An insight into the temporal dynamics of affective picture processing

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[1] The research presented in this dissertation is the result of a long and productive teamwork, not the achievement of the author alone. This is the reason why in the following the first person plural ("we", "our", etc.) is used, instead of the first person singular ("I", "me", etc.). Researchers contributing directly to this work were: Andreas Keil, Niklas Ihssen, Stephan Moratti, Katja Weber, Vera Leirer, Annette Gomolla and Olivia Epple.

Zusammenfassung

Die vorliegende Arbeit untersucht, welche Faktoren die Aufmerksamkeitszuweisung zu Bildern mit emotionalem Inhalt beeinflussen und welche neuronale Mechanismen das Erlernen affektiver Bedeutung unterstützen. Insbesondere interessieren dabei die zeitlichen Aspekte der Verarbeitung affektiver visueller Reize. Drei theoretische Modelle, die jeweils unterschiedliche Vorhersagen hierzu erlauben, werden berücksichtigt. Das zweidimensionale Modell des affektiven Raumes (Cacioppo & Gardner, 1999; Lang et al., 1998a) schreibt dem Erregungsniveau der Stimuli, sowohl bei positiver, als auch bei negativer Valenz eine entscheidende Rolle bei der Allokation von Ressourcen zu. Die „negativity bias"-Hypothese dagegen betont die evolutionäre Bedeutung einer schnellen und angemessenen Reaktion als Antwort auf gefährliche Reize und folgert hieraus präferenzielle Zuweisung von Aufmerksamkeit zu bedrohlichem, unangenehmen Reizmaterial (Carretié, Mercado, Tapia, & Hinojosa, 2001; Ito et al., 1998; Öhman, Lundqvist et al., 2001; Öhman & Mineka, 2001). Eine andere Forschungsrichtung belegt empirisch die bevorzugte Orientierung zu positiven Stimuli, wenn keine akute Gefahr droht (Juth et al., 2005; J. M. Leppänen & Hietanen, 2004), und bedient sich auch evolutionärer Argumente. Der sogenannte „positivity offset"-Mechanismus soll Exploration und Lernen begünstigen und liefert die theoretische Grundlage zur Erklärung experimenteller Befunde, bei denen die Reaktion auf positive Reize schneller und genauer erfolgt als auf negative und neutrale Stimuli (Ito & Cacioppo, 2005; Juth et al., 2005; J. M. Leppänen & Hietanen, 2004).

In einer Serie von vier aufeinander aufbauenden Verhaltensstudien, in denen das „Attentional Blink" – Paradigma (Chun & Potter, 1995a; Jolicoeur, 1998; Potter et al., 1998; Raymond et al., 1992, 1995) verwendet wurde, präsentierten wir den Probanden einen schnellen Strom von Bilderreizen. Ihre Aufgabe war es, zwei Zielreize zu erkennen und so schnell und so genau wie möglich darauf zu reagieren. Dabei variierten wir den zeitlichen Abstand zwischen den Zielreizen und den affektiven Gehalt des zweiten Zielreizes. Wir untersuchten, inwieweit diese zwei Faktoren die Fähigkeit die Zielbilder zu erkennen und die Reaktionsgeschwindigkeit beeinflussen. Die Ergebnisse früherer Studien mit affektiven Wörtern (Anderson, 2005; Anderson & Phelps, 2001; Keil & Ihssen, 2004; Keil et al., 2006) zeigten eine Verminderung des Attentional Blink Effektes für hocherregendes, verbales Material und belegen damit eine präferenzielle selektive Aufmerksamkeitszuweisung hierzu. Diese Befunde konnten durch die vorliegenden Studien unter Verwendung von Bildmaterialien nicht repliziert werden. Stattdessen fanden wir Effekte der affektiven

Kategorie, die unabhängig vom zeitlichen Intervall zwischen den Zielreizen bestanden. Die angenehmen Bilder wiesen durchweg höhere Treffergenauigkeit auf und lösten schnellere Reaktionszeiten aus als die unangenehmen Bilder. Ein Effekt des Zielreizintervalls konnte bei einem Teil der Experimentalvariationen ebenfalls beobachtet werden, dieser wurde jedoch von der affektiven Kategorie nicht beeinflusst. Es zeigte sich zudem, dass die Antwortmuster für Treffergenauigkeit und Antwortgeschwindigkeit durch unterschiedliche Experimentalvariationen moduliert wurden. Die Ergebnisse aus dieser Experimentalserie legen nahe, dass das Attentional Blink Phänomen mit komplexen Bildern existiert, jedoch durch den emotionalen Gehalt der Zielreize nicht selektiv moduliert wird und daher möglicherweise anderen Verarbeitungsmechanismen unterworfen ist, als dies bei affektiven Wörtern der Fall ist. Die Differenzen in den Modulationsmustern von Genauigkeit und Geschwindigkeit als Antwort auf identische Reize sprechen dafür, dass verschiedene Aspekte der Verarbeitung identischer affektiver Reize, unterschiedlichen Einflüssen unterliegen.

Der Untersuchungsschwerpunkt einer Konditionierungsstudie, die im zweiten Teil dieser Arbeit vorgestellt wird, lag auf dem Erlernen von affektiver Bedeutung. Wir konnten zeigen, dass schon die früheste messbare elektrophysiologische Antwort der primären visuellen Gehirnareale durch die zunehmende Konsolidierung affektiver Bedeutung verändert wird. Eine generelle kontextabhängige Modulation konnte ebenfalls nachgewiesen werden. Diese Ergebnisse sprechen für eine direkte Beteiligung von primären visuellen Kortexarealen an der Unterscheidung zwischen unangenehmen und neutralen visuellen Reizen. Als mögliche neuronale Grundlagen werden verteilte dynamische Netzwerke in Betracht gezogen. Diese begünstigen flexibles Lernen, möglicherweise mittels erhöhter Synchronisation der elektrokortikalen Antworten aus verschiedenen Arealen. Insgesamt werden die hier vorgestellten elektrophysiologischen und Verhaltensdaten im Sinne eines dynamischen Systems der affektiven Verarbeitung diskutiert, bei dem verschiedene Zeitpunkte, Modalitäten und Verarbeitungsniveaus in Wechselwirkung zu einander stehen.

1. Introduction: theoretical approaches in affective perception and their predictions with regard to the characteristics of attention allocation to pictorial affective stimuli

Perception and efficient processing of affective stimuli, as well as the generation and execution of an appropriate response to these features of the environment are crucial and well developed human abilities. One important question that psychological research has tried to answer using different experimental approaches concerns the nature of stimulus selection and attention allocation to emotional stimuli, when resources are limited. It has been repeatedly shown that affective and motivationally relevant input is processed faster and in a more efficient way than neutral material (Anderson & Phelps, 2001; Bensafi et al., 2002; Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley & Lang, 2000; Keil & Ihssen, 2004; Lang, Bradley, & Cuthbert, 1998a; Lewis et al., 2003; D. Pizzagalli, Regard, & Lehmann, 1999; Schupp, Cuthbert et al., 2004, for a review see Compton, 2003). General preferential resource allocation including faster and more precise responses, as well as higher recall or recognition performance for emotional stimuli of different modalities and under diverse experimental conditions have been demonstrated (Anderson, Wais, & Gabrieli, 2006; Bradley et al., 2003a; Carretié, Hinojosa, Martin-Loeches, Mercado, & Tapia, 2004; Keil, Stolarova, Moratti, & Ray, 2007; Lane, Chua, & Dolan, 1999; Maljkovic & Martini, 2005; Meinhardt, 2002; Moratti, Keil, & Stolarova, 2004). Research has also indicated that specific increase of motivational significance selectively amplifies perception and processing of certain stimuli classes. This is the case, for example, for phobic patients regarding phobic stimuli (Mogg, Philippot, & Bradley, 2004; Straube, Mentzel, & Miltner, 2006), for patients with an addiction disorder confronted with items relevant for their specific addiction even after successful detoxification (Childress et al., 1999; Cooper, Anastasiades, & Fairburn, 1992; Cox, Hogan, Kristian, & Race, 2002; Franken, Stam, Hendriks, & van den Brink, 2003; McDonough & Warren, 2001; Mucha, Geier, Stuhlinger, & Mundle, 2000) and for food-deprived participants concerning food relevant items (Drobes et al., 2001; Mogg, Bradley, Hyare, & Lee, 1998).

1.1. Arousal, negativity or positivity: which stimuli characteristics foster preferential attention allocation to affective stimuli? Three theoretical approaches.

The preferential attention allocation to emotional and motivationally significant stimuli compared to neutral ones seems a generally accepted presumption in affective psychology (Calvo & Lang, 2004; Nummenmaa, Hyona, & Calvo, 2006; Robinson, 1998; Royet et al., 2000; Waynbaum & Du Bois, 1994, for a review see Vuilleumier, Armony, & Dolan, 2003). One remaining controversy, however, concerns the selection, processing and response preferences within the category of affective stimuli, specifically regarding the comparison between pleasant and unpleasant stimuli. Vast evidence from behavioral, psychophysiological, electrophysiological and brain imaging studies suggests a selection preference according to the arousal dimension of affective stimuli (Bishop, Duncan, Brett, & Lawrence, 2004; Bradley et al., 2003a; Coull, 1998; Cuthbert, Bradley, & Lang, 1996; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Derryberry & Reed, 2002; Hartikainen, Ogawa, & Knight, 2000; Junghöfer et al., 2006; Lang, Bradley, & Cuthbert, 1990; Sabatinelli, Lang, Keil, & Bradley, 2006; Schupp et al., 2000; N. K. Smith, Cacioppo, Larsen, & Chartrand, 2003). In agreement with two-dimensional theories of emotional perception, as proposed for example by Lang and colleagues (1997), high-arousing stimuli engross more perceptional and attentional resources and are subject to a faster and more efficient processing than low-arousing ones, regardless of their valence (e.g. Anderson, 2005; Keil & Ihssen, 2004; Keil, Ihssen, & Heim, 2006). Support for this claim comes for example from studies utilizing indirect measures of brain activity such as Event Related Potentials (ERPs) and functional Magnet Resonance Imaging (fMRI). An increase of the P300 component (Keil et al., 2003; Schupp, Junghöfer, Weike, & Hamm, 2004), as well as modulation of earlier ERP responses, such as the P1 and the N1 components (Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004a; Keil et al., 2002; Baas, Kenemans, & Mangun, 2002; Schupp, Junghöfer, Weike, & Hamm, 2003) for high vs. low arousing stimuli has been demonstrated and interpreted as a sign of greater attention allocation enabling more efficient processing. Modulations of the activation in primary visual areas, measured by means of fMRI, also seem to depend on the level of arousal, when complex visual stimuli are presented (Pourtois, Grandjean, Sander, & Vuilleumier, 2004a; Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004, for a review see also Phan, Wager, Taylor, & Liberzon, 2002). On the output site of affective processing, a number of variables vary with arousal, rather than with valence, including skin conductance, viewing time (Lang, Greenwald, Bradley, &

Hamm, 1993) and recall (Blake, Varnhagen, & Parent, 2001; Bradley, Greenwald, Petry, & Lang, 1992; Dolcos & Cabeza, 2002; Hamann, Ely, Grafton, & Kilts, 1999).

There are, however, also certain experimental manipulations, which consistently demonstrate preferential processing of negative, specifically fear relevant over positive stimuli, regardless of their similar arousal levels. The visual search paradigm, as used by Öhman and collaborators (2000) is one prominent example thereof. When asked to pinpoint a deviant item out of an array, participants identify an angry face or potentially phobic stimuli such as snakes and spiders, faster than neutral and happy faces or flowers and mushrooms respectively (Eastwood, Smilek, & Merikle, 2001; Öhman et al., 2000; Öhman & Soares, 1994). As reported recently, this threat-detection advantage remains stable in older individuals (Mather & Knight, 2006). Masked threat-related stimuli in Rapid Serial Visual Presentation (RSVP) paradigms have also been shown to elicit stronger psychophysiological responses than neutral and pleasant stimuli (Fox, 1993; Mogg & Bradley, 2002; Öhman & Soares, 1993, 1994). Further evidence can be found in electrophysiological and behavioral studies using a variety of unpleasant, threat-related stimuli (e.g. Carretié, Hinojosa, & Mercado, 2003; Carretié, Mercado, & Tapia, 2000; Ito, Larsen, Smith, & Cacioppo, 1998; Northoff et al., 2000; N. K. Smith et al., 2003). Even with subliminal presentation of verbal material, higher accuracy of identification and categorization for negative compared to positive words have been reported (Dijksterhuis & Aarts, 2003). These results fall under the negativity bias hypothesis (Ito & Cacioppo, 2005; Ito et al., 1998; Rozin & Royzman, 2001), predicting stronger and faster physiological responses to aversive, threatening stimuli than to any other stimulus category. This approach builds on the evolutionary-based argument that a fast and appropriate reaction to dangerous and not to generally arousing stimuli is crucial for the survival of any species and thus could have evolved through the mechanisms of adaptive advantage and selection (Ohman, Flykt, & Esteves, 2001; Ohman, Lundqvist, & Esteves, 2001; Öhman & Mineka, 2001).

The results of a different line of research, finding faster response times in simple choice reaction tasks to pleasant pictures or words (Feyereisen, Verbeke-Dewitte, & Seron, 1986; Kiehl, Hare, McDonald, & Brink, 1999; Lehr, Bergum, & Standing, 1966), as well as to happy faces (Hugdahl, Iversen, & Johnsen, 1993; Jukka M. Leppänen, Tenhunen, & Hietanen, 2003) seemingly contradict the two theories described above. When fast recognition of, and immediate response to, a single affective stimulus are required, a speed advantage for pleasant over neutral and unpleasant stimuli is found, regardless of the arousal levels. This phenomenon is sometimes referred to as "positivity offset" and described as a tendency of the positive motivational system to respond more than the negative motivation system at low levels of evaluative input[1] (Cacioppo, 2004; Cacioppo & Gardner, 1999; Ito & Cacioppo, 2000, 2005). This is the case, for example, when participants are asked to make a prompt yes-no decision regarding a picture characteristic or to categorize words (Herbert, Kissler, Junghofer, Peyk, & Rockstroh, 2006; Strauss & Allen, 2006). Even introducing a slight change in the "face-in-the-crowd"-procedure (otherwise showing a consistent preference for threatening and fearful faces, see above) by employing photographs instead of schematic faces, produces an advantage in accuracy and speed for the happy compared to the angry and fearful faces (Juth, Lundqvist, Karlsson, & Öhman, 2005). Although the nature of these effects remains unclear and a solid theoretical foundation is lacking, Juth and colleagues (2005) attribute these advantages to the ease of processing for happy faces, while Leppänen and collaborators (2004) hypothesize that the speed advantage for the recognition of happy faces, pleasant pictures and positive words is due to a higher level recognition preference for pleasant vs. unpleasant stimuli.

Another theoretical basis can be found considering the "„defense cascade“" hypothesis, specifically its proposed first stage: "freezing". In the animal model the „defense cascade“ approach has been used to describe a hierarchical reaction pattern to threat or severe stress (Fanselow & Sigmundi, 1986; Graeff, 1994; Gray, 1988; Hunt, 2007; Misslin, 2003)**,** which includes behavioral and physiological responses. It has also been applied to human behavior in the context of threat, stress, maltreatment and trauma (de Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004; Lang, 1995) and has been used as a theoretical foundation for a multitude of adaptive and maladaptive human behaviors and even for mental illness (Elbert & Rockstroh, 2004; P. Gilbert, 2001; Pollak, Cicchetti, & Klorman, 1998). The activation level of this defense system depends on the intensity of the perceived danger and the closeness of the subject to the source of the danger (McNaughton & Corr, 2004). Originally, and for a long time, "flight" and "fight" were the two elements of the proposed defense system (Cannon, 1929). More recently, two more elements, "freeze" and "fright", have been added to incorporate advances in the understanding of the acute stress response (Bracha, 2004; Bracha, Ralston, Matsukawa, Williams, & Bracha, 2004; Bradley et al., 2001; Lang, Davis, & Öhman, 2000; Vila et al., 2003). Some authors also consider the "faint-response" as, for example in some cases of blood phobia to be part of this „defense cascade“ (Bracha, 2004). The first, so called "freezing stage", also referred to as the "stop, look and listen-response", describes a

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[1] According to Ito & Cacciopo (e.g. 2005) with an increase in evaluative input, a tendency of the negative system to respond more strongly called "negativity bias" prevails. These behavioural dispositions can be triggered by the requirements of the environment, but they also built on individual differences.

period of hypervigilance, a state of higher information intake, combined with heart rate deceleration and bodily stillness[1]. Its advantages are two-fold: as the predators detect moving targets easier, immobility is thought to serve as a camouflage and to promote survival. At the same time, the increase in perceptional gain and processing resources facilitates the choice of an appropriate, possibly life saving response. This phase of hypervigilance and movement deceleration is of particular interest to the study of attention allocation and stimulus selection for motivationally relevant material. It could be the reason for a response time advantage of pleasant over unpleasant stimuli in some simple reaction time tasks. As opposed to the hypothesis proposed by Leppänen and colleagues (2004), this theoretical assumption would suggest a decrease in response time for unpleasant and not an increase for pleasant stimuli. It would also lead to the prediction that this arousal independent reaction time difference might be limited in time to the very first „defense cascade“ stage. This could provide an explanation for the fact that the discrepancies in response times to pleasant and unpleasant stimuli are often reported in simple reaction time tasks. Recently, Azevedo and colleagues (2005) convincingly demonstrated that humans show a reduced body sway and heart rate deceleration when confronted with highly arousing unpleasant images, compared to highly arousing pleasant and low arousing neutral visual stimuli. The authors hypothesized that the described physiological and behavioral changes in humans resemble the “freezing-stage” and “fear-bradycardia” seen in other species. These results strengthen the assumption that humans might exhibit a short term reaction time slowing, when confronted with unpleasant or threat-related visual stimuli.

1.2. The temporal dynamic of affective processing can help integrate contradicting empirical results.

Considering the literature on the perception and processing of emotional stimuli, we find support for three different hypotheses regarding the preferential attention allocation within the category of affective stimuli: selection according to arousal levels, leading to similar processing of pleasant and unpleasant pictures (Cuthbert et al., 2000; Sabatinelli et al., 2006), preferential processing of threat-related unpleasant stimuli (Öhman & Mineka, 2001) and faster recognition of, and response to, pleasant stimuli (Feyereisen, Malet, & Martin, 1986; Jukka M. Leppänen et al., 2003). The empirical studies provide consistent and

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[1] The fact that the last stage called “fright” or “playing dead”, has sometimes also been referred to as “freezing”, has lead to some confusion in the literature. It describes, however, a cardinally different condition, characterized by tonic immobility and often triggered by direct physical contact with the predator and when neither escape nor winning a fight is possible.

convincing results within certain paradigms, across experimental designs, however, the outcomes are seemingly contradictory. In view of the fact that the various experimental designs capture different aspects of attention allocation and emotional processing and employ various response kinds, an integration of these diverse results into a theoretical model seems achievable, albeit far from accomplished. An important element that research needs to consider as a necessary step towards clarification and integration is the temporary dynamic of emotional processing. An appropriate and effective response to an affective stimulus poses different demands on the system, not only depending on the stimulus kind, but also considering the point in time of the ongoing processing. A fast perceptional intake, for example, cannot necessarily be equated to a fast motor response. Also, at a certain point of an affective response, the complete and thorough perception could well be of higher adaptive value than the fast, but partial intake and vice versa. The required output, e.g. fast response upon recognition, free recall or detection out of an array, is also an important determining factor. Given the complexity and the speed of affective perception, selection and response, a precise definition of the timing characteristics would provide useful information for understanding the processes behind the discrimination of pleasant and unpleasant stimuli.

Several independent lines of research have lately discovered the temporal dynamic of affective processing as a possible foundation for integration of seemingly contradicting results. Maljikovic and Martini (2005) have argued that arousal and valence serve as independent factors with different timing characteristics in modulating short-term memory performance for complex scenes with affective content. In their studies, higher arousal resulted in generally higher information accumulation speed. The influence of the valence factor depended particularly on the exposure time and dissociated negative stimuli, for which information was encoded slower at first and then increasingly faster, from positive and neutral stimuli, for which information accumulation occurred at a constant rate. These results are consistent with the predictions of the defence cascade model. A recent review (Kensinger, Garoff-Eaton, & Schacter, 2006) provides a possible theoretical foundation for these findings, hypothesizing that memory enhancement for arousing stimuli is mediated by an amygdale network, while valence dependent modulations rely on prefrontal-hippocampal interactions. Calvo and Avero (2005) emphasize a different aspect of processing changes in time, they show an initial attentional bias to arousing pleasant and unpleasant stimuli during the first 500 ms and a later avoidance of unpleasant threat-related pictures. Esslen and colleagues (2004) have reported on an electrophysiological study combining the viewing of emotional faces with the instruction to generate the emotion seen on the screen. The authors compared five affective states (happy, sad, disgusted, fearful and angry) and found evidence for specific electrophysiological patterns for each of the five tested conditions. The differences between them exhibited dynamic changes across time even within the small time window of 500 ms after stimulus onset. Other electrophysiological studies use steady-state Visual Evoked Potentials (ssVEP)[1] to explore the dynamics of affective processing. They report processing patterns with distinct temporal and topographical characteristics, modulated primarily through the arousal dimension of visual stimuli (Keil et al., 2003; Moratti, Keil, & Miller, 2006; Moratti et al., 2004).

One aim of this dissertation is to pinpoint ways of approaching different phases of emotional perception and processing. With an electrophysiological conditioning design we intended to capture the very early stages of affective meaning acquisition, initial information intake and perception. We hoped to learn more about the way stimuli become motivationally relevant and the mechanisms through which their perception is amplified. Using Event Related Potentials (ERPs) time-locked to originally neutral, later by means of classical conditioning emotionally significant stimuli, we were able to show learning dependent changes in the human brain activity at a time range of 65-90 ms, suggesting the direct involvement of the primary visual cortex in affective evaluation processes, mediated through learning dependent plasticity mechanisms. This study will be discussed in detail in the second part of the dissertation.

