probably consist of information regarding *what*, *when* and *where* something happened. But these information are not only ordered in place and time. Importantly they also represent the "*meaning*", the importance or relevance of such experiences. Thus, processes during an experience are substantially engaged in understanding bodily, facial, verbal and contextual information as actions and intentions, accompanied by emotional processes and they comprise perspective taking, empathic feelings, moral reasoning, attributions of traits and other evaluative insights, to extract what it is that makes the experience of significance, what it is, that is at stake and what the consequences for oneself or for someone else are – and by this means we preserve those experiences.

Laboratory research using narrative stimuli (e.g., Adolphs et al., 2005; Burke et al., 1992; Christianson, 1984; Christianson & Loftus, 1987) confirmed survey-based findings (e.g., Kızılöz & Tekcan, 2013; Peterson et al., 2014; Reese et. al., 2011) that the *theme* (meaning) or "plot-relevant" information from negative emotional stories and even plot-irrelevant details closely associated with central figures from picture stories (Burke et al., 1992) seem to be better remembered when the experience has a negative emotional context. And in contrast, findings suggest a diminishing effect of negative emotion regarding memory for details peripheral to the essence of an episode (cf., Christianson, 1992; Kensinger, 2009; Levine & Edelstein, 2009; Mather & Sutherland, 2011; Reisberg & Heuer, 2004).

Researchers in this domain commonly refer to differences in attentional processing of information to explain these emotional effects (e.g., Christianson, 1992; Adolphs et al., 2005; Kensinger, 2009; LaBar & Cabeza, 2006; Mather et al., 2006; Phelps, 2006). In extant investigations on the neural basis of these effects, findings are also interpreted in alignment to attentional explanations (Adolphs et al., 2005; Kensinger et al., 2007; Kensinger & Schacter, 2006; Mather et al., 2006; Waring & Kensinger, 2011).

Our studies however show, that not attention, but presumably, the neural correlates of processing picture stories with more relevance or meaning (i.e., enhanced allocation of resources "to make sense" of given visual information) seem to be the primary basis for arousal induced enhanced prioritizing of information. By this means memory for objects of central relevance is ensured, in spite of much less attentional processing, with the consequence, that information which is not important to the core of a narrative experience is less well retained, again more independently of attentional processes.

7. Zusammenfassung (German Summary)

Studien zum emotionalen Gedächtnis haben gezeigt, dass bei negativem Kontext differnzierte Effekte auf die Gedächtnisleistung für Details eines Erlebnisses festzustellen sind. Bei einem negativem Kontext werden Details besser erinnert, wenn sie von zentraler Relevanz sind, während periphere Details schlechter erinnert werden (für Reviews, siehe Christianson, 1992; Kensinger, 2009; Levine & Edelstein, 2009; Mather & Sutherland, 2011; Reisberg & Heuer, 2004). Der emotionale trade-off Effekt wird in verhaltensbasierten Studien und in Studien zu neuronalen Korrelaten gemeinhin mit Unterschieden in der Aufmerksamkeit begründet (Christianson, 1992; Adolphs et al., 2005; Kensinger et al., 2007; Kensinger & Schacter, 2006; Kensinger, 2009; LaBar & Cabeza, 2006; Mather et al., 2006; Phelps, 2006). Bei negativem Kontext, so die verbreitete Begründung, fokussiere sich die Aufmerksamkeit verstärkt auf zentrale Informationen, während periphere Informationen weniger fokussiert würden und dies bewirke den emotionalen trade-off bei der Erinnerungsleistung.