As opposed to electrophysiological measures, behavioral variables exploit the output dimension of affective processing, building upon different levels of perception, encoding, memory and retrieval. They are suitable for extracting information regarding the sum effects of emotional processing, leading to possible behavioral dispositions in real life situations. Depending on design and task demands, emphasis can be placed on different processing stages. In the first part of this dissertation, four studies, which use the Attentional Blink paradigm and investigate the automatic attention allocation to pleasant, neutral and unpleasant affective scenes of different arousal, will be reported.

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[1] ssVEP are brain oscillations elicited by a fixed-rate serial presentation of visual stimuli. The oscillatory brain response mirrors the frequency of the stimulus presentation, for details see Keil (2003)

2. The Attentional Blink procedure and its use in the study of affective processing

The Attentional Blink design has been used to study the timing and capacity of visual perception and visual short term memory with simple neutral stimuli, such as letters, digits and words (Chun & Potter, 1995b; Potter, Chun, Banks, & Muckenhoupt, 1998; Raymond, Shapiro, & Arnell, 1992; K. L. Shapiro, Raymond, & Arnell, 1994, for a recent review see Hommel et al., 2006). When participants are required to identify two targets in a rapid serial visual presentation (RSVP) stream with similar distracters, a period of reduced awareness, finding its expression in a decrease of identification accuracy and a response time increase for the second target (T2) following identification of the first target (T1), can be observed. The time interval between the targets, as well as the kind and amount of intervening distracting items and the explicit and voluntary processing of the T1, determine the characteristics of this so called Attentional Blink effect (AB). Individual differences determining the degree of its manifestation have also been demonstrated (Lahar, Isaak, & McArthur, 2001; S. Martens, Munneke, Smid, & Johnson, 2006; Rokke, Arnell, Koch, & Andrews, 2002). The AB-design constitutes a useful tool for the study of the attention allocation mechanisms under informational overload conditions and their temporal characteristics. Lately, researchers have begun to utilize this paradigm for the study of affective perception concentrating on the modulation of the AB effect when affective words are used as T2s. Anderson and Phelps (2001) found a selective decrease of the AB effect, that is higher accuracy of identification in short T1-T2 intervals, for highly arousing negative nouns compared to neutral ones. Later Anderson (2005) reported an arousal dependent modulation for pleasant and unpleasant nouns. Ogawa and Suzuki (2004) demonstrated similar effects for negative Kanji-symbols, while Keil and colleagues (2004) reported comparable results for highly arousing, both pleasant and unpleasant, compared to low arousing, neutral verbs. These findings were interpreted as a sign that, although attention limitations still apply, affectively arousing verbal material is selected preferentially from a temporal stream, leading to a facilitation of processing at different levels, such as perception, working memory consolidation and action (Keil et al., 2006). A few recent studies extend this research to complex visual images. Two reports (Most, Chun, Widders, & Zald, 2005; S. D. Smith, Most, Newsome, & Zald, 2006) utilize motivationally significant photographs (inherently affective or conditioned ones respectively) as first implicit[1] targets in a modified AB design. Both demonstrate that affective and conditioned stimuli capture attentional resources and thus induce an AB effect. Fox and collaborators (2005) used pictures of fearful and happy faces as second targets in an Attentional Blink design and showed a pronounced effect of anxiety: while low anxious individuals demonstrated similar attentional blink effects for happy and fearful faces, in highly anxious individuals a reduction of this effect specifically for the fearful faces was observed. The authors concluded that individual anxiety differences might increase the motivational significance of fear-related stimuli, leading to a category specific hypervigilance and thus might serve as a regulation mechanism for attention allocation (Fox et al., 2005). These studies demonstrate that the motivational significance of the visual stimuli alters the AB-effect and thus provide evidence for preferential attention allocation to affective stimuli. They also touch upon an important issue by extending the AB-design to the use of visual affective stimuli other than words. However, Smith et al. (2006) and Most et al (2005) concentrate on varying the motivational significance of the first target and do not report the general characteristics of the AB-effect, when neutral pictures are used. In the study by Fox et al. (2005) a control condition with neutral faces is missing, thus both studies leave unanswered questions regarding the basic features of the attentional blink phenomenon when pictures of affective scenes or of faces are used as T2s and as distracters.

In addition to the variation induced by task demands and the timing dimension of affective processing, discussed briefly above, there has been an ongoing debate regarding the discrepancies in affective enhancement across different categories of visual stimuli, e.g. affective pictures, emotional faces, words, body language or gestures with affective content (Alpers, Ruhleder, Walz, Muhlberger, & Pauli, 2005; de Gelder, 2006; Flaisch, Junghofer, & Schupp, 2006; Herbert et al., 2006). In humans, faces constitute a unique category of visual stimuli with highly-specialized processing (see for example Farah, Wilson, Drain, & Tanaka, 1998; Kanwisher & Moscovitch, 2000; Kanwisher, Stanley, & Harris, 1999; Vuilleumier, Armony, Driver, & Dolan, 2001). Assessing the affective meaning of symbolic stimuli such as words, on the other hand, requires detailed visual processing, followed by lexical and semantic consideration (Cohen & Dehaene, 2004; Gaillard et al., 2006). We adapted the AB-paradigm for the use of affective pictures, assuming that their perception and processing takes a direct and fast route through the visual system (Bradley et al., 2003a; Codispoti, Bradley, &

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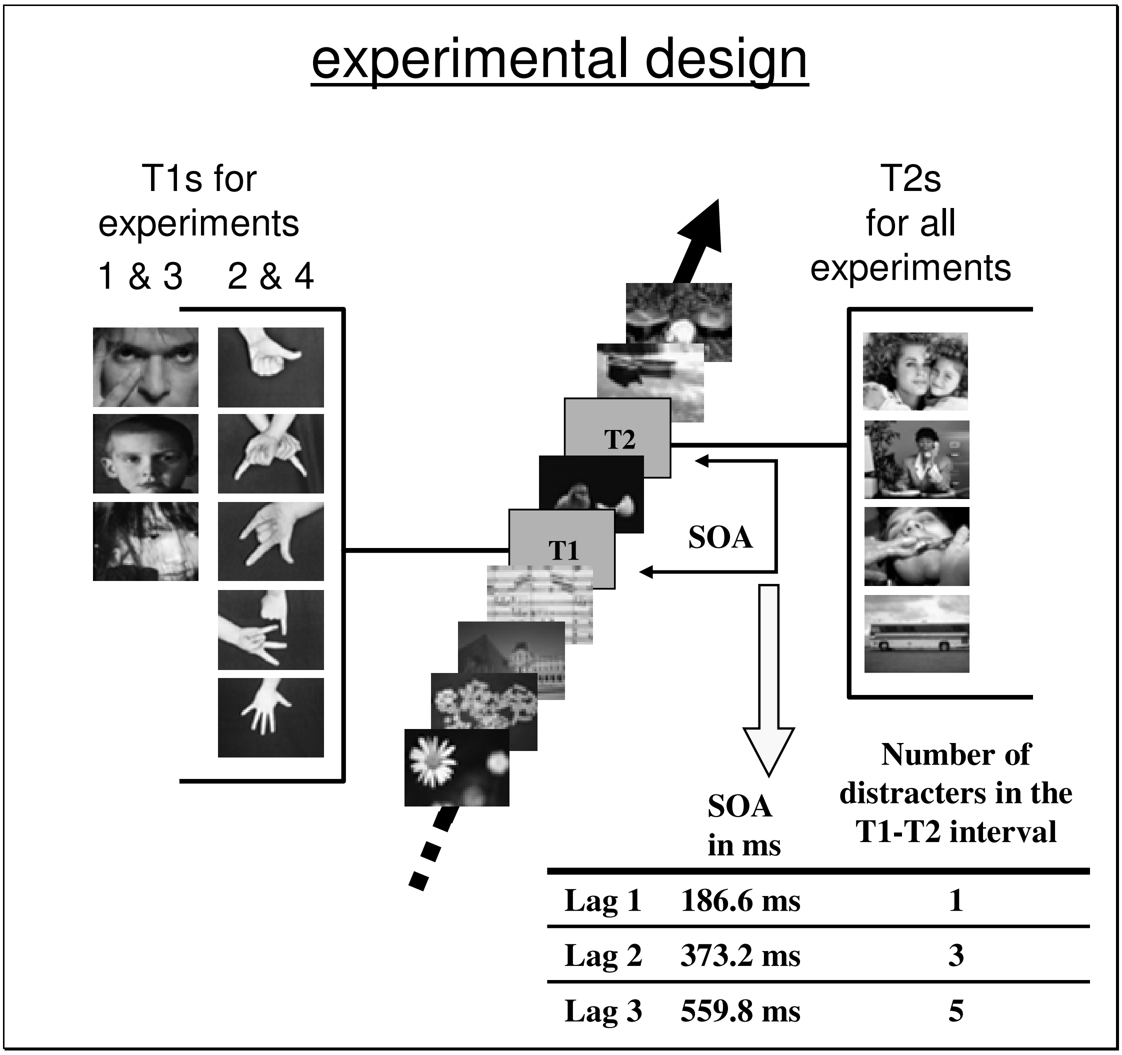
[1] A key feature of the traditional AB design is the explicit requirement to process both targets. Here, the authors make use of the automatic uninstructed attention allocation to motivationally significant stimuli and thus elicit an AB with only one explicit target. We use the term “implicit target” for a stimulus in a RSVP sequence that draws attention preferentially without an explicit instruction or task relevance.

Lang, 2001; Lang et al., 1993). This stimulus category is known to elicit strong physiological responses (Lang et al., 1993; Moratti et al., 2004). It has been repeatedly demonstrated that the perception of affective pictures is associated with fast and reliable modulations of early electrophysiological responses, such as event related potentials (Junghöfer et al., 2006; Kayser, Bruder, Tenke, Stewart, & Quitkin, 2000) and ssVEPs (Keil, Moratti, Sabatinelli, Bradley, & Lang, 2005; Kemp, Gray, Eide, Silberstein, & Nathan, 2002), as well as oscillatory activity e.g. in the gamma band (Keil et al., 2001; Müller, Keil, Gruber, & Elbert, 1999). These findings have been extended using MEG (Leon-Carrion, McManis, Castillo, & Papanicolaou, 2006; Northoff et al., 2000), fMRI (Grimm et al., 2006; Sabatinelli et al., 2004; Wrase et al., 2003) and PET (S. F. Taylor, Phan, Decker, & Liberzon, 2003). Behavioral studies have demonstrated high validity and sensitivity when affective scenes are used (e.g. Lang et al., 1993). Using affective scenes allows for a satisfactory dissociation between the valence and the arousal dimensions of emotional processing, thus enabling us to address the issue of preferential attention allocation within the category of affectively arousing pleasant and unpleasant stimuli.

2.1. Four explorative studies investigating the Attentional Blink with pictures: aims and methodological characteristics

We adapted a classical AB-design for the use with pictures of complex scenes. First, we had to establish the existence of an AB-effect when visual images are used as targets and as distracters. In a second step, we were interested in whether possible affective modulations would depend on the T2 arousal levels, as predicted by the experiment utilizing affective words (Anderson, 2005; Anderson & Phelps, 2001; Keil & Ihssen, 2004; Keil et al., 2006), thus resulting in a similar outcome for pleasant and unpleasant pictures, or if a valence modulation will be found, possibly building on the considerations reported above regarding the „defense cascade“ model and its role in attention allocation. Further questions concerned the differences in response pattern depending on the required response kind: fast reaction or recognition. In the following four AB-studies designed to answer these questions are reported, intermediate results summaries and brief discussions are included after each study to enhance readability. The section concludes with a general discussion and the integration of the AB-results, before an electrophysiological conditioning study is reported and discussed in the second part of this dissertation. We end with a general discussion attempting to integrate the behavioral and the electrophysiological results reported here and pinpointing possible directions for future research on the timing characteristics of affective perception.



	SOA in ms	Number of distracters in the T1-T2 interval
Lag 1	186.6 ms	1
Lag 2	373.2 ms	3
Lag 3	559.8 ms	5

Figure 1: A schematic outline of one trial, examples of the target and the distracter stimuli used in experiments 1-4. Each experimental trial consisted of an RSVP color picture stream and the presentation duration of each stimulus was 93.3 ms. The distracter stimuli before, in-between and after the target stimuli were drawn out of a picture set identical across the three experiments and the presentation order was randomized. The time interval between T1 and T2 varied to contain one, three or five distracter stimuli and the SOAs were 186.6 ms, 373.2 ms and 559.8 ms respectively. A total of 480 trials were shown in each experiment.

As in the classical AB-studies using symbols or words, we used a rapid serial visual presentation (RSVP) design. The target stimuli were embedded in a stream of neutral complex visual scenes (distracters) presented at a fixed rate. First targets (T1s) were drawn out of predefined sets of pictures; participants were required to detect their presence, to retain the specific stimulus in mind and to report on it, when asked at the end of each trial. Participants knew that in some trials there would not be a second target to detect, but that a T1 would always be presented and a report required. In Experiment 1 and 3 T1s were 3 distinct portraits. Participants were familiarized with them beforehand and learned to assign them to the numbers 1 to 3. At the end of each RSVP trial, they reported the number of the portrait they just saw. In experiments 2 and 4 the T1-sets were extended to include 78 different pictures of hands, in order to minimize learning effects, coercing participants to process every T1s in detail thorough the course of the experiment and thus increasing the task difficulty. In 25% of the trials there were no second targets, thus providing a control condition with a single task and no affective stimuli in the RSVP stream. In the remaining 75% of the trials, pleasant, neutral and unpleasant T2-pictures from the International Affective Picture System (IAPS, Lang, Bradley, & Cuthbert, 2005) depicting one or more persons were to be detected out of a stream of neutral scenes without people at some point after the presentation of the T1s. As common in AB-research, only trials with correct T1-responses were considered for further analysis, in order to ensure that participants were not willingly ignoring on unwillingly missing the T1s, thus possibly boosting their performance regarding the second targets. In all four experiments, the T1-inquiry took place immediately after the end of the RSVP stream. In the first two experiments, we asked our participants to respond to the T2s with a fast button press, as soon as they saw a person (immediate fast response). In experiments 3 and 4, after the end of the RSVP sequence and following the T1-inquiry, participants were presented with a 3 x 3 matrix and asked to identify the T2 (recognition task). Three stimulus onset asynchronies (SOAs), determining the time interval between the onset of the T1 and the onset of the T2s, were used in order to establish a possible AB-window, when visual scenes are utilized. Dependent variables were the percentage correct responses for the T1s and T2s, as well as participants' response times in each experimental condition. Subsequent to the AB-procedure, participants were asked to rate the target stimuli on the dimensions valence and arousal. Details of each study are given in the methods sections below. Please see Table 1 for a summary of the study variations and population sizes and Figure 1 for an example of the stimuli used, as well as for a schematic representation of a RSVP-trial.

study number	n	T1-kind	T1-response	T2-response
1	22	3 portraits	report portrait number	immediate fast mouse click
2	18	78 pictures of hands	report amount of outstretched fingers	immediate fast mouse click
3	27	3 portraits	report portrait number	recognition out of a 3 x 3 picture array
4	40	78 pictures of hands	report amount of outstretched fingers	recognition out of a 3 x 3 picture array

Table 1: Summary of the design variations, as well as the sample sizes for each of the four AB-studies.

2.2. AB-Study 1:

T1: three portraits: T2- response: immediate fast response

2.2.1. Methods

Participants

26 volunteers agreed to participate in this experiment (11 male, mean age = 24.2 years, SE = 1.1, range 18 – 50) and either received course credit or a financial incentive of €5.00 per hour. Four participants were excluded from further analyses because their data included more than 20 % false alarms. The remaining 22 data sets (10 male, mean age = 23.3 years, SE = .5, range 19 –29) constitute the final sample of this experiment.

Stimuli

The 180 pictures used here as second targets (T2s) all included images of people and were selected from the International Affective Picture System (IAPS) based on their valence and arousal ratings (Lang, Bradley, & Cuthbert, 1999). The 60 unpleasant/highly arousing pictures showed mutilated bodies and people involved in dangerous and/or unpleasant situations (mean valence = 2.4, SE = .09; mean arousal = 5.9, SE = .12), the 60 neutral/low arousing ones depicted people in different everyday situations, (mean valence = 5.9, SE = .12; mean arousal = 4.0, SE = .12), the 60 pleasant/highly arousing stimuli included erotic photographs and images of happy adults and children (mean valence = 7.3, SE = .07; mean arousal = 5.3, SE =.13). The three pictures used as first targets (T1) also came from the IAPS, they were portrait photographs of a woman, a child and a man. The 144 neutral pictures used as distracters were in part selected from the IAPS, in part found different digital picture libraries. They depicted landscapes, objects, food items, art work and abstract patterns. All stimuli were presented centrally on a 19 inch monitor with a retrace frequency of 75 Hz. They were edited to fit the same size of 326 x 244 pixels with a screen resolution of 1024 x 768 pixels and subtended visual angles of 14° horizontally and 11° vertically.

Procedure:

Upon arrival in the laboratory, participants were given oral and written instructions regarding the experimental procedure. The protocol included informed consent, handedness and personal information questionnaires, as well as the State and Trait Anxiety Inventory (Laux, Glanzmann, Schaffner, & Spielberger, 1981). After finishing all requested forms and questionnaires, participants were shown an example of an experimental trial. Numbers from one to three were assigned to each of the possible T1-stimuli and participants were asked to memorize the picture-number pairs. They were instructed to monitor the RSVP picture streams for one of the three T1-pictures. At the end of each trial they were asked to type in the number of the T1-stimulus they saw, or press the mouse button, if they couldn't remember it. Participants were also required to look for a second picture with people occurring some time after the T1 and press the left mouse button as soon as they saw one. They were told that each trial would contain one of the three T1-stimuli, but that there would not always be a second picture with people. A minimum of six test trials was completed in the presence of the experimenter, to ensure that participants were able to operate the equipment and had understood the requirements of the dual task correctly.

The experiment was performed using Presentation® software (Version 0.76, www.neuro-bs.com) and consisted of 480 trials divided by a break in two blocks with 240 trials each. In each trial participants saw a RSVP stream with a minimum of 17 and a maximum of 35 pictures including the two target stimuli (T1 and T2). The presentation rate was 10.7 Hz, the presentation duration of a single picture was 93.3 ms. A random number of 5 –15 distracter pictures preceded the T1 stimulus. The T1 –T2 intervals varied to contain one, three or five intervening distracter pictures, so that the stimulus onset asynchrony (SOA) between T1 and T2 was 186.6 ms, 373.2 ms and 559.8 ms respectively. The T2s were followed by a random number of distracter pictures varying between 9 and 13. For a schematic outline of the experimental design see Figure 1.

In each block, 60 pleasant, 60 neutral and 60 unpleasant pictures with people were used as T2s. Additional 60 trials without a T2 were included to control for the amount of false alarms. The presentation order was randomized across trials. A total of 40 trials (20 in each block) per SOA – T2-category combination were available. After completing all 480 trials, subjects were asked to rate the 183 target stimuli (T1s and T2s) on the dimensions valence and arousal using a computerized version of the Self Assessment Mannequin (SAM, Bradley & Lang, 1994).

Data analyses

Accuracy of target identification was measured as the percentage of correct responses for each of the 9 conditions (3 SOAs x 3 affective categories). The amount of false alarms was also monitored, percentages were calculated. Only trials with correct T1-detection were considered when determining T2-accuracy. A repeated measures ANOVA with the within subject factors SOA (3; 186.6 ms, 373.2 ms and 559.8 ms) and affective category (3, pleasant, neutral and unpleasant) and the between subject factor gender was conducted for the T1 and the T2 responses. The percentage values were subjected to a logarithmic transformation and a second repeated measures ANOVA with the same factors was conducted to monitor for possible effects of the percentage distribution. In addition, subjects' response times (RTs) for correctly identified T2s were measured as the time difference between the onset of the T2 and the participants' button press and were averaged together within the experimental conditions. Trials with response times of below 150 ms and above 850 ms were regarded as incorrect and excluded from the analyses. The mean RTs for each condition were subjected to a repeated measures ANOVA with the within subject factors SOA (3; 186.6 ms, 373.2 ms and 559.8 ms) and affective category (3, pleasant neutral and unpleasant) and the between factor gender. The ratings for the target stimuli were averaged for each picture, mean values for each of the two rating dimensions were subjected to a one way ANOVA with the factor category (4; pleasant, neutral and unpleasant T2s and neutral T1s). The rating results for all four studies are summarized in Figure 2.

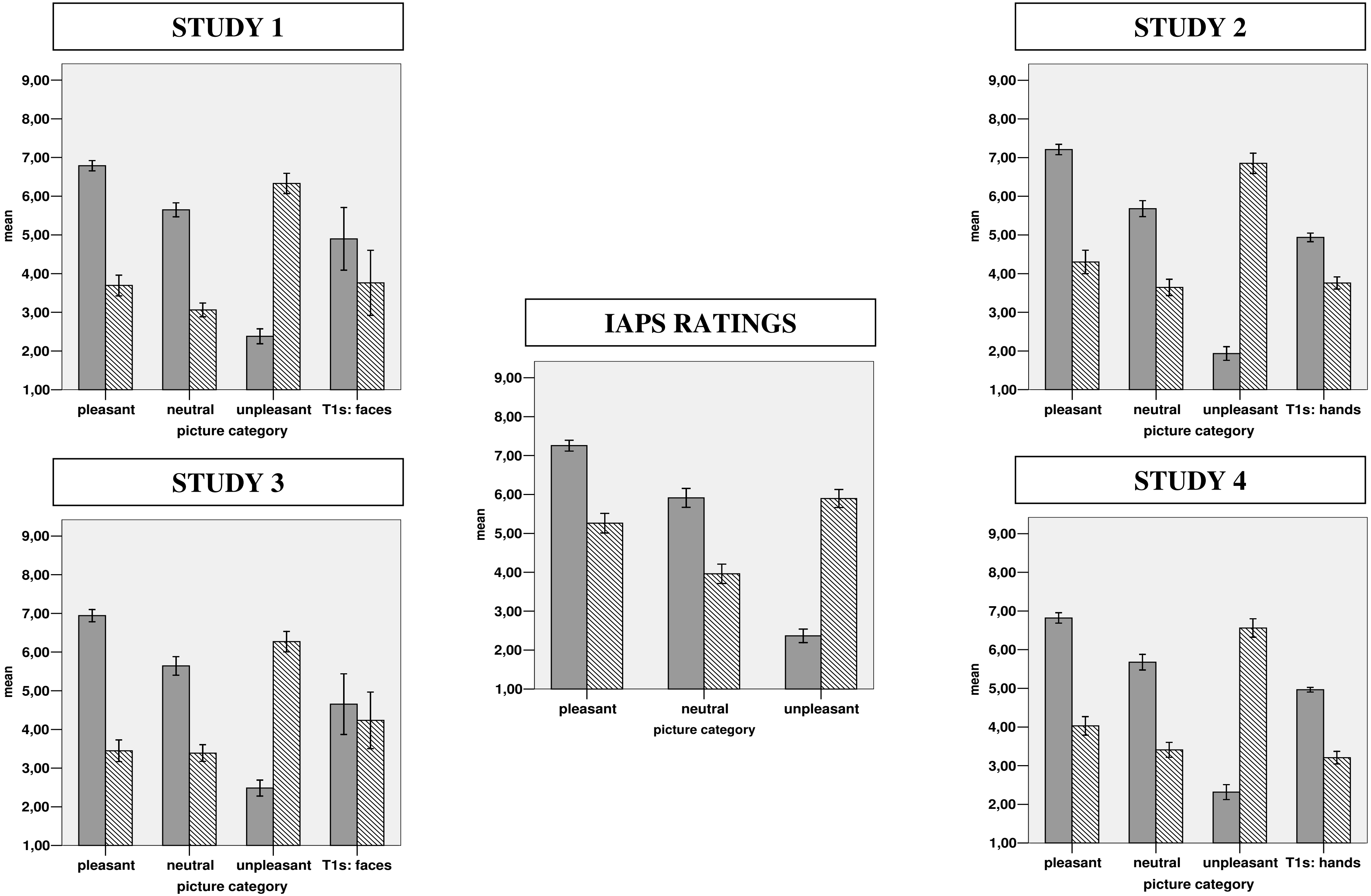


Figure 2: A summary of the SAM ratings for the valence and the arousal dimensions for each of the four AB-studies (error bars: +/-2.00 SE), as well as the standardized IAPS ratings of the same picture set. In all four studies we found the expected linear decrease in valence from pleasant through neutral to unpleasant stimuli with significant differences in all pairwise comparisons. In the reported experiments, the pleasant stimuli were on average rated less arousing than in the IAPS standardized ratings, leading to smaller or absent differences in arousal between the pleasant and the neutral categories.

2.2.2. Results

Subjective ratings

As expected, significant effects of category for the valence (F(3,179) = 483.5, p < .001) and the arousal (F(3,179) = 140.6, p < .001) dimensions were observed. A linear decrease in self-rated valence for pleasant (mean valence rating = 6.8, SE = .07), neutral (mean valence rating = 5.6, SE = .09) and unpleasant (mean valence rating = 2.4, SE = .1) pictures was observed. All follow-up pairwise comparisons corrected with Bonferroni were significant at the p < .001 level. Regarding the arousal dimension, participants rated the neutral pictures used as T2s (mean arousal rating = 3.1, SE = .09) as less arousing than the pleasant (mean arousal rating = 3.7, SE = .1) and unpleasant ones (mean arousal rating = 6.3, SE = .1), the follow-up comparisons were significant at a p <.01 level**.** The three pictures used as T1s had a mean valence rating of 4.9 (SE = .4) and a mean arousal rating of 3.8 (SE = .4). The subjective rating data suggests that our participants perceived the target pictures according to their affective categories, as determined by the standardized IAPS ratings.

Identification accuracy of T1 and T2

No effects of lag, T2-category or gender were observed regarding the accuracy of identification of the first target (T1). The mean identification rate across categories and lags was 96.2%, SE = .6. The lag independent control condition without a second target elicited a similarly high accuracy rate of 96.4%, SE = .59. The repeated measures ANOVA with the transformed values did not expose any additional effects.

Regarding the T2s, we found main effects of LAG (F(2,19) = 7.6, p < .01) and CATEGORY (F(2,19) = 58.4, p < .001), see Figure 3. Participants performance was lower in the shortest time interval between T1 and T2 (lag 1: mean = 76.3%, SE = 2.8), than in the two longer ones (lag 2: mean = 83.6%, SE = 2.2, lag 3: mean = 81.8%, SE = 2.0). The difference between lags 2 and 3 was not significant. Across lags, accuracy of T2-identification decreased linear from pleasant (mean = 85.9%, SE = 2.0), through neutral (mean = 80.8%, SE = 2.3) to unpleasant (mean = 75.0%, SE = 2.1) pictures, all follow-up pairwise comparisons corrected with Bonferroni were significant at the p < .001 level. The mean percentage of false alarms was 8.7% (SE = .9). The results from the repeated measures ANOVA with transformed values were identical as with the percentage values.

Response times

Main effects of LAG (F (2,19) = 105.7, p < 001) and CATEGORY (F(2,19) = 25.1, p < .001) were observed for the fast reaction times required as a response to the T2s. Participants had significantly longer reaction times in the shortest lag (mean = 540.5 ms, SE = 19.0) than in the two longer ones (lag 2: mean = 461.7 ms, SE = 16.5, lag 3: mean = 453.1 ms, SE = 13.3), which did not differ significantly from each other. The pleasant pictures elicited shorter reaction times (mean = 473.2 ms, SE = 16.0) than the neutral (mean = 491.2 ms, SE = 16.1), and unpleasant ones (mean = 491.0 ms, SE = 16.1), which did not differ from each other, see Figure 3.

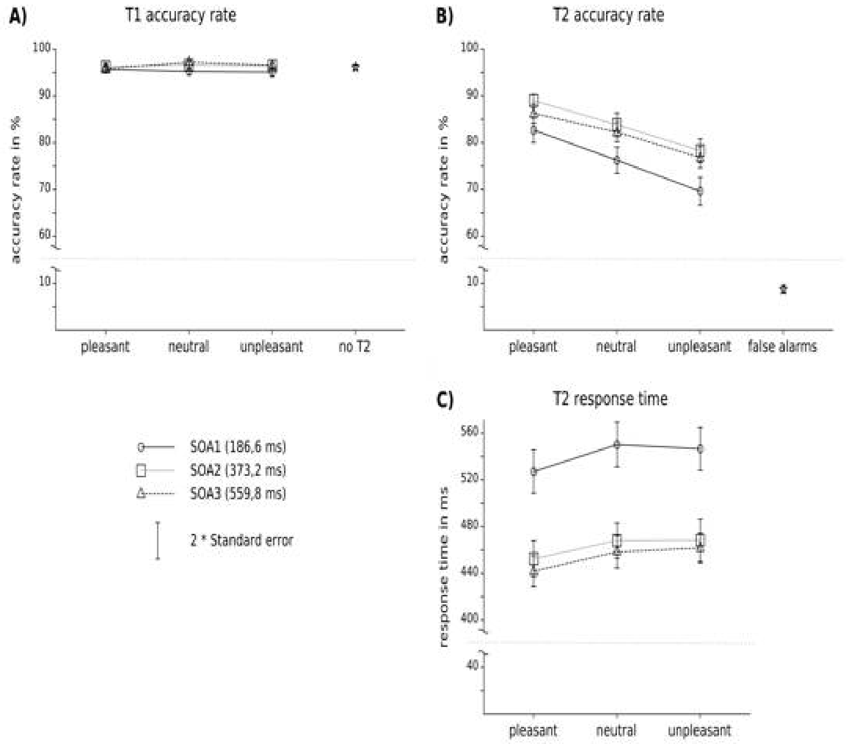


Figure 3: Mean accuracy of identification and mean response times across lags and categories for Study 1. No effects of lag or category were found for the T1-accuracy rate, which was high as expected. Main effects for lag and category regarding the T2-hit rate were observed. Participants' performance was lowest in the shortest lag, no differences between lag 2 and lag 3 were observed. Across lags, identification was best for the pleasant pictures, lower for the neutral and lowest for the unpleasant ones, all pair-wise comparisons were significant. No interactions of lag and category were found. With regard to participants' response time (RT), main effects of lag and category were found, no interactions were observed. Across category, slower RTs were found for lag 1, than for lag 2 and 3, which did not differ significantly from each other. Across lags the pleasant pictures elicited the shortest RTs and the neutral and unpleasant ones did not differ from each other.

2.2.3. Summary

Study 1 demonstrated the existence of an SOA-dependent AB-effect, when complex visual scenes are viewed. As expected, participants showed very high T1-accuracy rates. With a generally lower accuracy of T2-identification, a specific reduction was observed for the shortest SOA, compared to the two longer ones. With symbols, SOAs of around 400 ms are still considered within the attentional blink period, this first study suggests that with complex pictures, the AB-period might be shorter, as no differences between lag 2 and lag 3 were found. Similar conclusions can be drawn from the reactions time results: longer RTs were observed for the shortest SOA, there were no significant differences between the lag 2 and lag 3. Both dependent variables: RTs and accuracy rate were modulated by the affective valence of the stimuli. This influence, however, was present in a similar way across all three lags. No specific reduction of the AB-effect for any of the categories in the shortest lag was observed, rather a linear decrease in accuracy from pleasant, through neutral to unpleasant stimuli for all three SOAs was found. Regarding the RTs, we found faster response times for the pleasant pictures, than for the neutral and unpleasant ones, which did not differ from each other. Thus, these results imply the existence of a general AB-effect with complex images and a SOA-independent valence modulation of accuracy rate and RTs, when an immediate fast response is required. For a graphic summary of these results, please see Figure 3.

2.3. AB-Study 2:

T1s: 78 pictures of hands; T2-response: immediate fast response

With this experiment we attempted to increase the task difficulty by employing a bigger and more complex set of first targets. We aimed at decreasing the accuracy of T1-identification, to avoid ceiling effects and improve our ability to examine effects of the T2-category and SOA on the T1-identification. We used a category of pictures, differing from the T2s, in order to control for potential category specific interactions and changed the nature of the T1-report. All other parameters remained stable.

2.3.1. Methods

Participants

27 volunteers agreed to participate in this experiment (14 male, mean age = 25.7 years, SE = 1.4, range 19 – 51) and either received course credit or a financial incentive of €5.00 per hour. Nine participants were excluded from further analyses due to more than 20 % false

alarms and/or less than 50 % correct responses regarding the T1 or the T2 in any of the 9 experimental conditions. The remaining 18 data sets (9 male, mean age = 25.5 years, SE = 1.6, range 20 –51) constitute the final sample of this experiment.

Stimuli

The 180 affective targets (T2) and the 144 distracter pictures were identical to the ones used in Experiment 1. Instead of the 3 neutral faces used as T1 in Experiment 1, here we employed pictures of one or two hands with one to five fingers sticking out (for examples see Figure 1). These T1-pictures matched the T2s and distracter pictures in size and had a black background. A total of 78 T1 pictures were available (16 with 1, 2, 3 and 5, 14 with 4 fingers sticking out).

Procedure

The experimental procedure was identical to the one in Experiment 1, except that participants were instructed to monitor the RSVP stream for a picture with hands and remember the number of fingers sticking out and not for one of three previously learned neutral portraits. As soon as participants saw a picture with people, occurring some time after the one with hands, they were required to press the left mouse button as fast as they could. At the end of the trial, they were asked to type in the amount of fingers they saw sticking out, using the keyboard's number pad. At the end of the experiment participants rated the 180 target stimuli (T2s), as well as 15 randomly selected pictures with hands (T1s) on the dimensions valence and arousal using a computerized version of the Self Assessment Mannequin (Bradley & Lang, 1994).

Data analyses

Data analysis was conducted analog to Experiment 1.

2.3.2. Results

Subjective ratings

Significant effects of category for the valence (F(3,191) = 689.5, p < .001) and the arousal (F(3,191) = 126.8, p < .001) dimensions were observed. Participants rated the pleasant pictures as higher in valence (mean valence rating = 7.2, SE = .07), than the neutral ones (mean valence rating = 5.7, SE = .1) and the unpleasant ones (mean valence rating = 1.9, SE = .09). All follow-up pairwise comparisons corrected with Bonferroni were significant at the p

< .001 level. Regarding the arousal dimension, participants rated the neutral pictures used as T2s (mean arousal rating = 3.6, SE = .1) as less arousing than the pleasant (mean arousal rating =4.3, SE = .2) and unpleasant ones (mean arousal rating = 6.9, SE = .1), the follow-up comparisons were significant at a p<.01 level. The 15 randomly selected pictures with hands used as T1s had a mean valence rating of 4.9 (SE = .06) and a mean arousal rating of 3.8 (SE = .08). These subjective rating data suggest that the target pictures were perceived according to their affective categories.

Identification accuracy of T1 and T2

No effects of lag, T2-category or gender were observed regarding the accuracy of identification of the first target. The mean identification rate across categories and lags was 76.3% (SE = 1.5) and thus lower than in Experiment 1, suggesting a generally higher task difficulty, as in Study 2, thus reaching the goal of the parameter modification. The lag independent control condition without a second target elicited an accuracy rate of 77.1%, SE = 1.3. The repeated measures ANOVA with the transformed values did not expose any additional effects.

Regarding the T2s, we found a main effect of CATEGORY (F(2,15) = 24.0, p < .001), with lowest accuracy for the unpleasant pictures (mean = 62.4%, SE = 1.8) and no differences between the neutral (mean = 69.9%, SE = 1.9) and pleasant (mean = 70.7%, SE = 2.0) ones (see Figure 4). The mean percentage of false alarms was 6.8% (SE = 1.1). The results from the repeated measures ANOVA with transformed values were identical to the percentage values.

Response times

Main effects of LAG (F (2,15) = 112.8, p < 001) and CATEGORY (F(2,15) = 19.9, p < .001) were observed for the fast reaction times required as a response to the T2s (Figure 4). Participants had significantly longer reaction times in the shortest lag (mean = 503.6 ms, SE = 14.8), than in the two longer ones (lag 2: mean = 426.5 ms, SE = 14.7, lag 3: mean = 418.1 ms, SE = 12.6), which did not differ significantly from each other. Across lags, the pleasant pictures elicited shorter reaction times (mean = 433.6 ms, SE = 12.5) than the neutral (mean = 453.5 ms, SE = 12.7), and unpleasant (mean = 461.0 ms, SE = 16.0) ones, which did not differ from each other (see Figure 4).

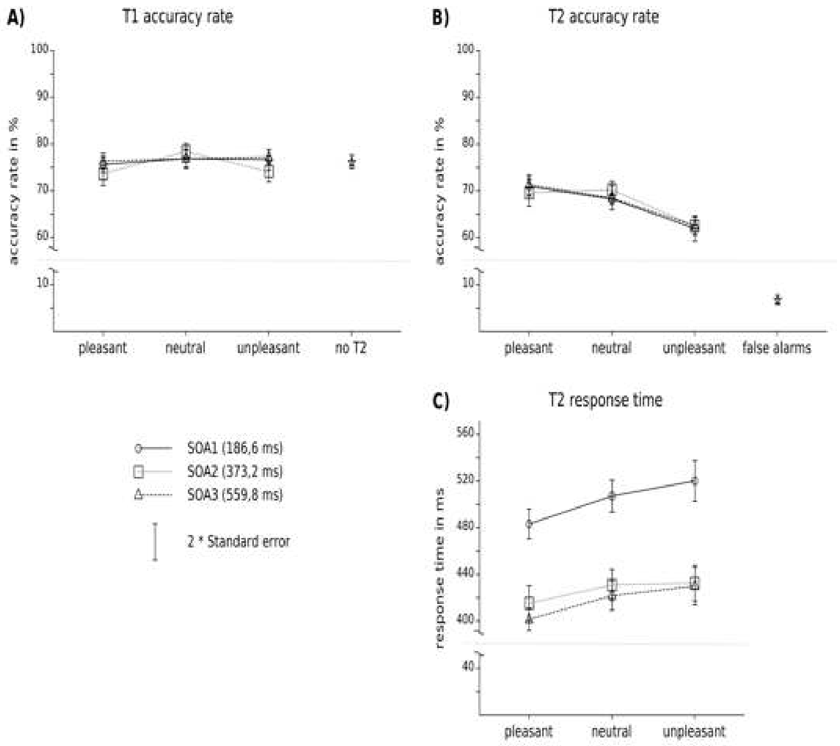


Figure 4: Mean accuracy of identification of the T1s (A) and the T2s (B), as well as mean response times (C) across lags and categories for Study 2. A: no effects of lag or category were found for the T1-accuracy rate, which was as intended significantly lower than in Study 1. B: Regarding the T2-hit rate, a main effect of picture category was found. Across lags participants' accuracy performance was lowest for the unpleasant pictures; there were no significant differences between neutral and pleasant stimuli in this experiment. No effects of lag on T2-accuracy and no interaction of lag and category were observed. C: with regard to participants response time (RT), main effects of lag and category were found, no interactions were observed. Across category, slower RTs were found for lag 1, than for lag 2 and 3, which did not differ significantly from each other. Across lags the pleasant pictures elicited the shortest RTs, the neutral and the unpleasant ones did not differ from each other.

2.3.3. Summary

Study 2 replicated Study 1 with regard to the RT data: longer response times were found for the shortest SOA, implying the existence of an AB-period, possible restricted to a shorter time interval than in studies with symbols and words. Also, a SOA-independent valence modulation with shortest RTs for the pleasant stimuli across lags and longer ones for neutral and unpleasant ones was found, as in Study 1. With regard to the accuracy rates, this second study did not find an AB-effect, as demonstrated in Study 1. No differences across lags with regard to the percentage correct T2-responses were observed. Although a lag-independent category effect was found, it also differed from the one found in the previous study. While in Study 1 accuracy increased linearly from unpleasant through neutral to pleasant pictures, in this second study the pleasant and the neutral picture did not demonstrate significant differences, accuracy rate of the fast response to both categories was better than for the unpleasant ones. Thus, in both studies the unpleasant pictures elicited the lowest accuracy and the pleasant pictures elicited the highest accuracy rate across the three lags. However, the accuracy rate of the neutral stimuli in the second study did not differ from the one of the pleasant ones, thus no linear effect can be reported here. Considering the fact that the exact same T2-stimuli set was used, these differences with regard to the accuracy rate data are surprising. Possible reasons for, and implications of, these results are discussed in the general AB-discussion below.

2.3.4. Intermediate discussion Study 1 and Study 2

Summarizing the results from the two experiments utilizing an attentional blink paradigm with pictures and requiring a fast response to the second target, we observed effects of T1-T2-SOA on participants' response speed that remained stable across experiments. These results suggest a period of reduced awareness when processing two targets in a stream of complex visual stimuli, analog to the attentional blink effect demonstrated with symbols or words (Luck, Vogel, & Shapiro, 1996). This limitation effect seems yet independent of the affective category of the pictures, the AB was not reduced selectively for any of the three picture categories utilized here. The results indicate a linear increase in response times from pleasant, through neutral to unpleasant stimuli for all three lags. No interaction of affective category and lag was found; the relative differences between the categories remained nearly identical for all three T1-T2-SOA conditions. This outcome contradicts the results obtained with affective words, convincingly demonstrating a selective arousal dependent reduction of the attentional blink effect for pleasant and unpleasant words (Anderson, 2005; Keil & Ihssen, 2004; Keil et al., 2006), possible reasons and implications are discussed below, after exploring the effects of a change in response type in Experiments 3 and 4.

Regarding participants' accuracy of identification, the results from the second experiment failed to replicate those from the first one. The effects of affective category remained stable, albeit not entirely identical across experiments. While in Experiment 1 participants' identification accuracy of the T2s decreased linearly from pleasant, through neutral to unpleasant pictures across SOA-intervals, in Experiment 2 differences between pleasant and neutral stimuli failed to reach significance**.** Also, in Experiment 2, as opposed to Experiment 1, no differences in hit rate across lags were found and thus a classical attentional blink effect on the accuracy rate could not be demonstrated. Considering the fact that the T2-stimuli sets, as well as the T2-response kind were identical across the two experiments, and that all other parameters except the T1-kind, the amount of available T1-stimuli and the T1-response, were kept constant, these results are unexpected. The reason must be sought behind the T1-changes and their effects on response requirements and task difficulty. A consequence of the different T1-stimuli set implementation was that the two target stimuli (T1s and T2s) in this second experiment belonged to two distinct categories with differences in content, as well as in perceptual features. As shown by Awh and his colleagues (2004), qualitative differences in processing load, caused by dissimilarities of the stimuli kind, diminish the AB interference. The authors argue that diverse stimuli categories occupy different processing channels, thus eliminating recourse competition, as seen with similar stimuli. In an earlier study, Raymond and collaborators (1995) also demonstrated that feature dissimilarity of the two targets leads to attenuation of the AB effect. It is possible that in Experiment 2, as opposed to Experiment 1, differences between the T1 and T2 picture categories (hands vs. every day scenes involving people) and tasks (counting and delayed report vs. identification and immediate fast response) reduced the AB interference. This could have led to attenuation of the AB-effect, occurring then only with regard to response times, but not mirrored in the accuracy rates. In addition to the stimuli differences, the task difficulty in Experiment 2 was greater than in Experiment 1, resulting in a generally lower hit rate for both targets. These two factors might have contributed to the lack of SOA effects on accuracy of identification in Experiment 2, as well as to the differences regarding the affective content of the T2s, however further studies are necessary to clarify the precise role of T1-T2 dissimilarities and task difficulty, when affective pictures are used.

As opposed to previous studies using simple neutral stimuli and finding an increase in identification accuracy up to a lag of about 600 ms when the processing of the first target doesn't seem to influence the processing of the second one any more (Luck et al., 1996; S. Martens & Johnson, 2005; Nakatani, Ito, Nikolaev, Gong, & van Leeuwen, 2005; Potter et al., 2005), with the complex pictures used here, we did not observe an additional performance increase from lag 2 (373.2 ms) to lag 3 (559.8 ms) in any of the two reported experiments. The fact that the single task control condition without presentation of any affective stimuli in experiment 3 resulted in a hit rate of about 80 % similar to the one achieved for the experimental conditions in the two longer lags, suggests that a performance ceiling was reached. We can, however, not completely rule out the possibility, that for the two longer lags a medium level of performance was achieved. Further studies with higher lag sampling would help specify the time line of the AB effect when complex visual stimuli are used.