Unser Interesse galt der Untersuchung der trade-off Effekte und möglichen Erklärungen dieser Effekte durch Aufmerksamkeitsprozesse und neuronale Korrelate. Dabei war ein zentrales Anliegen die Generalisierbarkeit von experimentellen Befunden auf lebensechte Ereignisse. Daher haben wir13 negative und 13 neutrale Bildergeschichten entwickelt und Probanden zur inzidenziellen Enkodierung dargeboten. Blickbewegungen wurden mit einem Eye-Tracker aufgezeichnet und neuronale Aktivität wurde ebenfalls erfasst. Erinnerungsleistung wurde anhand von zentralen und peripheren Objekten aus den Bildergeschichten getestet und zudem wurden Nacherzählungen der Bildergeschichten ausgewertet. Erwartungsgemäß wurden negative Bildergeschichten als erregender und negativer beurteilt. Ebenso zeigte sich mit einer signifikanten Interaktion zwischen Emotion (negativ vs. neutral) und Relevanz (zentral vs. peripher) der emotionale trade-off Effekt in der Gedachtnisleistung. Entgegen der allgemeinen Annahme scheint der emotionale trade-off Effekt jedoch nicht durch Aufmerksamkeitsprozesse mediiert zu sein. Analysen der Blickbewegungen legen dagegen folgenden Befund nahe: der prädiktive Zusammenhang von Aufmerksamkeitsparametern (während der Enkodierung der

Bildergeschichten) für die spätere Erinnerungsleistung von zentralen und peripheren Details nimmt ab, je negativer Bildergeschichten erlebt werden. Im Gegensatz zur Mediationshypothese deuten unsere Ergebnisse darauf hin, dass die trade-off Effekte in neuronalen Unterschieden während der inzidenziellen Enkodierung begründet sind. Diese Unterschiede scheinen primär mit der Verarbeitung von sozialen Kognitionen zusammenzuhängen und verweisen auf die Bedeutung von öklogisch validen Experimenten.

8. Limitations and Outlook

Higher-order social cognitions are at the core of remembered events. It seems possible to experimentally investigate attentional and neural processes during incidental encoding of experiences with ecological validity regarding these higher-order social cognitions and to investigate the function of attentional and neural processes for later memory. For future research it seems promising to use (qualitative) factors of autobiographical memories (e.g., *narrative coherence* and it's dimensions (Reese et al., 2011)) to understand whether an experience will be remembered and what will be remembered, and to understand the role of attentional processing and the neural basis thereof. Specifically could *narrative coherence* (high vs. low) of free recall memory be used to analyze relationships to attentional and neural processes during incidental encoding. Additionally it seems that better understanding of quantitative characteristics of autobiographical memories would be informative. To the best of my knowledge no research was dedicated to describe or categorize the content of (emotional) autobiographical memory in a general approach. How many and what kind of specific details do we normally (in average) remember and how many are there normally in extreme experiences? How does the amount differ as a function of the kind of remembered event and does the amount systematically relate to personality scores or to psychological disorders? All the same seems relevant regarding categories of information, those dimensions that are most probable constituents (of a certain kind) of an emotional experience. How many categories tend to exist for a certain kind of emotional experience, how does each category relate to retention periods or to individual differences or to psychological disorders? These investigations may also help to better understand eyewitness testimonies or help in constructions of concealed information tests. Qualitative and quantitative factors of autobiographical memories could for example help to define probabilities whether certain information will be remembered given it's relevance for what has happened. Advanced technologies like eye-tracking and fMRI can be used while participants are viewing film clips and might soon be analyzed with help of computer-based object, person and probably even emotion recognition, to define regions of interest. This may introduce the possibility to use much more ecologically valid incidental encoding experiences and help to define relevance of objects and of social information in a much finer-grained manner. Likewise are eye-tracking and measuring neural activity while participants encounter computer simulated interactive experiences and also further new technologies, like real-life eye-tracking, fascinating possibilities for research in this direction. Such technologies, a focus on qualitative characteristics of autobiographical memories and a better understanding of quantitative characteristics of autobiographical memories seem worthwhile to consider in experimental research on emotion, attention and memory and could establish an ecologically more valid interpretation of these interacting factors and the neural basis thereof.

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List of Abbreviations

FFG	Fusiform Gyrus
IFG	Inferior Frontal Gyrus
ROI	Region of Interest
STS	Superior Temporal Sulcus
TPJ	Temporo-Parietal Junction