At this point, we can conclude that a period of reduced awareness exists, when two complex visual stimuli of the same kind are to be identified in a RSVP picture stream. Our results demonstrate that this AB effect finds its expression in prolonged reaction times, when a speeded response immediately after the T2 is required, and in reduced accuracy of identification of the second target for the shortest SOA, compared to the two longer ones used here. Specific features of the experimental design and stimulus categories modulate strength and precise characteristics of these effects. The affective content of the second targets influences the general response accuracy and speed. It does not, however, modulate the attentional blink effect itself. The category differences seem to depend on the valence of the stimuli, rather than on their arousal levels: responses to the pleasant pictures are associated with shorter reaction times and higher accuracy rates than for the unpleasant pictures. RTs to the neutral stimuli lie in between the affective categories, accuracy rates pattern vary across the two studies reported above. In order to determine, whether these patterns are contingent upon, and limited to, the fast reaction condition, we extended the investigation to include two experiments employing a recognition task for the second target report. All other experimental parameters remained identical.

2.4. AB-Study 3:

T1 – three portraits, T2-response – recognition

2.4.1. Methods

<u>Participants</u>

27 volunteers agreed to participate in this experiment (12 male, mean age = 23.8 years, SD = 6.3, range 19 – 45) and either received course credit or a financial incentive of €5.00 per hour. None of them reported any neurological or psychiatric problems and all had normal or corrected to normal vision.

Stimuli

The three pictures used as first targets (T1), the 180 pictures used here as second targets (T2s), as well as the 144 neutral pictures used as distracters were identical to the ones used in Experiment 1.

An additional 360 pictures were chosen to match the affective target pictures (T2s) in content, affective connotation, arousal and complexity, all of them depicted people. These pictures were used in a 3 x 3 recognition matrix, which appeared at the end of each trial. The matrix included the T2-stimulus of the preceding RSVP stream, 7 randomly selected distracter pictures with people and a blue box in the middle with the text “I did not see a second picture with people”. Participants used the mouse to select one of nine answer possibilities. The mouse click caused the whole recognition matrix to disappear and a black box with the text “Please start the next trial with a mouse click” was presented. Participants determined the start of the next trial without any time constraints.

Procedure

The experimental procedure was to a great extent identical to those used in experiments 1 and 2; differences concerned particularly the instructions regarding the recognition task. Nevertheless, the whole procedure is reported here again, in order to facilitate recollection of details and increase readability of this section. The same applies to parts of the data analysis section Here, however, additional analyses regarding the position of target presentation, as well as a manipulation check were introduced and are described in detail below.

Upon arrival in the laboratory, participants were given spoken and oral instructions regarding the experimental procedure. The protocol included informed consent, handedness and personal information questionnaires, as well as the State and Trait Anxiety Inventory (Laux et al., 1981). After finishing all requested forms and questionnaires, participants were shown an example of an experimental trial. Numbers from one to three were assigned to each of the possible T1-stimuli and participants were asked to memorize the picture-number pairs. They were instructed to monitor the RSVP picture streams for one of the three T1 pictures. At the same time, they were supposed to look for a second picture with people occurring some time after the T1 and remember it. At the end of the trial, participants first entered the number of the T1-picture they saw or pressed the mouse button, if they could not remember it. Then, the 3x3 recognition matrix was presented and participants were instructed to either click on the picture they saw some time after the first target, or on the blue box in the middle, if they hadn’t recognized any of the pictures. Participants were told that each trial would contain one of the three T1-stimuli, but that there would not always be a second picture with people. A minimum of six test trials was completed in the presence of the experimenter, to ensure that participants were able to operate the equipment and had understood the requirements of the dual task correctly.

The experiment was performed using Presentation® software (Version 0.76, www.neuro-bs.com) and consisted of 480 trials divided by a break in two blocks with 240 trials each. In every trial participants saw a RSVP stream with a minimum of 17 and a maximum of 35 pictures including the two target stimuli (T1 and T2). Presentation rate was 10.7 Hz, the presentation duration of a single picture was 93.3 ms. A random number of 5 –15 distracter pictures preceded the T1 stimulus. The T1 –T2 intervals varied to contain one, three or five intervening distracter pictures, so that the stimulus onset asynchrony (SOA) between T1 and T2 was 186.6 ms, 373.2 ms and 559.8 ms respectively. The T2s were followed by a random number of distracter pictures varying between 9 and 13. For a schematic outline of the experimental design see Figure 1.

In each block, 60 pleasant, 60 neutral and 60 unpleasant pictures with people were used as T2s. Additional 60 trials without a T2 were included as a control condition. The presentation order was randomized across trials. A total of 40 trials (20 in each block) per SOA – T2-category combination were available. After completing all 480 trials, subjects were asked to rate the 183 target stimuli (T1s and T2s) on the dimensions valence and arousal using a computerized version of the Self Assessment Mannequin (Bradley & Lang, 1994).

Data analyses

Accuracy of target identification was measured as the percentage of correct responses for each of the 9 conditions (3 SOAs x 3 affective categories). Only trials with correct T1-detection were considered when determining the T2-accuracy. The percentage values were subjected to a logarithmic transformation. A repeated measures ANOVA with the within subject factors SOA (3; 186.6 ms, 373.2 ms and 559.8 ms) and affective category (3, pleasant neutral and unpleasant) and the between subject factor gender was conducted for the T1 and the T2 responses.

Subjects’ response times (RT) for correctly identified T2s were measured as the time difference between onset of the recognition matrix and participants’ mouse click, they were averaged together within the experimental conditions. Trials with response times below 150 ms and above 10 s were regarded as incorrect responses and excluded from the analyses. The mean RTs for each condition were subjected to a repeated measures ANOVA with the within subject factors SOA (3; 186.6 ms, 373.2 ms and 559.8 ms) and affective category (3, pleasant neutral and unpleasant) and the between factor gender.

In addition, the percentage of correct "no picture seen" answers and the corresponding average RTs were calculated. They were used as a control condition, allowing the evaluation of participants' performance in the absence of an explicit T2 and monitoring the amount of false detections. These control data were collected by randomly assigning an additional distracter item to one of the three lag-positions, otherwise occupied by an affective T2 picture with people. Thus, although undistinguishable to the participants, the control response data was collected separately for each SOA. We were able to perform a manipulation check by comparing the responses to the distracter items across lags, we expected a random distribution.

The position in which the T2-picture appeared in the recognition matrix was also considered. The percentage of correct responses, as well as response times were averaged for left, middle and right positions within the affective categories and across the three SOAs. They were subjected to a repeated measures ANOVA with the within subject factors position (3; left, middle and right) and affective category (3, pleasant neutral and unpleasant) and the between subject factor gender.

The ratings for the target stimuli were averaged for each picture, mean values for each of the two rating dimensions (valence and arousal) were subjected to a one way ANOVA with the factor category (3; pleasant, neutral and unpleasant T2s).

2.4.2. Results

Subjective ratings

Significant effects of category for the valence (F(3,179) = 337.4, $p < .001$) and the arousal (F(3,179) = 112.1, $p < .001$) dimensions were observed. A linear decrease in self-rated valence for pleasant (mean valence rating = 6.9, SE = .08), neutral (mean valence rating = 5.6, SE = .12) and unpleasant (mean valence rating = 2.5, SE .10) pictures was observed. All follow-up pairwise comparisons corrected with Bonferroni were significant at the $p < .001$ level. Regarding the arousal dimension, participants rated the neutral (mean arousal rating = 3.4, SE = .11) and the pleasant (mean arousal rating = 3.4, SE = .14) pictures as less arousing than the unpleasant ones (mean arousal rating = 6.3, SE = .13). The three pictures used as T1s had a mean valence rating of 4.7 (SE = .39) and a mean arousal rating of 4.2 (SE = .37), for a summary of the rating results, see Figure 2.

Identification accuracy of T1 and T2

A main effect of LAG (F(2,24) = 3.4, p < .05) regarding the identification accuracy of the first target (T1) was found. With a generally very high hit rate (mean = 97.4 %, SE = .44) there was a tendency for lower accuracy in the shortest lag (mean = 96.5 %, SE = .79), than in the two longer ones (Lag 2: mean = 97.8 %, SE = .46, Lag 3: mean = 97.6 %, SE = .43). The lag independent control condition resulted in a similar high report accuracy as the two longer lag conditions (mean = 97.5 %, SE = .57), see Figure 5.

Regarding the T2s, we found main effects of LAG (F(2,24) = 39.6, p < .001) and CATEGORY (F(2,24) = 48.2, p < .001. Participants performance was lower in the shortest time interval between T1 and T2 (lag 1: mean = 74.5%, SE = 3.0), than in the two longer ones (lag 2: mean = 84.3%, SE = 2.5, lag 3: mean = 86.4%, SE = 2.0). The difference between lags 2 and 3 was not significant. The accuracy of correctly identified no-T2 trials of the control condition amounted to an average of 96.9% (SE = .79), see Figure 5. The manipulation check comparing the control trials across lags did not reveal any systematic differences regarding the T2 identification accuracy. Regardless of the lag condition, accuracy of T2-identification decreased linear from pleasant (mean = 87.2%, SE = 2.1), through neutral (mean = 81.5%, SE = 2.7) to unpleasant (mean = 76.4%, SE = 2.6) pictures, all follow-up pairwise comparisons corrected with Bonferroni were significant at the p < .01 level.

The ANOVA considering the presentation position of the target items in the recognition matrix confirmed the above effect of CATEGORY (F(2,24) = 53.4, p < .001) with a linear accuracy of identification decrease from pleasant, through neutral to unpleasant stimuli, regardless of their matrix position. In addition, a main effect of POSITION (F(2,24) = 3.8, p < .05) was observed. Stimuli shown to the right side of the recognition template (mean = 80.5 %, SE = 2.2), tended to be less accurately identified than those seen in the middle (mean = 83.2%, SE = 2.5), the other pairwise comparisons were not significant.

Decision times

Participants' decision times in the T2 recognition task were averaged across affective categories and lags and subjected to a repeated measures ANOVA with the within subject factors lag (3; 186.6 ms, 373.2 ms and 559.8 ms) and affective category (3, pleasant neutral and unpleasant) and the between factor gender. We found main effects of LAG (F(2,24) = 3.8, p < .05) and CATEGORY (F(2,24) = 26.7, p < .001). A decrease in decision times for T2s shown in the longest SOA (mean = 1835.2 ms, SE = 59.0) compared to the two shorter ones (lag 1: mean = 1918.5 ms, SE 74.6; lag 2: mean 1934.6 ms, SE = 89.9) was found. Across lags longest decision times were found for the unpleasant picture category (mean = 2075.8 ms, SE = 80.0) compared to pleasant (mean = 1835.7 ms, SE = 67.8) and neutral (mean= 1776.8 ms, SE = 80.7). The pairwise comparisons corrected with Bonferroni did not show significant differences regarding the decision times for neutral and pleasant pictures. In the control no-T2 condition participants had the shortest decision times (mean = 1659.3 ms, SE = 171.8). The manipulation check comparing these control trials across lags did not reveal any systematic differences. For a graphic summary see Figure 5.

A CATEGORY x GENDER interaction ($F(2, 24) = 5.0$, $p < .05$) was also observed and followed up with separate ANOVAs for each gender. In females, a main effect of CATEGORY ($F(2,13) = 8.3$, $p < .01$) with a linear pattern was observed. The decision times increased from pleasant (mean = 1793.4 ms, SE = 105.1), through neutral (mean = 1844.6 ms, SE = 130.0) to unpleasant (mean = 2018 ms, SE = 127.7) pictures. The pairwise comparisons demonstrated significant differences between pleasant and unpleasant ($p < .05$) , as well as neutral and unpleasant ($p = .05$), but not between pleasant and neutral ($p = .7$) stimuli. In males, the CATEGORY effect ($F (2, 10) = 22.0$, $p < .001$) had a different pattern with a tendency for an arousal modulation. The neutral pictures elicited the shortest decision times (mean = 1709.1 ms, SE = 77.7), followed by pleasant (mean = 1878.0 ms, SE = 75.0) and unpleasant (mean = 2133.1 ms, SE = 79.9) stimuli. The difference between pleasant and neutral pictures failed to reach significance ($p = .06$), all other pairwise comparisons were significant at the .05 level, see Figure 5.

The ANOVA considering the presentation position of the target items in the recognition matrix confirmed the above effect of CATEGORY ($F(2,24) = 27.8$, $p < .001$), as well as the described CATEGORY x GENDER ($F(2, 24) = 3.8$, $p < 05$) interaction. A main effect of POSITION ($F(2, 24) = 50.2$, $p < .001$) was also found: the decision times for target stimuli shown in middle positions were shortest (mean = 1697.9 ms, SE = 75.0), followed by those for pictures shown in left (mean = 1925.6 ms, SE = 76.6) and right (mean = 2074.5 ms, SE = 73.4) positions, all pairwise comparisons were significant at the $p < .01$ level.

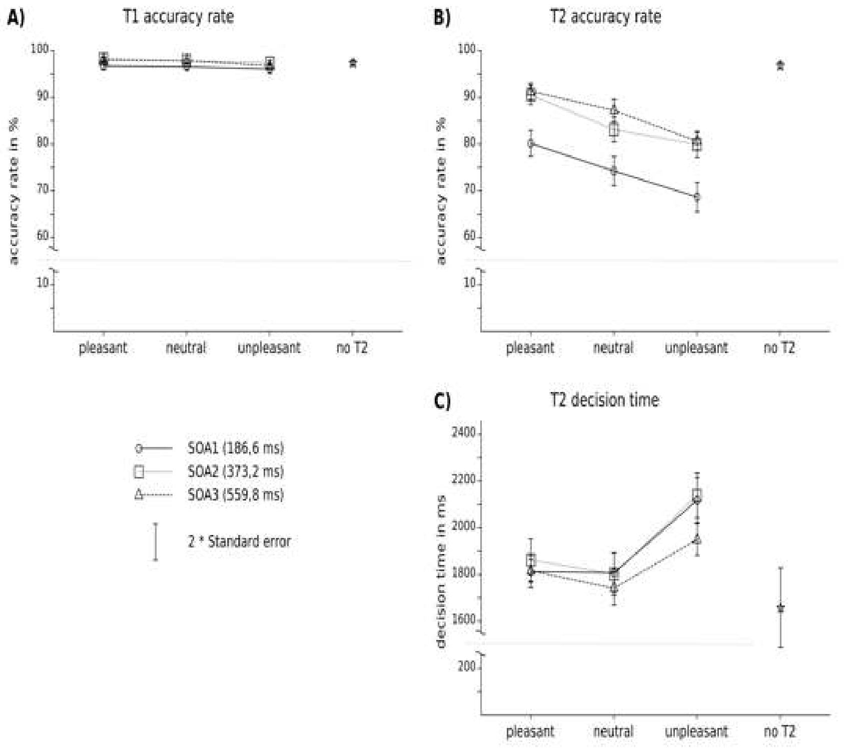


Figure 5: Mean accuracy of identification and mean response times across lags and categories for Study 3. An effect of lag on the T1-accuracy rate was observed. Across categories the generally high T1-hit rate was lower for lag 1 than for lags 2 and 3. Main effects of lag and category regarding the T2-hit rate were observed. Participants’ performance was lowest in the shortest lag, no differences between lag 2 and lag 3 were observed. Across lags, identification was best for the pleasant pictures, lower for the neutral and lowest for the unpleasant ones, all pair-wise comparisons were significant. No interactions of lag and category were found. With regard to participants' decision times, main effects of lag and category were also observed. Across categories participants exhibited longer decision times for the two shorter lags compared to the longest one. Across lags greatest decision times were observed for the unpleasant pictures, differences between the pleasant and neutral stimuli failed to reach significance.

2.4.3. Summary

In Study 3 the same picture set as in Study 1 was utilized. The overall experimental design was also kept identical, except for the T2-response kind: instead of an immediate fast response to the T2s, recognition out of a matrix was required. This manipulation led to a SOA dependent modulation of the T1-accuracy, not found in studies 1 and 2. Participants’ accuracy rate for the T1-stimulus was lower for the shortest SOA than for the two longer ones. This effect was independent of the T2-stimulus category. As the traditional AB-theories do not consider a possible backward interference, resulting in recognition reduction of the T1, depending on the time interval between T1 and T2, this is an interesting finding and will be discussed in greater detail in the general AB-discussion in section XY.

Regarding the T2-accuracy rate, this study confirmed the existence of an AB-effect, when pictures are used: lowest accuracy rates were observed for the shortest SOA, the two longer ones did not differ from each other. Again, the AB-window with pictures seemed to be shorter than with symbols and with words. In agreement with the two previous studies this performance limitation was not selectively modulated by the affective content of the pictures, the category differences remained stable across SOAs and seemed to depend on the valence rather than on the arousal of the stimuli: a linear decrease in recognition performance from pleasant, through neutral to unpleasant stimuli was found.

Participants' decision times also implied the existence of an AB-effect, not modulated by the pictures affective category: longer decision times were found for lag 1 and lag 2 compared to lag 3, the two shorter lags did not differ from each other. Interestingly, with regard to the accuracy rates, lag 2 and 3 did not differ from each other, while with regard to the decision time lag 1 and 2 elicited similar results. In studies 1 and 2, where a fast immediate response to the T2 was required, both dependent measures accuracy rate and response times differentiated between the shortest and the two longer SOAs. This variability could be seen as evidence for variance in the AB-window, depending on the output measures and the captured time point of affective perception. With regard to the affective categories, across lags unpleasant pictures elicited the longest decision times compared to pleasant and neutral pictures which did not differ from each other. An interaction with the between factor GENDER was observed, in that females demonstrated a tendency for a linear increase in decision times from pleasant, through neutral to unpleasant pictures, while males showed an arousal dependent modulation with shortest decision times for the neutral picture category and longer ones for the affective stimuli.

The position of the target stimuli in the recognition matrix also elicited effects on participants' accuracy rates and decision times. Independent of their affective category, stimuli shown at the right site of the screen elicited the longest decision times and the lowest accuracy rates. The pictures presented in the middle positions elicited the shortest decision times. This result, however, has to be considered with caution, as the starting position of the cursor (the middle of the screen) and the relative distance to the stimuli from there, were confounded with the allocation of target stimuli to the left, right and middle columns in the recognition matrix. Thus, the fact that the middle positions elicited the fastest response times across categories, might be in part due to this confound. The pictures presented on the left side elicited faster decision times than those presented on the right site of the screen, this cannot be attributed to the confounding variable factor.

2.5. AB-Study 4:

T1 – 78 pictures of hands, T2-response – recognition

This experiment was conducted as an extended replication of Experiment 3, considering also the results from Experiment 2. We increased the task difficulty by employing a more complex set of first targets differing from the T2s as in Experiment 2, in order to control for potential category specific interactions. At the same time, we wanted to decrease accuracy of T1-identification, in order to avoid ceiling effects and improve our ability to examine effects of the T2 affective category and SOA on the T1-identification.

2.5.1. Methods

Participants

44 volunteers agreed to participate in this experiment and either received course credit or a financial incentive of €5.00 per hour. None of them reported any neurological or psychiatric problems and all had normal or corrected to normal vision. The data of four participants were excluded due to technical difficulties during the data collection, the remaining 40 participants (13 male, mean age = 24.5 years, SE = .76, range 19 - 49) constitute the final sample of this study.

Stimuli

The 180 affective targets (T2) and the 144 distracter pictures were identical with the ones used in the above experiments. Instead of the 3 neutral faces used as T1 in Experiment 3, here we employed pictures of one and two hands as in Experiment 2.

Procedure

The modification of the T1-stimuli kind as described above was the only significant change in Experiment 4 compared to Experiment 3, the procedure was otherwise identical.

Data Analysis

The data analysis was conducted analog to Experiment 3.

2.5.2. Results

Subjective ratings

Significant effects of category for the valence (F(3,191) = 492.1, $p < .001$) and the arousal (F(3,191) = 171.0, $p < .001$) dimensions were observed. A linear decrease in self-rated valence for pleasant (mean valence rating = 6.8, SE = .07), neutral (mean valence rating = 5.7, SE = .1) and unpleasant (mean valence rating = 2.3, SE = .1) pictures was observed. All follow-up pairwise comparisons corrected with Bonferroni were significant at the $p < .001$ level. Regarding the arousal dimension, participants rated the neutral pictures used as T2s (mean arousal rating = 3.4, SE = .1) as less arousing than the pleasant (mean arousal rating = 4.0, SE = .1) and unpleasant ones (mean arousal rating = 6.6, SE = .1), the follow-up comparisons were significant at a $p<.01$ level. The 15 randomly selected pictures with hands used as T1s had a mean valence rating of 5.0 (SE = .03) and a mean arousal rating of 3.2 (SE = .08). This subjective rating data suggests that our participants perceived the target pictures according to their affective categories (see Figure 2).

Identification accuracy of T1 and T2

A main effect of LAG (F(2,37) = 3.4, $p < .05$) regarding the identification accuracy of the first target (T1) was found. In the shortest lag the accuracy of identification for the first target was lower (mean = 72.3 %, SE = 1.4), than in the longest one (mean = 75.2 %, SE = 1.0), the other pairwise comparisons corrected with Bonferroni did not reach significance. The lag independent control condition resulted in similarly high report accuracy as the longest lag conditions (mean = 75.5%, SE = 1.2), see Figure 6. The T1-identification rates were generally lower than in Experiment 1, suggesting higher task difficulty.

Regarding the T2s, we found main effects of LAG (F(2,37) = 7.2, $p < .01$) and CATEGORY (F(2,37) = 41.3, $p < .001$. Participants performance was lower for the shortest lag (mean = 55.6 %, SE = 2.0), than in the two longer ones (lag 2: mean = 58.2%, SE = 2.3, lag 3: mean = 59.8%, SE = 1.9). The difference between lags 2 and 3 was not significant. The accuracy of correctly identified no-T2 trials of the control condition amounted to an average of 72.5% (SE = 1.6). The manipulation check comparing the control trials across lags did not reveal any systematic differences regarding the T2 identification accuracy. With regard to the main effect of CATEGORY, accuracy of T2-identification decreased linear from pleasant (mean = 62.2%, SE = 2.1), through neutral (mean = 59.2%, SE = 2.1) to unpleasant (mean = 52.2%, SE = 2.1) pictures, all follow-up pairwise comparisons corrected with Bonferroni were significant at the $p< .05$ level. A LAG x CATEGORY interaction (F(4,35) = 3.7, $p <.01$)

followed up with separate ANOVAs showed that this effect was carried mainly by the difference between unpleasant and pleasant stimuli. While the accuracy of identification for the unpleasant stimuli was lowest across all 3 lags, it improved significantly from Lag 1 to Lag 2 (mean Lag 1 = 46.5 %, SE = 2.2; mean Lag 2 = 54.7%, SE = 2.6 , mean Lag 3 = 55.5%, SE = 2.2), while the generally higher performance for the pleasant pictures remained nearly identical across all 3 lags (mean Lag 1 = 62.5%, SE = 2.7, mean Lag 2 = 61.9%, SE = 2.5, mean Lag 3 = 62.2, SE = 2.1). The neutral pictures showed a tendency for an increase from Lag 2 to Lag 3 (mean Lag 1 = 57.9%, SE = 2.2, mean Lag 2 = 58.1%, SE = 2.7, mean Lag 3 = 61.7, SE = 2.2), but it failed to reach significance (p = .09), for a graphic summary see Figure 6.

The ANOVA considering the presentation position of the target items in the recognition matrix confirmed the above effect of CATEGORY (F(2,37) = 33.1, p < .001) with a linear accuracy of identification decrease from pleasant, through neutral to unpleasant stimuli, regardless of their matrix position. In addition, a tendency for a main effect of POSITION (F(2,37) = 3.0, p = .06) was observed. As in Experiment 1, stimuli shown at the right sight of the recognition template (mean = 68.1 %, SE = 1.9), tended to be less accurately identified than those seen in the middle (mean = 60.5%, SE = 2.0).

Decision times

Participants' decision times in the T2 recognition task were averaged across affective categories and lags and subjected to a repeated measures ANOVA with the within subject factors lag (3; 186.6 ms, 373.2 ms and 559.8 ms) and affective category (3, pleasant neutral and unpleasant) and the between factor gender. We found main effects of LAG (F(2,37) = 4.7, p < .05) and CATEGORY (F(2,37) = 34.7, p < .001). A decrease in decision times for T2s shown in the longest SOA (mean = 1813.8 ms, SE = 59.1) compared to the shortest one (mean = 1919.1 ms, SE 61.5) was found. Across lags an arousal modulation was observed with longest decision times for the unpleasant picture category (mean = 2041.1 ms, SE = 70.4), shorter ones for the pleasant (mean = 1810 ms, SE = 56.0) and shortest for the neutral stimuli (mean= 1724 ms, SE = 54.0). All pairwise comparisons corrected with Bonferroni were significant. In the control no-T2 condition participants had the shortest decision times (mean = 1614.8 ms, SE = 130), these results are summarized in Figure 6. The manipulation check comparing these control trials across lags did not reveal any systematic differences.

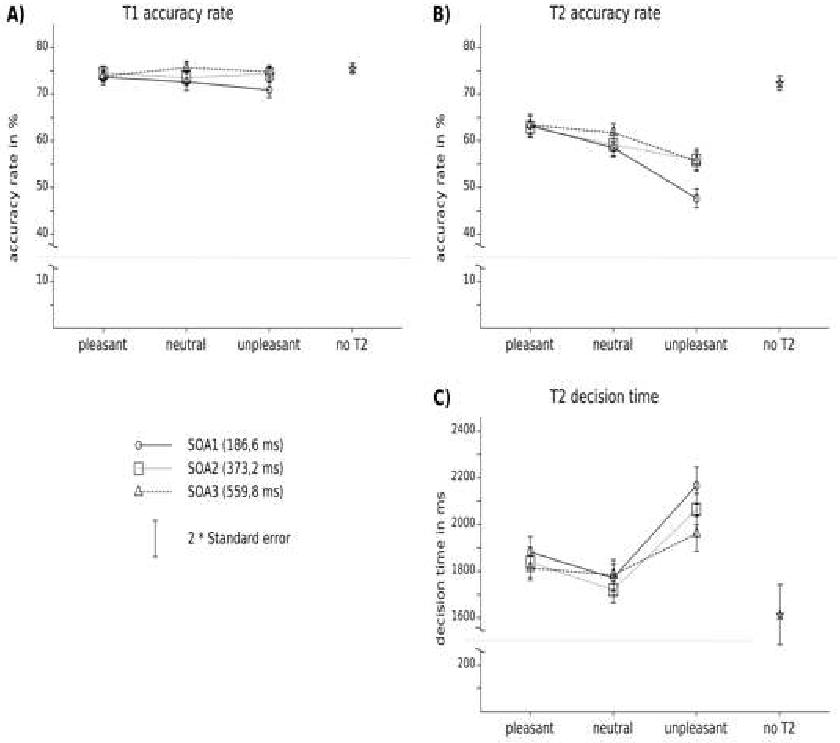


Figure 6: Mean accuracy of identification and mean response times across lags and categories for Study 4. An effect of lag on the T1-accuracy rate was observed. Across categories the T1-hit rate was lower for lag 1 than for lag 3 and was, as intended, generally lower than in Study 3. Main effect of lag and category regarding the T2-hit rate were observed. Participants' performance was lowest in the shortest lag**,** no differences between lag 2 and lag 3 were observed. Across lags, identification was best for the pleasant pictures, lower for the neutral and lowest for the unpleasant ones. All pair-wise comparisons were significant. An interaction of lag and category was found, indicating a selective attenuation of the AB-effect for the pleasant stimuli. With regard to participants' decision times main effects of lag and category were also observed. Across categories longer decision times for the two shorter lags compared to the longest one were found. The decision times were highest for the unpleasant, lower for the pleasant and lowest for the neutral pictures.

The ANOVA considering the presentation position of the target items in the recognition matrix confirmed the above effect of CATEGORY (F(2,37) = 32.1, p < .001). A main effect of POSITION (F(2, 37) = 59.0, p < .001) was also found: the decision times for target stimuli shown in middle positions were shortest (mean = 1630.0 ms, SE = 60.1), followed by those for pictures shown in left (mean = 1939.0 ms, SE = 61.8) and right (mean = 2019.9 ms, SE = 60.5) positions. The Bonferroni corrected comparison between left and right positions failed to reach significance (p = .09). Decision times at peripheral positions were significantly longer (p < .001) than at midline.

2.5.3. Intermediate discussion Study 3 and Study 4

Experiments 3 and 4 both employed an attentional blink paradigm with pictures and required free report of the first target and recognition of the second one. They differed only concerning the T1-category and thus regarding the assumed degree of difficulty. The results regarding the percentage of correctly reported targets demonstrated significantly lower hit rates in Study 4 compared to Study 3 for both targets and herewith endorsed this supposition. Study 4 replicated Study 3 with regard to most other parameters. In both recognition experiments we found effects of SOA-interval on the identification accuracy of the first targets (T1s), the T1 hit rate is lowest in the shortest compared to the longer lag conditions. The T2 accuracy of identification in both experiments provided evidence for an attentional blink across affective categories with a lowest performance in the shortest T1-T2-intervall and no differences between the two longer lags. Across lags in both experiments, we found the same linear decrease in accuracy of identification from pleasant through neutral to unpleasant pictures. Results regarding participants' non constrained decision times for the recognition task in Experiment 4 also replicated those in Experiment 3. Both studies provided support for the existence of a category independent attentional blink effect mirrored in subjects' decision times. Across categories the shortest decision times were recorded for the longest T1-T2-interval, the two shorter ones did not differ from each other. For the picture categories across lags we observed an arousal modulation of the decision times, the recognition of affective pictures took longer than of neutral ones, the unpleasant stimuli in both experiments required the longest decision times. Concerning the effects of T2-presentation position in the recognition matrix, Study 4 also, replicated Study 3: we found longest decision times and lowest accuracy rates across categories for pictures shown in the right column of the recognition matrix. No category specific modulations were observed. The gender effect found in Study 3 could not be replicated in Study 4.

The novel finding in Experiment 4, not established in any of the other 3 studies reported here, is an interaction of affective category and T1-T2-interval regarding the accuracy of identification. Here, the recognition performance for unpleasant and neutral pictures, while generally lower than for pleasant ones, increased linearly from Lag 1 to Lag 3. The hit rate for the pleasant stimuli remained nearly identical cross lags, suggesting that there might be a selective attenuation of the AB-effect for the pleasant pictures. This category specific modulation is of an unexpected nature, AB-studies with affective words predict an attenuation of the AB-effect for both pleasant and unpleasant arousing words. We will discuss possible reasons and implications below.

2.6. General Discussion of the AB-studies

2.6.1. Main methodological characteristics and main results of the four reported AB-experiments

Previous studies investigating the attentional blink (AB) effect have used simple letters (Chun & Potter, 1995a; Jolicoeur, 1998; Jolicoeur & Dell'Acqua, 2000; Kranczioch, Debener, & Engel, 2003; Raymond et al., 1992, 1995), digits (Awh et al., 2004; Kawahara, Zuvic, Enns, & Di Lollo, 2003), colors (Ross & Jolicoeur, 1999), ideographs (Ogawa & Suzuki, 2004), neutral and emotional words (Anderson, 2005; Anderson & Phelps, 2001; Arend, 2002; Keil & Ihssen, 2004; Keil et al., 2006; Luck et al., 1996; Rolke, Heil, Streb, & Hennighausen, 2001) and faces (Raymond, Fenske, & Tavassoli, 2003). They have convincingly demonstrated the existence of a reduced awareness period, called attentional blink, occurring when observers are asked to identify two targets in an RSVP stream. Recently, interest has turned to the modulations of this effect caused by the affective connotation of verbal (Anderson & Phelps, 2001; Arend, 2002; Keil & Ihssen, 2004; Ogawa & Suzuki, 2004) and pictorial (Raymond et al., 2003; S. D. Smith et al., 2006), stimuli. We set out to extend this research to complex affective pictures, hoping to gain a better understanding of the resource allocation to emotional content and its temporal dynamics in human visual processing. First, we needed to establish the existence of an AB effect when complex color images are viewed. As dependent variables, we used speeded reaction (Experiments 1 and 2) and delayed decision times (Experiments 3 and 4) to the T2s, as well as accuracy rates for all experiments. We manipulated the time interval between onset of the T1 and onset of the T2 (SOA1 = 186.6 ms, SOA2 = 373.2 ms, SOA3 = 559.8). In a second step we were interested in the affective modulations of the AB and varied valence and arousal of the T2s. Hence, pleasant, neutral and unpleasant pictures showing people in different situations were presented as targets.

The results of these four experiments provided evidence for a reduced awareness period when complex affective pictures are used with regard to both, response times and accuracy rates. The response time data were in agreement for example with reports by Zuvic and colleagues (2000) and Jolicoeur and collaborators (1998). We also found the expected lower accuracy of T2-identification with the shortest SOA in Experiments 1, 3 and 4. Similar accuracy effects have been reported in most AB studies (e.g. Awh et al., 2004; Chun & Potter, 1995b; Kranczioch et al., 2003; Ogawa & Suzuki, 2004; Olson, Chun, & Anderson, 2001; Raymond et al., 1992). The specific characteristics of this AB, however, varied with design modifications. First, the response time data will be summarized and discussed, and then we will turn to the accuracy rates, a brief discussion of the T1-accuracy results will follow.

2.6.2. Response time and decision time data

As illustrated in the summary Figure 7, the fast response condition in Experiments 1 and 2 elicited identical reliable AB effects on the reaction time: the shortest SOA in both studies led to significantly longer reaction times than SOA2 and SOA3, thus suggesting that the AB window, when pictures are used, might be shorter than with digits or words, where an SOA of 400 ms is still considered within the AB time interval (Luck et al., 1996; S. Martens & Johnson, 2005). With no additional response time decrease from lag2 to lag3, it is likely, albeit not proven, that a performance ceiling has been reached. In Studies 1 and 2 a consistent, but SOA-independent valence modulation was found: pleasant pictures elicited the fastest reaction times in all lags, neutral and unpleasant pictures did not differ from each other, indicating that response facilitation for the pleasant stimuli, rather than response attenuation for the unpleasant ones, has taken place. A different pattern, consistent across Experiments 3 and 4, immerged, when a delayed recognition of the T2s was required. In both studies not requiring an immediate fast response to the T2, the longest SOA elicited the shortest decision times. This AB-effect was significant, albeit notably weaker, than in the fast reaction conditions[1]. In both studies we also observed similar lag independent effects of affective category on the decision times. There were, however, different from those found in Experiments 1 and 2. By far the longest response times were elicited by the unpleasant pictures, the pleasant stimuli did not differ from the neutral ones (Study 3), or showed slightly faster decision times than the neutral pictures (Study 4). In addition, responses to the neutral and the pleasant pictures were closer to the no-T2-responses in the control condition, thus

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[1] Higher interval sampling and additional SOAs would be necessary, in order to determine the real AB-window under these conditions. The data at hand do not allow a conclusion, it is possible that with longer SOAs, additional decision time decrease can be achieved and that the current SOA2 and SOA3 represent an intermediate stage where the processing and reporting of the T1s still impairs processing of the T2s, albeit less than with SOA1.

suggesting an inhibition for the unpleasant category, rather than facilitation for the pleasant and neutral ones.

With regard to the participants’ response times to the second target in an RSVP dual task design with pictures, we found a strong AB effect in the fast reaction condition and a weaker, but still reliable AB effect in the delayed recognition condition. In both cases, these effects were not modulated by the affective category of the pictures. We also observed distinct effects of affective category, which were similar across the three investigated lags, but different for the fast reaction and the delayed recognition conditions. The data presented here suggest facilitation for the pleasant stimuli in the fast response experiments, and an inhibition for the unpleasant. These results can be considered in the context of the „defense cascade“ (Öhman, Flykt, & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001) and “positivity offset” (Cacioppo, 2004; Ito & Cacioppo, 2005), models described earlier. In the immediate fast response condition, we found an increase in response time from pleasant to unpleasant pictures and no difference between pleasant and unpleasant stimuli, and we thus assume an arousal independent facilitation for the pleasant stimuli. Similar results have been obtained in simple choice reaction tasks with words, faces and complex pictures (Herbert et al., 2006; Juth et al., 2005; J. M. Leppänen & Hietanen, 2004; Strauss & Allen, 2006) and are often conflated under the term “positivity offset” (Cacioppo, 2004; Ito & Cacioppo, 2005). This is a frequently reported phenomenon for categorization tasks with low arousal levels. The proposed theoretical foundation implies a default approach state of the organism under low arousal conditions, which enables exploration and learning and thus survival. Only under highly arousing conditions does the so called “negativity bias” prevail. Although we chose highly arousing visual stimuli, it is likely that the experimental context was of generally low arousal to our participants. We did not direct their attention towards the emotional content of the second targets, which were embedded in a stream of low arousing neutral distracters and were not present at the time of the participants’ (fast) response. Rather, we demanded high concentration under safe conditions, possibly a situation where the “positivity offset” prevails over the “negativity bias” and leads to a facilitated response to the pleasant stimuli. At this point, this is a working hypothesis. Future research, systematically manipulating the experimental context and/or comparing groups of people with different levels of negativity bias, e.g. patients with depression or highly anxious individuals, could help provide a more solid theoretical base for these findings.

Positivity offset alone cannot account for the decision time results in Study 3 and 4, where rather than finding facilitation for the pleasant stimuli and no difference between neural and unpleasant ones, we observed a marked delay or response inhibition selectively for the unpleasant picture category. Here, participants were presented with a 3x3 picture matrix including the T2, 7 distracting stimuli, as well as a blue box with inscription "I did not see a second picture with people." Their task was to select the correct T2. Thus, at the time of the response, participants were explicitly looking at the second target. A possible explanation for this response delay can be found in the earlier described „defense cascade"-hypothesis. As mentioned before, human and animal initial responses to potentially threatening situations are frequently characterized by a stage of immobility and increased information intake, often termed "freezing" (Bracha, 2004; Bracha et al., 2004). It is likely that our delayed recognition condition, as implemented in Experiments 3 and 4, captured this processing stage. Earlier studies with animals and humans have shown heart rate deceleration within a window of 2-3 seconds after stimulus onset (Lang et al., 2000; Moratti et al., 2006). For example, a study by Ramirez and colleagues (2005) demonstrated that the cardiac defense response, seen as a decisive part of the freezing stage in the „defense cascade" model beginning at around 2 – 3 s after stimulus onset, strongly depends on the duration of the triggering stimulus and is not seen with duration shorter than 500 ms. The observed slowing of body movements in a recent study by Azevedo and colleagues (2005) also illustrated freezing like behavior in the presence of mutilation pictures starting within this time range. Thus, it is likely that the recognition condition with its prolonged presentation of the T2-stimulus and explicit attention allocation to it might have triggered a defense response selectively to the unpleasant, potentially threatening material not present in the fast response condition and resulting in a selective slowing for the unpleasant pictures.

Summarizing the results concerning fast reaction and decision time in the four studies presented here, we conclude that a category independent AB-effect can be demonstrated with complex visual images. The two response conditions (immediate fast response vs. delayed recognition) seemed to capture different processing stages, the implied AB-window differed, as well as the response pattern with regard to the affective categories. Concerning these output measures of affective perception, we did not find an arousal dependent response modulation. Rather we observed two different kinds of valence dependent modulation with an inhibition of the recognition response to the unpleasant pictures in the delayed recognition condition and response facilitation for the pleasant pictures in the immediate fast response condition. These results provide support for the opinion that the AB-phenomenon with pictures cannot be restricted to "bottle neck" perceptional limitations and should be sought in later processing stages or in the interplay of different levels in perception, processing and output. Similar conclusions were drawn by Jolicoeur (1998) when comparing the results of speeded and delayed unspeeded AB-task with letters. In this case, the response to the T1 was varied; the required response to the T2 was always an unspeeded report at the end of the trial. Lower accuracy of identifications and thus larger AB in the fast RT condition was found. In addition faster reaction times in the speeded condition were associated with smaller and shorter AB[1]. The results reported here supplement earlier findings and provide additional support for the notion that the required output is of decisive relevance to the characteristics of the AB-effect, and thus to the assessment of attention resources, facilitation and interference. They support the idea that the timing characteristics of affective perception and processing, including output requirements, have to be carefully considered when conclusions on the influence of valence and arousal are drawn.

2.6.3. T2-accuracy rate data

Interestingly, the response time data were not at all susceptible to differences in degree of difficulty, as introduced by the changes in picture category, task and the amount of available T1-stimuli in Experiments 2 and 4, compared to Experiments 1 and 3 and affirmed by the generally lower accuracy rates for the T2s, as well as for the T1s (Figure 7). This manipulation specifically influenced the accuracy of identification rates, not only eliciting generally lower hit rates but also changing the response pattern and influencing directly the AB effect. In Studies 1 and 3, where a small set of 3 distinct T1-stimuli, learned and assigned to the numbers 1 to 3 at the beginning of the experiment, was used, a clear and reliable AB-effect with lower accuracy rates for SOA 1 than for SOA 2 and 3 and independent of the affective category of the T2, was observed. Studies 2 and 4 utilized a bigger and more complex T1-set, consisting of 78 different pictures of hands. Instead of reporting the number of the T1-picture seen at the end of the trial, participants had to count, remember and report the amount of outstretched fingers. In study 3, an AB-effect on the accuracy rate was completely absent, in Study 4, although present, it selectively affected the unpleasant picture category and was, by and large, diminished. As discussed briefly in section XY, this discrepancy can be attributed to the differences between the two targets (T1 and T2) concerning the stimulus category (pictures of hands vs. pictures of scenes with people), the identification task and the required report (counting, remembering and reporting a number vs. fast response immediately after identification). It has been repeatedly demonstrated that

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[1] The T2-response time was not reported and the T2-response kind was not varied, making a direct comparison to the reported above results impossible.

dissimilarities in stimulus kind can lead to attenuation of the AB-effect, as it reduces the AB-interference by decreasing resource competition (Awh et al., 2004; Raymond et al., 1995). This is probably the main reason for the lack of an AB-effect regarding the accuracy rates in Study 2 and its reduction in Study 4. Surprisingly, the results also demonstrate that requiring delayed recognition instead of an immediate fast response, and thus adding a working memory component to the processing load of an otherwise identical AB-design (comparison experiments 1 to 3 and 2 to 4), does not have a substantial influence on the overall accuracy rate performance. The only apparent difference was with regard to the attenuation of the AB-effect for the pleasant picture category, while clearly present for the unpleasant stimuli in Experiment 4. Such category specific modulation was not found with regard to accuracy rates in any of the other experiments and was not present at all with regard to response and decision time performance. Possible reasons can be sought in the fact that Experiment 4 had a higher amount of participants (n = 40), possibly exposing smaller effects that had remained hidden in the other experiments, as well as in the higher proportion of females (67,5%). It is, however, also probable, that a combination of increased task difficulty through a bigger and more complex T1-set, and increased processing load through recognition requirements, as achieved in Experiment 4, caused the category specific modulation of the AB, not present, when one of the two aspects was implemented.

With regard to the accuracy rate results, reduced awareness period for the shortest SOAs, compared to the two longer ones were observed in Experiments 1 and 3. The change in T1-category as implemented for Experiments 2 and 4, led to a general decrease in accuracy and to an extinction of the AB-effect. This dependent variable was not sensitive to changes in the required output (immediate fast response vs. delayed recognition). The results obtained here regarding the second target in an AB design, emphasize the fact that response times and accuracy rates are sensitive to different aspects of the experimental design manipulations, likely mirroring different processing levels and stages in time, although both constitute simultaneously collected output measures. They also raise the question as to the nature of the differences in AB-effects when using different kinds of stimuli. This aspect is considered in greater detail in the following section.

2.6.4. Characteristics of the AB with pictures in relation to previous reports utilizing other stimuli types

Attentional blink studies using letters or words as a rule require delayed free recall after the end of the trial, first of the T1, then of the T2 (Chun & Potter, 1995a; Raymond et al., 1992) and they rely mostly on perceptual differences between targets and distracters (e.g. color). Under these conditions, reliable arousal modulations of the AB effect have been found (Anderson, 2005; Keil & Ihssen, 2004; Keil et al., 2006). It was not possible to implement free recall with pictures, thus the recognition condition seemed the best achievable approximation.[1] The fast response conditions built on choice reaction tasks and resulted in consistent modulation of accuracy as a function of emotional valence. Our findings in the recognition and in the fast response conditions contradict the results from previous studies using verbal affective material and showing selective increase in identification accuracy during the AB period, but not during the longer SOAs for negative (Anderson & Phelps, 2001; Ogawa & Suzuki, 2004) and generally emotionally arousing (pleasant and unpleasant) (Anderson, 2005; Keil & Ihssen, 2004) compared to neutral, low arousing words. This attenuation of the AB effect for affective verbal stimuli has been attributed to their higher motivational significance, leading to facilitation and preferential processing when attentional resources are limited. The same can very well be applied to pictorial material. Electrophysiological and behavioral, as well as imaging studies with affective pictures, have demonstrated arousal dependent facilitation at early processing stages (Delplanque et al., 2004a; Keil et al., 2002; Schupp, Cuthbert et al., 2004) and this is the reason why we originally expected to see similar modulations of the AB with pictures as those found with words. Nevertheless, the observed stable affective modulations in the experiments with pictures reported here depended on the valence, rather than on the arousal of the presented stimuli and were similar across the three lags investigated.