Appendix

Appendix 1 - Accuracy and Generalizability of *canonical aspects*

Although a "flashbulb" memory is a clear and vivid recollection of an arousing experience, the probability can still be high, that some central content is falsely remembered, especially with longer retention periods. (Neisser & Harsch, 1992) investigated the accuracy of "flashbulb" memories by surveying twice. They tested participants' memory of the circumstances when hearing of the Challenger space shuttle disaster one day following the incident and again after about 2.5 years. *Canonical aspects*, as identified in the study by (Brown & Kulik, 1977) were analyzed for consistency and it was found, that over 90% of the participants reported at least one major inaccurate aspect (see also Schmolck, Buffalo, & Squire (2000) and Talarico & Rubin (2003) for similar findings on the accuracy of "flashbulb" memories and Barclay & Wellman (1986) for related findings on everyday memory). The probability whether a vivid and long lasting memory will be formed or not, furthermore differs with differing events. (Brown & Kulik, 1977) also reported "flashbulb" memories related to other deaths, assassinations, or assassination attempts of public figures, and the rates that such am memory was formed were much lower (e.g., Robert F. Kennedy (56%), Ted Kennedy (29%), Gerald Ford (49%)). Though we may bear in mind, that survey-based studies have found that "flashbulb" memories are prone to even major distortions, (Brown & Kulik, 1977) nevertheless introduced a method to investigate memory of relatively comparable experiences that occurred at about the same time and showed that emotionally arousing autobiographical episodes can be remembered vividly even after many years. Furthermore the authors demonstrated that memory reports of hearing shocking news most often relate to a few *canonical aspects*. From an empirical argument these aspects may be considered to represent the essential content of what is remembered from such an episode. However, hearing of shocking news, and especially those related to public events like the assassination of a president, are very special experiences. The public events relate to a major nationally shared event, are communicated massively via media technology and are talked about relatively often within the circle of friends, colleagues and acquaintances. Thus generalization or inferences to episodic memory for emotionally arousing events that are not of this kind might be treated with caution. But scientific debates on this issue seem to indicate, that "flashbulb" memories do not differ principally to memories of emotionally arousing episodes in general (cf., McCloskey et al., 1988; Pillemer, 1990; Rubin & Kozin, 1984). For example, a study contrasted memory for public events to memory of comparably high vividness but from private events (Rubin & Kozin, 1984). The authors collected 3 very vividly retained memories from each of 58 participants. Of the reported 174 events 31 were related to an injury or accident, 20 to a sports event, 18 to sexual encounters, 16 involved an animal, 9 deaths, 9 referred to the first week at college, 9 to a vacation, 5 to an appearance in front of an audience and 5 incidents at school. The remaining 52 memories could not be categorized in groups. Participants then had to rate these episodes regarding: national importance, personal importance, surprise, consequentiality, vividness, change in ongoing activity, emotionality, times discussed and likeliness to occur. The authors found little differences between memories for public and for private events regarding the factors investigated. Only consequentiality and surprise were rated higher for memories related to public events. These results may be taken for indication that findings of vivid memory related to shocking public events may apply at least to some degree to emotional arousing memories of real-life in general. This assumption is also supported by investigations usefully applying questionnaires that ask for *canonical aspects* to identify "flashbulb" memories for other private experiences, like girls memory of their menarche (Pillemer, Koff, Rhinehart, & Rierdan, 1987), or "flashbulb" memories for events that had happened during earlier love relationships (Harvey, Flanary, & Morgan, 1986) or "flashbulb" memories from cognitive therapy of patients (Thomsen & Berntsen, 2003). But though "flashbulb" memories do not represent a different kind of memory, the derived *canonical aspects* are very specific to narrations about hearing shocking news. And though some of these *categories* like place, ongoing activity, own affect or aftermath may be quite common in the many different emotional episodes of autobiographical memories, such categories can be assumed to differ at least to some degree with the kind of an experience (e.g., Thomsen & Berntsen, 2003), and many individual emotional experiences may even be constituted by some aspects that are very unique.

Danke Matthias.

Danke Mama und Papa und danke Nuna.

Danke Muri und danke Natan!

Eidesstattliche Erklärung

Ich versichere ausdrücklich, dass ich die Arbeit selbständig und ohne fremde Hilfe verfasst, andere als die von mir angegebenen Quellen und Hilfsmittel nicht benutzt und die aus den benutzten Werken wörtlich oder inhaltlich entnommenen Stellen einzeln nach Ausgabe (Auflage und Jahr des Erscheinens), Band und Seite des benutzten Werkes kenntlich gemacht habe.

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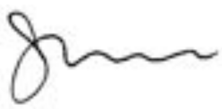

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