At this stage, we can only speculate as to the reasons for these pronounced differences between the attentional blink results obtained using affective words and affective pictures. Further studies and direct comparisons would be necessary to determine the cause of these dissimilarities and their implications for the processing of affective stimuli of different kinds. Two major factors, however, seem to play an important role: the response modalities and the processing stage they capture, as well as the processing route. While in experiments using affective words, delayed free recall and report of both target words or their beginning letters

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[1] In the four studies reported here, participants| attention was directed to the picture content, by specifically requiring the identification of people. In retrospect, it seems possible to detach the task from the content by using grayscale images and dye distracters and targets in different colors and thus achieve an even closer approximation of the picture and the word design, although a free recall would still not be possible. This is a possible variation for future research, which might help to clarify, if the discrepancies between pictures and words are not due to design variations rather than to substantial modality differences.

at the end of the trial in the absence of any time constraints are required, we asked our participants to respond with a speeded button press immediately after perceiving the second target, keeping in mind the first target and reporting it at the end of the trial (Experiments 1 and 2), or required free report of the T1 and a recognition of the T2 (Experiments 3 and 4). Both variations might have posed lower processing requirements than the complete free recall, which is, however, as mentioned above, hard to implement with affective pictures. One hint in this direction can be seen in the selective AB-modulation in Experiment 4, although its direction did not follow the predictions of the AB studies with affective words. Both response variations also seem to illustrate different processing stages, as suggested by the systematic and response dependent variations across the four experiments (Figure 7). Another important factor should be sought in the different processing routes proposed for verbal vs. pictorial material (Koivisto & Revonsuo, 2003; M. C. Smith, Meiran, & Besner, 2000). While affective words require an in depth processing with semantic and lexical analyses (Brown, Stolz, & Besner, 2006; M. C. Smith & Besner, 2001; M. C. Smith et al., 2000), the processing of pictures might well be taking a more direct, or at least a different processing route (Bovet & Vauclair, 2000; Gorno-Tempini, Cipolotti, & Price, 2000).

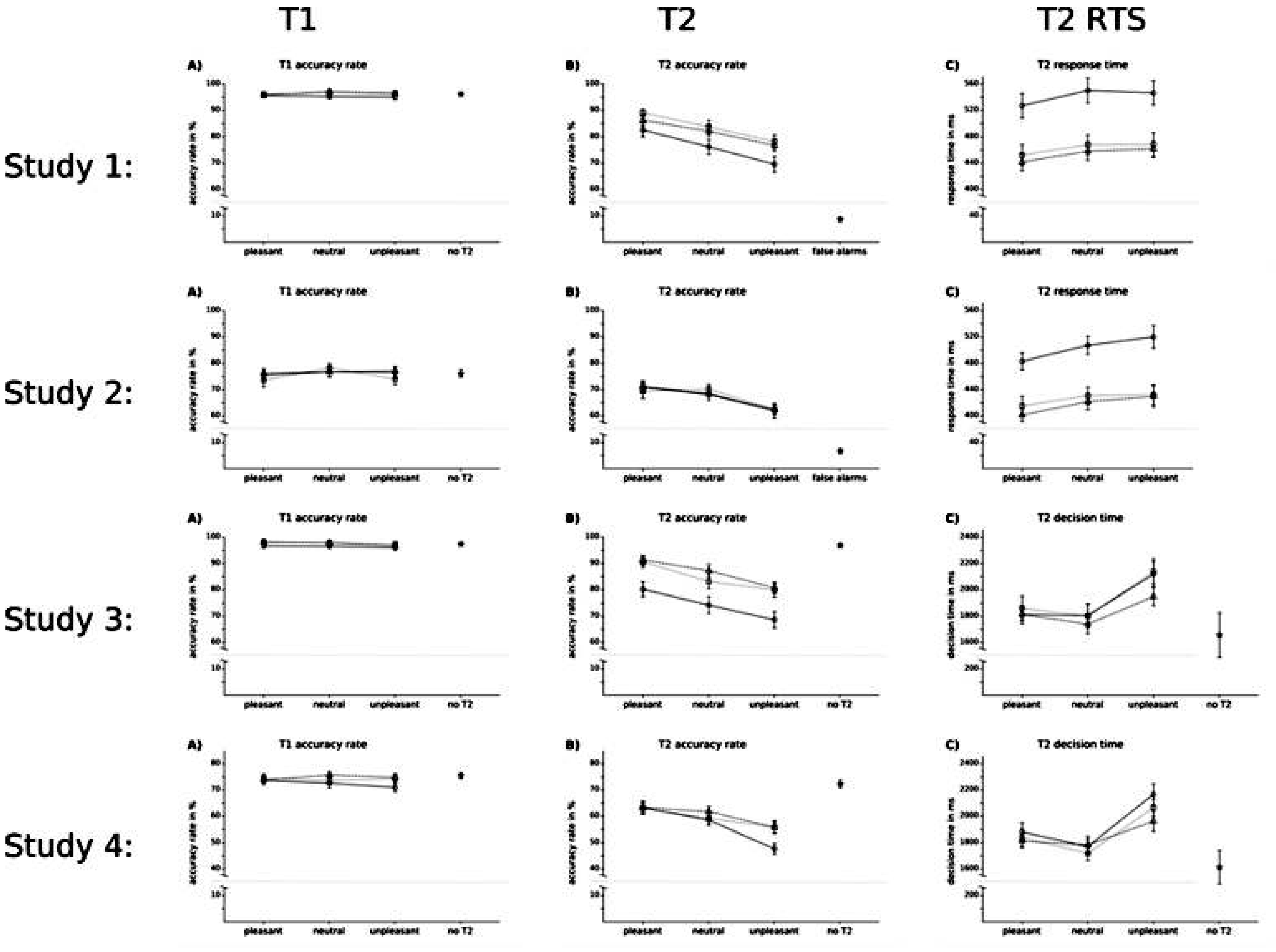

Figure 7: A summary of the results of the four AB-studies.

In addition, pictures are categorized faster than words, possibly due to their access to multiple semantic processing routes (Viswanathan & Childers, 2003). While the ability to read abstract symbols has developed late in evolution, emerges relatively late in individual development and is culture dependent, the appropriate response to complex visual scenes is an earlier and more general capacity both in phylogenies and in individual development. Thus, it might well be the case that a direct comparison between the modalities as originally intended in this work, is not achievable. Conclusions drawn in one modality might not necessarily be transferable in another. In a similar vein, the results obtained with regard to response time and those obtained considering accuracy rate seem to mirror different processing levels and show selective sensitivity to different design variations.

With regard to the T1-accuracy rates, no effect of T1-T2-SOA was found in the fast response condition (Experiments 1 and 2). In the recognition condition (Experiments 3 and 4), however, a small, but significant and reliable modulation was found, in that a short T1-T2-lag elicited lower accuracy rates than the two longer ones. Although precisely identical effects of lag on the T1 accuracy have to our knowledge not been reported yet with symbols, words or pictures, recent electrophysiological (K. Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006) and behavioral (Christmann & Leuthold, 2004) studies demonstrate the existence of a trade-off effect in that the probability of an accurate behavioral response to the second target depends on the amount of attention resources (measured, for example, by means of the electrophysiological activity elicited by the T1) allocated to the first target. As only trials with correct T1- response were considered for analyses, we cannot directly test this hypothesis. The fact that the recognition experiments, coercing participants to keep both targets in mind until the end of the trial and report first the T1, than the T2, elicits such an effect, while the fast response condition, where the response to the second target follows and is completed immediate after its presentation, does not, supports such an assumption. Future research can help clarify whether these behavioral effects on the report of the first target are limited to the processing of visual images, and if, as hypothesized for example by Shapiro and colleagues (2006), the attentional blink phenomenon constitutes an individual processing strategy, rather than an universal processing limitation.

2.6.5. Conclusions

Taking into consideration the results of the four AB-studies with complex visual images and systematic variation of the affective content of the T2s presented here, we can conclude that an AB-effect with pictures exists. However, that expected specific affective modulation of the period of reduces awareness was not observed. Rather, reliable, but SOA independent effects of valence were found and the results pattern varied depending on the required response kind and task characteristics. The two dependent variables, accuracy rate of the T2 responses and reaction, respectively decision, time, are output measures, conflating a series of perception, categorization, motor preparation and response execution processes. It is possible that, at the captured response stages, the valence of visually presented stimuli determined the reaction processes, although at earlier stages, e.g. early perceptional levels, or on different processing paths, e.g. when verbal material is presented, the arousal of the stimulus might selectively increase perceptional gain and facilitate processing.

The electrophysiological conditioning study presented in the next sections of this dissertation, turns to the question of affective meaning acquisition and the perceptional facilitations it might cause. It is an attempt to capture the very early stages of emotional perception with a conditioning design and by means of electrophysiological recording and analyses.

3. Electrophysiological evidence for sensory plasticity in early perception elicited by affective meaning acquisition

3.1. Conditioned stimuli and affective meaning acquisition: an introduction

Conditioned stimuli, often used in experimental settings to study basic learning processes and the acquisition of affective or motivational connotation, have also been reported to elicit faster behavioral responses and enhanced electrophysiological activity in humans (Hermann, Ziegler, Birbaumer, & Flor, 2000; D. A. Pizzagalli, Greischar, & Davidson, 2003). In the domain of auditory classical conditioning, research has repeatedly shown learning induced plasticity in the receptive fields of the primary auditory areas in animals (Diamond & Weinberger, 1984; Recanzone, Schreiner, & Merzenich, 1993; Scheich, Heil, & Langner, 1993; Weinberger, 1998, 2004) and humans (Morris, Friston, & Dolan, 1998). As a possible underlying mechanism for such fast experience dependent cortical reorganization, an increase in dopamine (Bao, Chan, & Merzenich, 2001) or acetylcholine release (Weinberger, Javid, & Lepan, 1995) have been proposed, leading to long-term potentiation and strengthening neural connectivity. The limbic system, specifically the amygdala, has been thought to mediate these processes (J. E. LeDoux, Iwata, Cicchetti, & Reis, 1988). Support for this view comes from neuroanatomical and neuroimaging studies showing strong connections between the amygdaloid regions and primary auditory cortices (J. E. LeDoux, Sakaguchi, Iwata, & Reis, 1985).

Training-induced changes of the visual receptive fields, which are similar to the learning induced cortical reorganization in primary auditory areas, have been reported (Das & Gilbert, 1995; Kapadia, Gilbert, & Westheimer, 1994). More recently, the interaction between early cortical reorganization and attention has been studied in detail (C. Gilbert, Ito, Kapadia, & Westheimer, 2000). Lee and colleagues have demonstrated that increasing behavioral relevance of complex visual stimuli led to preferential processing of these stimuli in V1 and V2 neurons of macaque monkeys (Lee, Yang, Romero, & Mumford, 2002). Studies on early discrimination of aversive visual stimuli in humans also aim at clarifying the relationship between motivational significance, attention, and early cortical plasticity. A recent line of evidence suggests that this differentiation involves the occipito- temporal cortices (D. A. Pizzagalli et al., 2003). Analyses of the topographic distribution of electrophysiological brain responses, specifically of the P3 component, point in the same direction (Baas, Kenemans, Bocker, & Verbaten, 2002; Schupp, Junghofer, Weike, & Hamm, 2004). Affective modulation of earlier ERP responses, for example the N1 and the P1 visual components, have also been reported (Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004b; Keil et al., 2002; Schupp, Junghofer, Weike, & Hamm, 2003), giving rise to the hypothesis that affective discrimination might be mediated by sensory gain mechanisms as proposed for selective attention (Hillyard, Vogel, & Luck, 1998; Martinez et al., 2001). In line with that notion, there is growing evidence for increased activation of primary visual areas when emotional stimuli are viewed (Bradley et al., 2003b; Lang, Bradley, & Cuthbert, 1998b; Pourtois, Grandjean, Sander, & Vuilleumier, 2004b; Sabatinelli et al., 2004). Taken together with anatomical studies in primates, finding projections from the amygdala and other limbic regions directly to primary visual areas (Amaral, Behniea, & Kelly, 2003), these observations raise the question of how visual cortices are involved in affective differentiation. As outlined above, visual cortical activity might be mediated by amygdaloid complex, leading to an increase of attention/awareness for affectively arousing stimuli, as has been suggested, for example by Anderson and Phelps (2001). Consequently, acquisition of motivational significance through learning, may involve increasing amplification of threat-relevant features in primary visual cortices across time. Such tuning of early vision may rely on short-term plastic changes, which are expected to increase during exposition to reinforcement contingencies.

3.1.1. The C1 component of the visual event-related potential

One way to investigate this possibility is to turn to the earliest recordable event-related response of the visual cortex and examine its sensitivity for affective content across trials. Extensive research in the domain of visual event-related potentials (VEP) has demonstrated the existence of an early negative deflection peaking between 60-90 ms labeled C1-component and reflecting the initial response of the primary visual cortex to a stimulus (Di Russo, Martinez, & Hillyard, 2003). Taking into account the topography of the C1, specifically its retinotopic properties, demonstrated for example by Hillyard and colleagues (1998), together with evidence from imaging studies and source analysis approaches, researchers have argued that its neural generators are probably located in deep structures of the primary visual cortex, specifically the calcarine regions (Di Russo, Martinez, Sereno, Pitzalis, & Hillyard, 2002; Pourtois et al., 2004b). It has also been repeatedly demonstrated that the C1, as opposed to, for example, the P1 and N1 components, is not modulated by spatial or feature-based attention tasks when simple neutral visual stimuli, such as gratings or checkerboards, are used (Di Russo et al., 2003; Fu, Fan, Chen, & Zhuo, 2001; Gomez Gonzalez, Clark, Fan, Luck, & Hillyard, 1994; Martinez et al., 1999). In a recent study, Pourtois and colleagues (2004b) made use of a classical spatial attention paradigm adapted for the study of affective modulation. The authors investigated the effects of emotional cues on selective spatial attention in healthy participants, employing high-density EEG and source localization techniques. They reported C1 modulation when the initial VEPs to fearful vs. happy faces were analyzed, with fearful faces eliciting greater C1 amplitude than happy ones. The authors concluded that the emotional relevance of the stimuli had led to an increased activation within the primary visual cortex, possibly due to an interaction with sub-cortical structures responsible for the detection of threat-related stimuli in the environment.

3.1.2. General aims, experimental characteristics and hypotheses of the present study

We sought to replicate and extend these findings by investigating the affective modulations of the C1 visual component across time. Further, we aimed to provide additional evidence for the involvement of early visual processing in the evaluation of affective stimuli and to investigate the acquisition of affective meaning. To this end, we attempted to induce learning within the visual system, employing pictures from the International Affective Pictures System (IAPS) as unconditioned stimuli (UCS) in a classical conditioning paradigm. Building on previous reports discussing the VEP with regard to the C1 component (Fu et al., 2001; Kenemans, Baas, Mangun, Lijffijt, & Verbaten, 2000), we chose small, high contrast, eccentrically presented gratings to serve as conditioned stimuli eliciting the ERP component of interest. The electrophysiological brain potentials elicited by these originally neutral gratings were recorded during four experimental blocks using a high-density electrode montage. In the baseline condition, no affective stimuli were presented. The gratings were shown along with neutral checkerboards instead. During the two consecutive conditioning blocks one grating was paired with highly arousing unpleasant pictures, the other one with neutral ones. The extinction condition was identical to the baseline block, with affective pictures being again replaced by checkerboards (Figure 8). This experimental protocol allowed for an evaluation of the early differentiation between two originally neutral stimuli, both gaining an affective meaning through controlled learning and losing it again in an extinction procedure. We expected that with time successful conditioning would lead to differentiation between the CS+ and the CS-, as the CS+ will become associated with an unpleasant event, while the CS- will be regarded as signaling the absence of threat. We anticipated differentiation between the CS+ and the CS- at the C1 visual component in the conditioning blocks, reflecting higher sensitivity of visual cortex to CS+ features. Should optimization of visual response to specific features continue to increase on a learning continuum, the expected differences within (CS+ vs. CS-) and between (baseline and extinction versus conditioning) experimental blocks will increase across time.

As an external measure of conditioning, we recorded participants' startle responses, elicited by a noise probe in selected trials, while the gratings were presented. Both, the CS- and the CS+ can be assumed to be affectively more arousing during conditioning than during baseline and extinction. Thus, during conditioning an increase in startle magnitude for the CS+ and a decrease for the CS- compared to the startle response elicited in the inter-trial intervals (ITIs), as well as to the ones elicited during baseline and extinction, were expected.

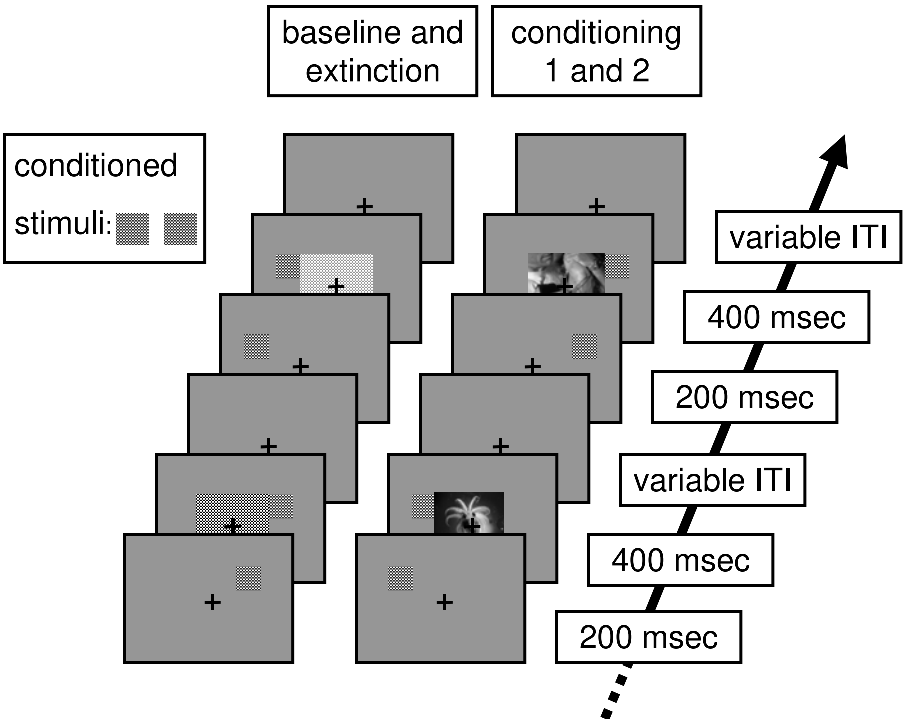

Figure 8: Schematic outline of the experimental design. Small, high contrast, eccentrically presented gratings served as conditioned stimuli (CS). In the baseline block the gratings were shown along with neutral checkerboards. During the two consecutive conditioning blocks one grating was paired with highly arousing unpleasant pictures (UCS), the other one with neutral ones. The extinction condition was identical to the baseline block, with affective pictures being replaced by checkerboards. Each trial consisted of 200 ms grating presentation, 400 ms UCS and CS presentation and a variable intertribal interval (ITI).

3.2. Methods

Participants

23 volunteers consented to participate in this experiment and either received course credit or a financial incentive of 20 €. One subject withdrew from the study prior to the completion of the protocol and these data were not included in the analysis. An additional four data sets were excluded from further processing due to equipment errors. The final data set included 18 participants (9 male, 14 right-handed) with normal or corrected-to-normal vision, age range 19-33 years, of a mean age of 25.6.

Stimuli

120 pictures were selected from the International Affective Picture System (IAPS) based on their valence and arousal ratings (Lang et al., 1999). The 60 unpleasant/arousing pictures showed mutilated bodies, attack scenes and disgusting objects (mean valence: 2.2, SD = 0.6; mean arousal: 6.1, SD = 0.8), the 60 neutral photographs depicted landscapes, people, objects and abstract patterns (mean valence: 5.9, SD = 0.7; mean arousal: 3.8, SD = 0.9). In addition, checkerboards of four different colors (black-bright red, black-dark red, black-bright green and black-dark green) were generated to match the affective pictures in size. The affective pictures and the checkerboard patterns were presented centrally on a 19 inch computer monitor with a refresh rate of 70 Hz and subtended a visual angle of 7.2° horizontally.

Two small black and white squares (visual angle horizontally: 2.2°) differing only in grating orientation (45° or 135°) were used as CS+ and CS-. They had a spatial frequency of 2.3 cpd with 100% contrast. The gratings were flashed in the upper left or right visual field (eccentricity: 3.58°). White noise bursts (50 ms; 90dB) were used as acoustic startle probes and were delivered binaurally through headphones.

Procedure

The experimental design consisted of four recording blocks: a baseline block, two consecutive conditioning blocks and an extinction block. During the conditioning blocks the grating pattern randomly designated as CS+ was presented together with the unpleasant/arousing photographs, used here as unconditioned stimuli (UCS). The other grating pattern (CS-) was paired with the neutral, low arousing pictures, the presentation order was randomised. During the baseline and the extinction blocks, the affective pictures were replaced by the checkerboard patterns described above. They were presented without any systematic relationship between the grating pattern and checkerboard color. The timing and presentation parameters of the affective stimuli and the checkerboards were otherwise identical (see Figure 8).

A total of 480 standard trials (grating followed by a checkerboard during baseline and extinction, and by an IAPS-stimulus during conditioning) were presented in each of the four recording blocks, resulting in 120 trials per condition: grating orientation (45° or 135°) and visual hemi field (left or right) combination. In order to maintain vigilance during baseline and extinction, an additional 60 target trials were included, during which participants were required to respond with a speeded button press to a checkerboard of a certain color. Subjects sat at a distance of 80 cm from the computer screen. They were asked to maintain fixation of a white cross in the middle of the screen present at all times throughout recording. A chin rest was used to ensure consistency and to minimize head movements.

In both the standard and the target trials, the grating patterns (CS+ and CS-) were shown for 600 ms. 200 ms after grating onset, an affective picture or a checkerboard appeared in the middle of the screen, the grating square remained attached to the upper left or right corner of the centrally presented stimulus for the rest of the trial (400 ms). The inter-trial interval (ITI) varied randomly between 400 ms and 1400 ms. The 120 affective pictures (60 unpleasant, 60 neutral) were repeated randomly eight times across the two conditioning blocks, allowing for a total of 240 trials per affective category and conditioning block.

In order to record subjects' startle response in addition to their EEG, 54 startle trials per block were included. 18 startle probes were presented during randomly selected ITIs, 36 were delivered along with the conditioned stimuli (18 with the CS+ and 18 with the CS-) at varying times after the grating onset (700, 800 or 900 ms). During the startle trials the gratings were shown for a total of 1500 ms and were followed by a prolonged variable ITI (650-1850 ms). To prevent learning of an association between the acoustic startle and the longer grating presentations, 60 trials with prolonged grating presentation (1500 ms) but without a startle probe were intermixed in each recording block.

The experiment was conducted in two sessions on two consecutive days at the same time of the day with each participant. On day one, the protocol included informed consent, handedness and personal information questionnaires, as well as collection of EEG and startle responses during the baseline block. Two parallel versions of a mood questionnaire MDBF (Steyer, Schwenkmezger, Notz, & Eid, 1997) were administered at the beginning and at the end of this first testing session. On day two, the protocol included recording of the two conditioning blocks and the extinction block. There were breaks between the different blocks as well as in the middle of the extinction block, approximately every 15 to 20 min. Parallel versions of the MDBF were administered at the beginning, middle, and end of the second session. In addition, during the pause between the second conditioning block and the extinction block, subjects were asked to rate four grating patterns on a scale from 1 (most unpleasant) to 4 (most pleasant). Two of the grating patterns were identical with the ones used as CS+ and CS- (45° and 135° grating orientation), the other two were new in the context of this experiment and had horizontal (180°) and vertical (90°) orientations. At the end of the extinction block participants were asked if they were aware of seeing two different grating patterns, and if they had noticed any connection between the kind of picture they saw and the grating presented with it. Finally, all participants viewed the 120 affective pictures used in the experiment in pseudo-randomized order and rated them on the dimensions affective valence and arousal, using a paper and pencil version of the self-assessment manikin (Bradley & Lang, 1994). No time constraints were imposed during the rating and the subjects' viewing time for each picture was recorded.

Electrophysiological data collection, data reduction and analyses

Event-related potentials

The EEG was recorded using an Electrical Geodesics, Inc. 128-channel system, the vertex (Cz) was the recording reference (for the electrode array see Figure 9). The sampling rate was set at 250 Hz and impedances were kept below 50 kΩ as recommended by the manufacturer. Data were subjected to a 0.1 Hz high-pass and a 100 Hz low-pass online filters. Artifact-free epochs (196 ms pre- and 600 ms post-stimulus interval) were obtained using the SCADS-procedure suggested by Junghöfer and colleagues (2000). In a subsequent step, data were re-referenced to average reference and additional filtering was applied (highpass: 1-3Hz). The mean number of artifact-free trials per condition was 76 for block 1, 80 for block 2, 80 for block 3 and 81 for block 4.

Given the deep location of C1 sources, as well as the high amount of anatomical variability of primary visual vortex (Van Essen, Drury, Joshi, & Miller, 1998), we decided to rely on voltage data, rather than conducting source-space analyses. Indeed, inspection of the present data on the single-subject level, suggests low reliability of topography, but highly consistent timing of the electrocortical response across individuals. Accordingly, artifact-free epochs of 196 ms pre- and 600 ms post-stimulus were averaged separately for each subject, condition and recording block. The mean voltage of a 150 ms segment preceding the onset of the grating stimulus was used for baseline subtraction. Visual inspection of the grand means and the individual averages for each condition revealed six components of interest, and the corresponding time windows were identified. The first three time windows were used to evaluate the ERP response following the grating stimulus (CS- or CS+, presented in the left or right hemifield) and included the following components: C1 (65-90 ms), P1 (120-150 ms) and N1 (160-196 ms). Three additional time windows were used to analyze the ERP response following the presentation of checkerboards (baseline and extinction blocks) or affective pictures (conditioning blocks) at 200 ms after the onset of the grating stimulus: bP1 (310-340 ms), bN1 (360-420) and P3 (520-600 ms).

For the purpose of statistical analyses, regional means for the ERP-amplitude in the six selected windows were created, using four groups of six electrodes each: left anterior, left posterior, right anterior and right posterior. This configuration allowed the evaluation of hemisphere effects due to hemifield stimulation, as well as the analyses of caudal effects. The mean values of the four electrode groups for each component were subjected to an omnibus repeated measures ANOVA with the factors BLOCK (baseline, conditioning 1, conditioning 2 and extinction), CONDITION (CS+, CS-), HEMIFIELD (right, left), HEMISPHERE (left, right), CAUDALITY (anterior, posterior) and SITE (6 electrodes each). Follow-up ANOVAs for each block were conducted where appropriate. To correct for violation of the sphericity assumption, Greenhouse-Geisser correction for sphericity was applied to all repeated measures ANOVAs. In the following, we report uncorrected degrees of freedom together with corrected p-values, where appropriate.

Startle Response

Startle responses were extracted from the vertical EOG-recordings of the right eye by subtracting the data recorded at the upper-eye electrode (# 8) from the lower-eye electrode (# 126), see Figure 10. The 54 startle trials (18 ITIs, 18 CS+ and 18 CS-) obtained per block were edited individually for each participant, artifact-contaminated trials were omitted. The complete data sets of two participants were excluded due to the absence of scorable startle responses. The startle magnitude was obtained by subtracting the peak amplitude within a 20-120 ms window from the baseline. The absolute values were then standardized within subject in order to decrease variability caused by differences in absolute size of the startle response across participants and were expressed in z-scores. For each recording block, a repeated measures ANOVA was conducted to test for condition differences in the magnitude of the startle response, again the Greenhouse-Geisser method was applied, where appropriate.

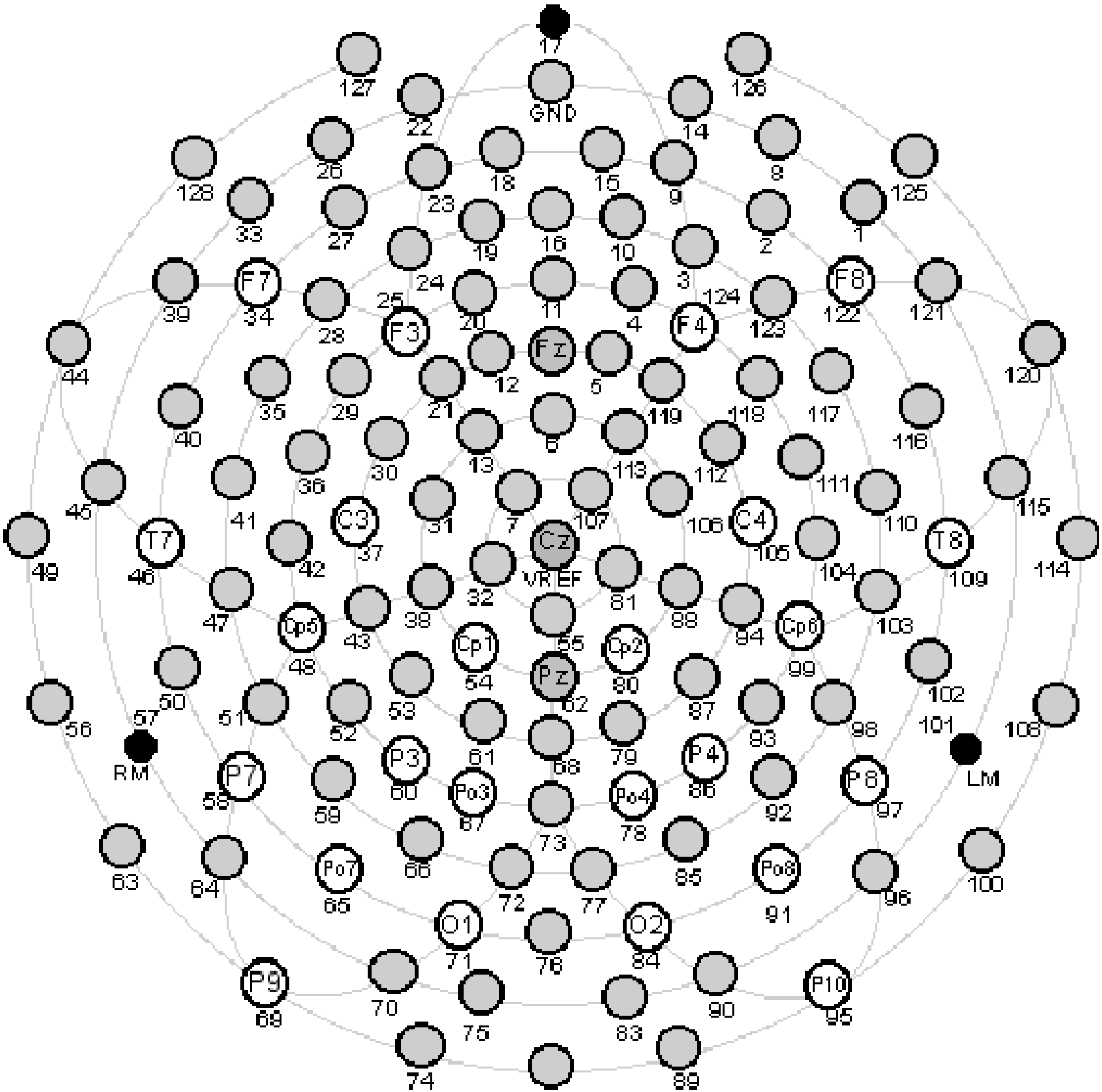

Figure 9: Layout of the electrode array. The electrodes labeled here according to the international 10-20-system were grouped for the purpose of statistical analyses. Electrodes posterior to Pz built the posterior groups, the midline divided left and right electrode groups.

3.3. Results

3.3.1. Behavioral data

Mood questionnaire (MDBF)

The MDBF-questionnaire (Steyer *et al.*, 1997) was used to assess the participants' mood changes during the different phases of this experiment. It included scales for the following dimensions: feeling well-not well, alert-tired and calm-aroused. The participants were asked to complete one of two parallel versions of this questionnaire at five time points during the experiment. A repeated measures ANOVA with TIME POINT and DIMENSION as within-subject factors and GENDER as a between-subject factor revealed main effects of TIME POINT (F = 4.5 , p < .01) and SCALE (F = 9.4, p < .01), as well as a significant TIME POINT X SCALE interaction (F = 2.5, p < .05.). While participants demonstrated similar levels of well-being, alertness and calmness at the beginning of the recording sessions on day 1 and day 2, the reported values for all three scales decreased more when measured after the conditioning blocks compared to the baseline block. At the end of the experiment, after recording the extinction block, well-being and calmness increased again, while the reported alertness continued to decrease.

SAM-ratings and viewing time

As expected, participants rated the unpleasant pictures (valence: M = 2.5, SD = 0.8; arousal M = 6.6, SD = 0.9) lower in valence (t(59) = -26.3, p < .001) and higher in arousal (t(59) = 21.3 , p < .001) than the neutral pictures (valence: M = 6.4, SD = 1.0; arousal: M = 3.0, SD = 0.9). The analysis of the viewing times during the rating procedure revealed no significant differences between the neutral and the unpleasant pictures.

Awareness and grating ratings

When asked at the end of the EEG recordings, 16 out of 18 participants (88.9 %) were not aware of any systematic relationship between the gratings and the pictures they saw during the conditioning blocks, nine participants reported not to have realized that two different kinds of gratings (45° and 135°) were shown. Nevertheless, 15 participants (83.3 %) rated the stimulus used as CS+ as less pleasant than the one used as CS- (Wilcoxon-test: p < .05). No differences were found in any of the other comparisons, including the two novel gratings (90°- and 180°-gratings) used as distracters. An additional 18 age- and gender-matched controls were recruited to assess a priori differences in the affective valence of the four gratings. The analyses revealed no differences between the two grating patterns used as CS+ and CS- in the present study, however, the two distracter-gratings (not used in the reported experiment, 90° and 180) were rated as less pleasant (p<.05) than the 135°-grating.

3.3.2. Startle responses

No condition differences in magnitude of the startle responses were found for the baseline and the extinction blocks. A reliable modulation was found during the first conditioning block, where participants demonstrated a weaker startle response to the CS- than to the CS+ (F(2,16) = 3.5, p < .05). This differentiation did not reach significance during the second conditioning block, but pointed in the same direction, while amplitudes generally decreased across blocks (Figure 10).

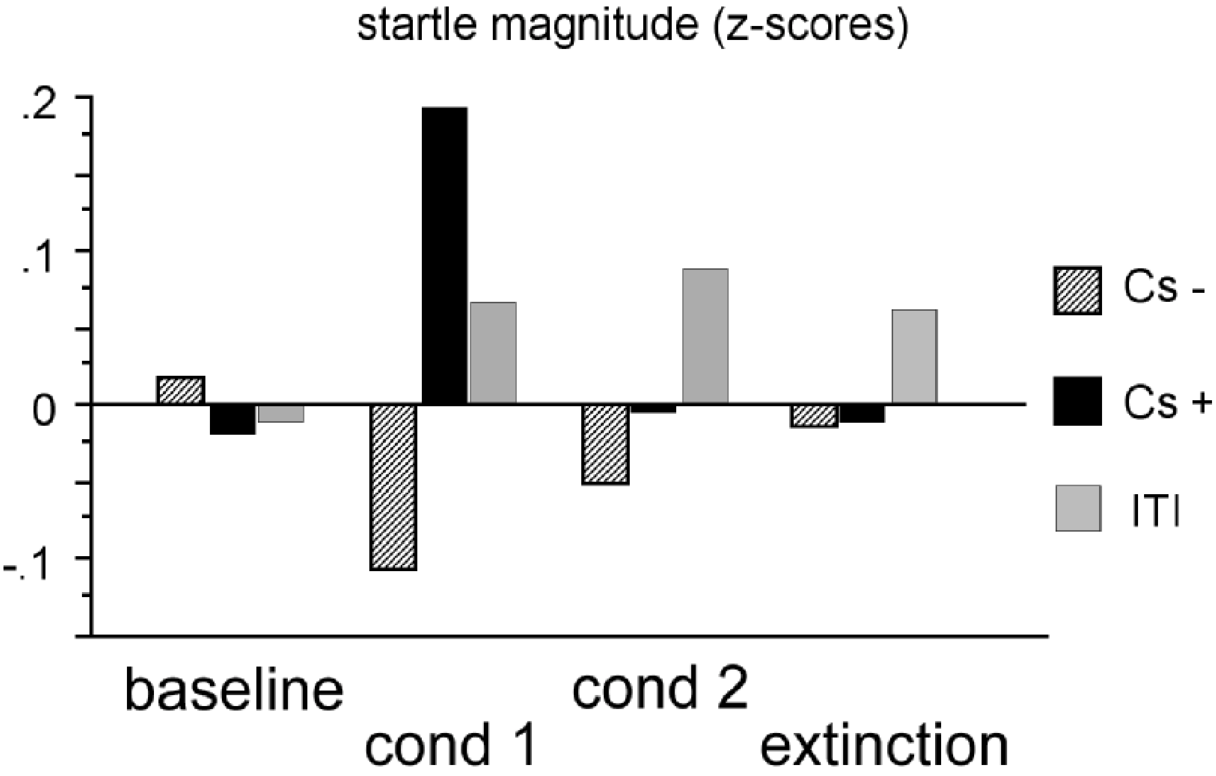

Figure 10: Changes in startle magnitude (expressed in z-scores) across recording blocks and conditions.

3.3.3. ERP response to the grating stimuli

Figure 11 shows the time course of topographical distribution across all blocks and CS conditions, for stimuli being present in the left (top) or right visual field (bottom). Using the average reference, the distribution of the C1 component started with a negativity contralateral to the stimulus location at around 60 ms after stimulus onset. Consistent with a deep calcarine generator, this negativity was widely distributed and shifted towards the ipsi-lateral hemisphere while increasing in amplitude and giving rise to contralateral P1 at around 80-90 ms and a contralateral N1 around 140 ms after stimulus-onset. Statistical analyses were conducted for mean voltages, with the C1 time segment encompassing both the initial contralateral negativity as well the ipsilateral part, to increase signal-to-noise of the mean voltage.

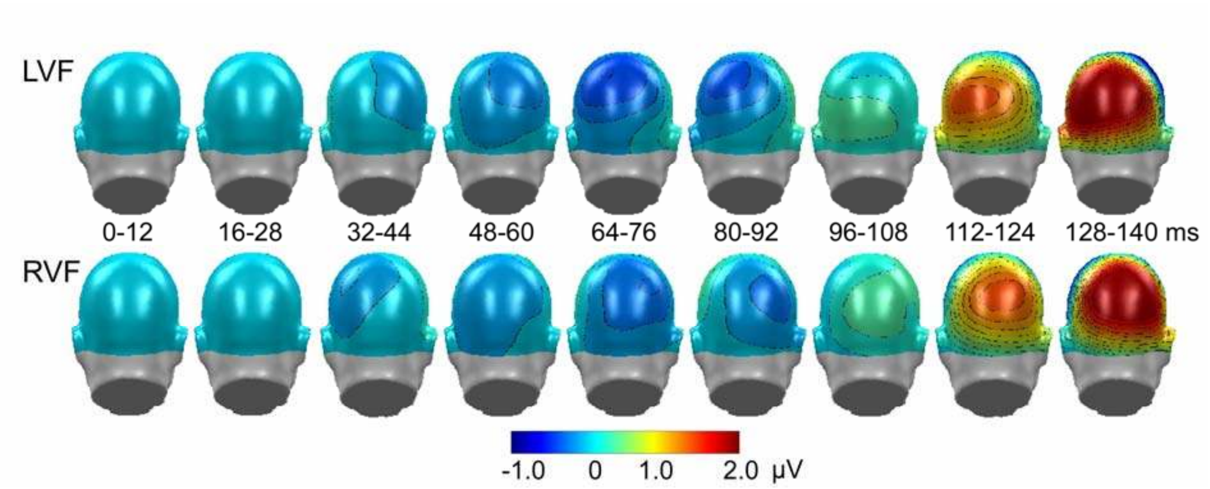

Figure 11: Grand mean (n=18) spline interpolated topography of the mean voltage amplitude across all blocks and CS conditions, for stimuli being present in the left (top) or right visual field (bottom). The distribution of the C1 component started with a negativity contralateral to the stimulus location at around 60 ms after stimulus onset. Consistent with a deep calcarine generator, this negativity was widely distributed and shifted towards the ipsi-lateral hemisphere while increasing in amplitude and giving rise to contralateral P1 at around 80-90 ms and a contralateral N1 around 140 ms after stimulus-onset.

C1: 65-90 ms

The omnibus ANOVA with BLOCK (baseline, conditioning 1, conditioning 2 and extinction), CONDITION (CS+, CS-), HEMIFIELD (right, left), HEMISPHERE (left, right), CAUDALITY (anterior, posterior) and SITE as within-subject factors revealed a main effect of BLOCK (F (3, 17) = 5.9, p < .01) with a significantly more negative C1-amplitude during the two conditioning blocks than during baseline and extinction as well as an effect of CAUDALITY (F (1, 17) = 8.4, p < .05) confirming the expected C1 distribution with negativity at posterior sites and positivity at anterior ones. Across all blocks there was an interaction of HEMIFIELD x HEMISPHERE (F (1, 17) = 6.6, p < .05), the grating stimuli elicited overall stronger negativity at ipsilateral, compared to contralateral sites. This negativity was greater for left than for right hemifield presentation. In addition, a three-way interaction of BLOCK x HEMIFIELD x HEMISPHERE was observed (F (3, 17) = 3.0, p < .05), showing that the difference between left and right hemifield presentation was greatest during the baseline block. Summarizing the results of the C1 omnibus ANOVA, a clear effect of experimental context emerged across the four recording blocks: the C1 for all conditions was more negative during the two conditioning blocks than during baseline and extinction. In addition, an interaction between presentation site and response site was observed, with a stronger response measured ipsilaterally to the presentation hemifield. All interactions including the factor CONDITION were followed up using separate ANOVAs for each block.

For the baseline block, a HEMIFIELD x HEMISPHERE interaction (F (1,17) = 18.1, p < .01) was observed, confirming the above-reported effect found in the omnibus ANOVA. Regarding the first conditioning block, a main effect of CAUDALITY (F (1,17) = 14.3, p < .01) was found, reflecting the topography of the C1 component with strong negativity at posterior and weak positivity at anterior sites. In addition, a CONDITION x HEMIFIELD x HEMISPHERE x CAUDALITY interaction (F (1,17) = 6.0, p < .05) was observed, showing that the CS+ elicited a more negative response at left and right posterior sites than the CS-, when presented in the right hemifield. When shown in the left hemifield, the CS- tended to elicit stronger negativity than the CS+, but only at the ipsilateral posterior sites. During the second conditioning block an effect of CAUDALITY (F(1,17) = 12.5, p < .01) similar to the one reported above was observed. In addition a CONDITION x HEMIFIELD interaction (F (1,17) = 8.0, p < .01) emerged, showing that the CS+ elicited a larger C1, when presented in the right hemifield, while, when presented in the left hemifield, the CS- elicited larger response at posterior sites. As opposed to the first conditioning block, here this effect held true for both hemispheres. For the extinction block, a CAUDALITY effect (F (1, 17) = 4.4, p = .05) was found. For illustration see Figure 13.

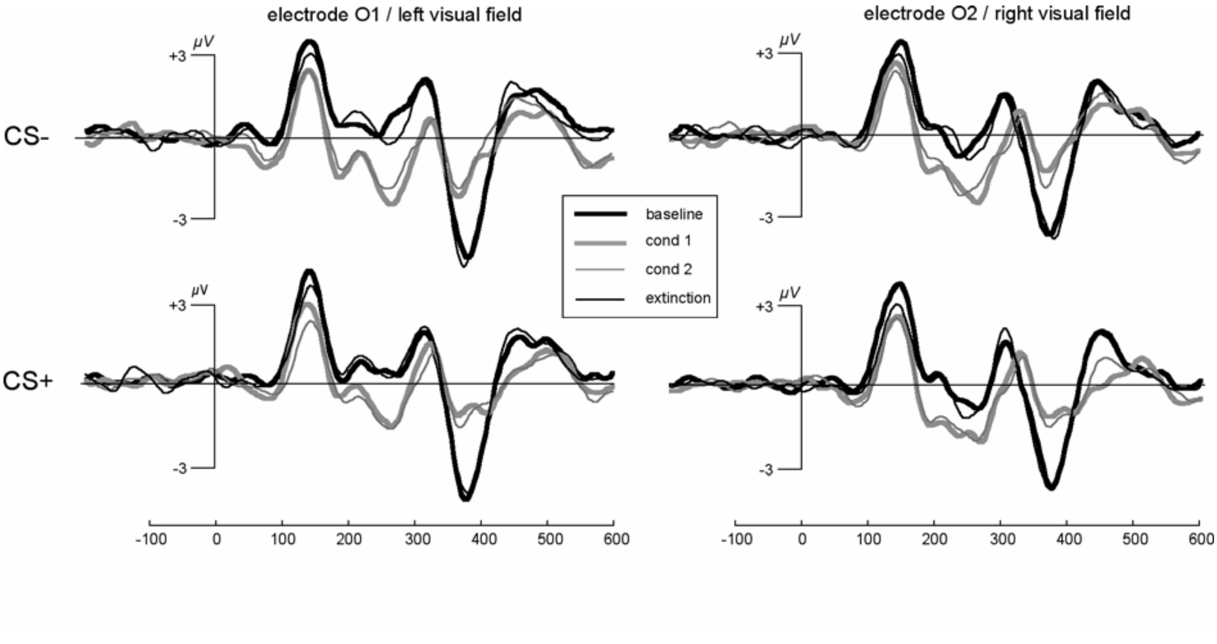

Figure 12: Grand mean (n=18) event related potentials at O1 (left hemifield presentation) and O2 (right hemifield presentation) for each condition across the recording blocks

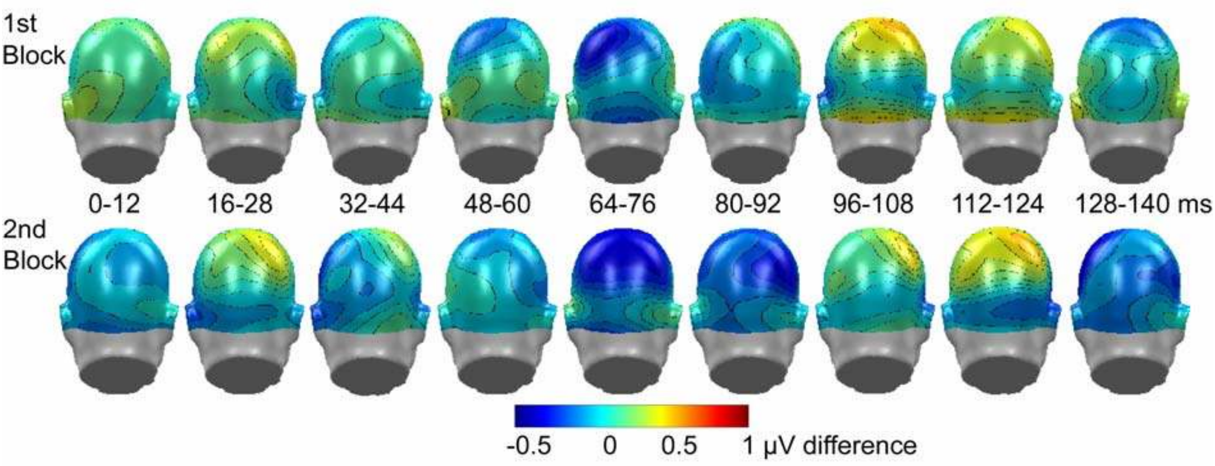

Figure 13: Difference topographies (n = 18) for CS+ minus CS- across presentation sites. Greater and more widespread negativity for the CS+ can be seen around 70 ms in the second conditioning block.

During baseline and extinction no condition effects for the C1 were found. Differences between the early electrophysiological response following the CS+ and the CS- emerged during the first conditioning block, where the discrimination pattern differed across the two hemispheres and depended on the presentation site of the conditioned stimuli. During the second conditioning block, the influence of presentation site remained significant, the effects of condition, however, spread across both hemispheres alike. These effects are summarized in Figure 13, showing the time course of difference topographies for CS+ minus CS- across presentation sites. While differences are small, greater and more widespread negativity for the CS+ can be seen around 70 ms in the second conditioning block.

P1: 120-150 ms

The omnibus ANOVA revealed main effects of BLOCK (F (3,51) = 5.6, p <. 01) and CAUDALITY (F (1,17) = 36.7, p <.01), as well as a BLOCK x CAUDALITY interaction (F (3, 51) = 4.6, p <. 01). As expected, the P1 distribution was characterized by posterior positivity and weaker anterior negativity. At posterior sites, the P1 amplitude was greater during the baseline and extinction blocks, as compared to the two conditioning blocks. There were no differences at anterior sites. A HEMIFIELD x HEMISPHERE interaction (F (1,17) = 21.9, p < .01) was also found, the eccentric grating presentation elicited a stronger P1-response in the ipsilateral hemisphere than in the contralateral one. No interactions with condition were observed, thus no follow-up ANOVAs were conducted.

N1: 160-200 ms

For the N1 component a main effect of BLOCK (F(3,51) = 4.6, p <. 01) and a BLOCK x CAUDALITY interaction (F(3,51) = 8.1, p < .01) were observed. At posterior sites, the N1 was more negative for the two conditioning blocks than for the baseline and the extinction block. There was also a HEMIFIELD x HEMISPHERE interaction (F(1,17) = 10.1, p < 01), the grating stimuli elicited a greater negative response in the contralateral hemisphere compared to the ipsilateral one.

3.3.4. ERPs in response to the unconditioned stimuli (UCS)

At 200 ms after onset of the grating stimuli (CS+ and CS-), a centrally presented checkerboard (in the baseline and the extinction blocks) or an affective picture (conditioning 1 & 2) appeared on the screen for 400 ms. The following three time windows were used to evaluate the ERP response to these stimuli.

bP1: 310 – 340 ms

For the P1 component following the checkerboards or affective picture presentation (called here bP1), a main effect of BLOCK (F (3,51) = 4.2, p <. 01) was found, showing that the amplitude of the bP1 was smaller following the affective pictures during the two conditioning blocks, than following the checkerboards in the baseline and in the extinction blocks. The main effect of CAUDALITY (F (1,17) = 7.7, p <.05) was due to the expected greater positivity at posterior sites than at anterior ones. A HEMIFIELD x HEMISPHERE interaction (F (1,17) = 13.3, p <. 01) was also observed: when the grating stimulus (CS) was presented in the right hemifield, the centrally presented UCS elicited a lateralized response with stronger left hemisphere positivity and vice versa: CS-presentation in the left hemifield led to a stronger right hemisphere positivity in response to the UCS. Interactions with the factor CONDITION were followed up with separate ANOVAs for each block. As the UCS differed for baseline and extinction versus the conditioning blocks, they were not directly comparable.

For the baseline block, a main effect of CAUDALITY (F (1, 17) = 5.6, p <. 05) illustrated the bP1 surface distribution with posterior positivity. The reported above HEMIFIELD x HEMISPHERE interaction (F (1,17) = 7.0, p <.05) was also present. For the first conditioning block, analyses of the bP1-amplitude revealed the expected CAUDALITY effect (F (1,17) = 7.5, p < .05) and stronger HEMIFILED x HEMISPHERE (F (1,17) = 20.1, p < .001) interaction than in the baseline block. In addition, CONDITION x HEMISPHERE

(F (1,17) = 4.3, p < .05) and CONDITION x CAUDALITY (F (1,17) = 5.2, p < .05) interactions were observed. The unpleasant pictures elicited a significantly larger bP1 response at posterior, right hemispheric sensors than did the neutral pictures. A three-way CONDITION x HEMIFIELD x CAUDALITY interaction (F (1,17) = 10.5, p < .01) showed that the condition differences at posterior sites were biggest, when the CS were presented in the left hemifield. During the second conditioning block, the same effects and interactions as in the first one were observed with an additional significant CONDITION x HEMIFIELD interaction (F (1,17) = 6.7, p < .05) showing again that the unpleasant pictures elicited a larger bP1 amplitude, when the CS+ preceding them was shown in the left visual hemifield. In the extinction block a main effect of CAUDALITY (F (1,17) = 7.6, p < .05) with greater positive amplitude at posterior leads was observed. Also, a HEMIFIELD x HEMISPHERE x CAUDALITY interaction (F (1,17) = 5.1, p < .05) showing that the P1 amplitude as response to the UCS at right posterior leads was greater, when the CS were presented in the left hemifield, than in the right one.

For the bP1 component following the centrally presented checkerboards during baseline and extinction, and affective pictures during the two conditioning blocks, we observed effects of presentation site of the preceding grating stimuli. These effects were stronger during the two conditioning blocks than during baseline and extinction. In addition, effects of affective content during the conditioning blocks were found: the unpleasant pictures elicited greater bP1 than the neutral ones. This effect was strongest at right hemispheric posterior sites when the CS+ preceding the unpleasant picture was presented in the left hemifield.

bN1: 360-420 ms

The omnibus ANOVA revealed main effects of BLOCK (F (3,51) = 28.9, p < .001) and CAUDALITY (F (1,17) = 33.0, p < .001), as well as a BLOCK x CAUDALITY interaction (F (3,51) = 18.6, p < .001). The bN1 amplitude in response to the UCS was significantly more negative during baseline and extinction than during the two conditioning blocks, it had the expected surface distribution with negativity at posterior and positivity at anterior sensors. The block differences applied to the posterior negativity, but not to the anterior positivity of the bN1 component. In addition, a HEMIFIELD x HEMISPHERE interaction (F (1,17) = 42.0, p < .001) showed that the bN1 component was bigger at left hemispheric sensors than at right hemispheric ones when the CS were presented in the left visual field . The interactions with CONDITION were followed up with separate ANOVAs for each block.

For the baseline block, the above- reported effect of CAUDALITY (F (1,17) = 37.7, p < .001) and the HEMIFIELD x HEMISPHERE (F(1,17) = 24.1, p < .001) interactions were confirmed. Beside the CAUDALITY (F (1,17) = 6.3, p < .05) and the HEMIFIELD x HEMISPHERE (F (1,17) = 4.2, p < .05) effects explained above, a CONDITION x HEMIFIELD x CAUDALITY (F (1,17) = 5.0, p < .05) interaction was found in the first conditioning block and showed that the bN1 to the unpleasant pictures (UCS) was more negative than to the neutral ones at posterior leads when the CS was presented in the right visual hemifield, whereas when the CS was presented in the left visual field no significant differences were found. During the second conditioning block a CAUDALITY effect (F (1, 17) = 9.7, p < .01) was observed. Similar effect of CAUDALITY (F (1,17) = 56.8, p < .001) and HEMIFIELD x HEMISPHERE (F (1,17) = 20.1, p < .001) interaction as in the baseline block were found during extinction.

Similar to the effects found for the bP1 response, for the bN1 component we observed effects of presentation site of the preceding grating stimuli in all four recording blocks. In the first conditioning blocks, we also found effects of affective content, with unpleasant pictures eliciting greater bN1 than neutral ones.

P3: 520 – 600 ms

The omnibus ANOVA revealed a main effect of BLOCK (F (3, 51) = 12.3, p < .001), as well as BLOCK x CAUDALITY (F (3,51) = 5.3, p < .01) and BLOCK x HEMISPHERE (F (3,51) = 6.0, p < .01) interactions. The P3 showed the expected distribution with posterior positivity. It was more positive in the baseline and in the extinction blocks when checkerboards were presented than during the two conditioning blocks, following presentation of affective pictures. The block differences were more pronounced over the left than over the right hemisphere. A HEMIFIELD x HEMISPHERE interaction (F (1,17) = 8.8, p < .01) was also found: the P3 to the UCS had greater positive amplitudes at left hemispheric sensors than at right ones, when the CS preceding the UCS was presented in the left visual hemifield.

A main effect of CONDITION, as well as all interactions with condition were followed up with separate ANOVAs for each block, as the UCS were checkerboards during baseline and extinction and affective pictures during conditioning. No significant main effects or interactions were found in the baseline block. In the first conditioning block a main effect of HEMISPHERE (F (1,17) = 8.3, p < .05) and a CONDITION x HEMISPHERE (F (1,17) =

6.6, $p < .05$) interaction were found. The P3 was more positive at left hemispheric sites, however, only over the right hemisphere significant differences between the unpleasant and the neutral pictures were found, with the unpleasant stimuli eliciting more positive P3 than the neutral ones. During the second conditioning block we observed the reported above main effect of CAUDALITY ($F(1,17) = 10.1$, $p < .01$) and HEMIFIELD x HEMISPHERE interaction ($F(1,17) = 5.6$, $p < .05$), as well as a main effect of CONDITION ($F(1,17) = 7.3$, $p < .05$) and a CONDITION x CAUDALITY ($F(1,17) = 6.1$, $p < .05$) interaction. At posterior sites the unpleasant pictures elicited a more positive response than the neutral ones, now over both hemispheres. No condition effects were found for the extinction block. A main effect of HEMISPHERE ($F(1,17) = 9.3$, $p < .01$) and a HEMIFIELD x HEMISPHERE interaction ($F(1,17) = 9.1$, $p < .01$) showed that the response to the checkerboards was generally more positive over left hemispheric sites, this effect was strongest when the grating preceding the centrally presented checkerboard appeared in the left visual hemifield.

For the P3 component effects of presentation site were observed, similar to those reported for the bP1 and the bN1 components. We also found a greater P3 for the unpleasant pictures than for the neutral ones, in the first conditioning block predominantly over the right hemisphere, in the second one over both hemispheres alike.

3.4. Discussion

With this conditioning study, we set out to examine the modulations of early visual ERPs as a result of affective learning, hoping that this will let us gain a better understanding of the processes and structures involved in rapid affective evaluation of visual stimuli. We focused on the earliest visual component (C1), which is thought to be generated in the primary visual cortex and is known to peek at around 65-90 ms (Martinez et al., 1999). The experimental manipulation was designed to elicit a measurable C1 and to allow for an evaluation of its changes, both between two originally neutral stimuli, gaining divergent affective meanings through classical conditioning and losing it again in an extinction procedure, as well as within the same stimulus across a learning continuum from a baseline measure through two consecutive conditioning blocks to an extinction block. As we aimed to study conditioning within the visual modality, we used affective pictures as UC stimuli.

3.4.1. Startle responses

The behavioral results indicated that the conditioning protocol had been effective, even though pictures can be regarded as relatively weak UC stimuli. After conditioning, participants were more likely to rate the originally neutral grating stimulus used as CS+ as less pleasant than the one used as CS-. As expected, they also rated the unpleasant pictures as more arousing and more unpleasant, than the neutral ones. The majority of participants was not aware of the contingencies associated with conditioning. In addition to the behavioral ratings, we recorded participants' startle responses and ERP responses in each of the experimental blocks (Figure 10). The startle responses were used to directly assess the success of conditioning by means of the fear potentiated startle procedure (Hamm & Vaitl, 1996; Koch, 1999). During baseline and extinction, no differentiation between the startle responses to the CS+ and CS – presentation was observed. In the first conditioning block, the startle elicited during CS- presentation was significantly weaker than the one elicited during CS+ presentation (Figure 10). In the second conditioning block, the pattern of discrimination remained similar, although the magnitude of the startle response across all three conditions (CS+. CS- and ITI) decreased and the difference between CS+ and CS- conditions failed to reach significance. This may be due to several factors, including habituation effects, small group size, or the fact that we indirectly monitored the startle responses using vertical EOG, rather than using electrodes directly attached over the m. orbicularis oculi. Nevertheless, we regard the startle results as evidence that conditioning within the visual modality occurred, even in the absence of awareness concerning the experimental manipulation.

3.4.2. C1, N1 and P1 components: results and implications

With regard to the C1 ERP component, which was of main interest in our study, we observed the typical C1 response having widespread distribution over the occipito-parietal part of the scalp. As shown for example by Di Russo and colleagues (2002), the C1 component originates in the striate cortex (area 17 in the primary visual cortex). While the primary cortical response was stronger and earlier contralateral to the locus of stimulus presentation, negativity moved to ipsilateral sites, giving rise to contralateral positivity of the P1 component. Overall, the morphology and the topography of the C1 visual ERP component elicited in this study (Figures 12 and 13) were very similar to those reported in previous studies on early visual selective attention and perceptual processing (Di Russo et al., 2003; Gomez Gonzalez et al., 1994; Hillyard & Anllo-Vento, 1998), where it has been convincingly demonstrated that the C1 is not affected by spatial and feature based attention, when simple neutral stimuli are used. We did, however, find reliable modulations based on the acquired affective content of the conditioned stimuli. Importantly, the C1 was more negative during both conditioning blocks, indicating that providing contingencies enhanced early visual processing. While there were no differences between the C1 components elicited by the two grating patterns (i.e. CS+ and CS-) during the baseline and the extinction blocks, differentiation of the CS+ and the CS – was found in the two conditioning blocks (see Figure 13). The direction of this difference varied with the presentation site of the stimuli. During conditioning the CS+ elicited a more negative C1 than the CS- when presented in the right visual field. When presented in the left visual field, the CS- elicited greater negativity. The differentiation between CS+ and CS- increased from the first to the second conditioning block, the effects also spread over both hemispheres, possibly an indication of continuing learning enabling growing efficiency of processing.

Our results provide evidence that the learned affective meaning of originally neutral stimuli can lead to a modulation of the earliest measurable electrophysiological response as indicated by the C1. These results are in agreement with three recent studies that report similar modulations of early visual responses using faces as stimuli. Eger and colleagues (2003) provided evidence that an early VEP component with a latency of 80-90 ms is sensitive to the emotional content of facial expression. Pourtois and his collaborators (2004a) showed modulation of the C1 component, with fearful faces eliciting a more negative response than happy faces. Halgren and colleagues (2000) reported on an early MEG response, possibly originating in the calcarine fissure and distinguishing between happy and sad faces. As Pourtois and colleagues (2004a) point out, the lack of a greater number of previous reports on C1 modulations depending on valence or arousal might be partially due to the fact that emotional stimuli have often been presented centrally, or along the horizontal meridian, which cancels out this relatively small component with retinotopic topography.

In this study, we chose eccentric presentation in the upper visual field and high contrast black and white stimuli, enabling us to elicit a stable C1 component and analyze its changes along a learning continuum. The fact that we did not find differentiation at the C1 component during baseline and extinction in this study, along with the consistent previous reports, showing no modulation of the C1 with spatial attention tasks and with the recent findings of C1 modulations depending on emotional facial expressions, strengthen our conclusion, that the modulation we report here, is solely due to the learned affective meaning of the stimuli. The overall statistical analysis of the four recording blocks did not reveal a significant interaction of block x condition, which could have been one way to provide direct statistical support for this assertion. Merely a main effect of block was found, the condition differences were observed in the follow-up ANOVAs. We think, however, that the significant effects of learning within the two conditioning blocks, along with the absence of differentiation during baseline and extinction and the results from the startle measurements, showing that conditioning had occurred, provide sufficient evidence that the C1 visual component was modulated by the learned affective meaning of an originally neutral stimulus. This study was built to capture changes along a learning continuum. The between-block manipulations aimed at creating controlled representations of the three learning stages (pre-conditioning, acquisition, possible consolidation and maintenance of a learned coherence, and extinction). The block design also provided a sufficient number of trials for an averaged ERP with a good enough signal-to-noise ratio enabling visualization and analysis of the relatively small C1 component at all three stages. Thus, by means of the within-block analyses, we were able to track even small condition differences that could have been overridden in the omnibus ANOVA. As reported above, the pattern of differentiation depended on the presentation site of the CSs and changed in topography across the two conditioning blocks, two factors that might have contributed to the fact that no interactions with condition were found in the omnibus ANOVA. The main effect of block, found here, applied to all four conditions and to all analyzed ERP components. It seemed independent of the learning manipulation and from the presentation site of the stimuli. This occurred despite the fact the first 200 ms of the experimental trials in all recording blocks were identical. We assume that the mere presence of affective pictures, some of them highly arousing and unpleasant, led to these differences between the conditioning blocks, compared to baseline and extinction (see below for a more detailed discussion regarding the context effects on all recorded components). Theoretically, this relates to the fact that both CS- and CS+ obtain predictive value by contingent presentation with different US and thus both gain motivational/affective relevance. Similar findings have been obtained with pleasant and unpleasant affective stimuli, which were reported to elicit greater visual N1/P2/P3 responses, compared to affectively neutral stimuli (Keil et al., 2002).

We also analyzed the P1 and the N1 ERP components elicited by the grating stimuli. Previous studies report reliable selective attention modulations of these components (Gomez Gonzalez *et al.*, 1994; Hillyard *et al.*, 1998), valence and arousal modulations have also been repeatedly observed before (Delplanque et al., 2004b; Keil et al., 2002; Schupp, Junghofer et al., 2003). Although we were able to measure the P1 and N1 visual components showing the expected topography, morphology, and reliable effects of presentation site, we did not find condition dependent differentiation between the CS+ and the CS- in any of the recording blocks. As mentioned above, our stimuli and presentation parameters were chosen specifically to elicit the C1 component and were thus not ideally suited to measure modulations of the P1 and N1 component. Studies showing arousal modulations of the P1 and N1 components mostly use very salient, relatively big and often colorful, centrally or laterally presented affective pictures (Keil et al., 2002; Schupp, Junghofer et al., 2003). In contrast, our conditioned stimuli were small black and white gratings and were presented in the periphery of the visual field.

3.4.3. Electrophysiological Responses to the gratings and the pictorial UCS

In addition to the ERP response following the CS+ and CS-, we also analyzed the electrophysiological brain response following the centrally presented unconditioned stimuli (neutral checkerboards during baseline and extinction and affective pictures in the two conditioning blocks). As expected, no differentiation was found between the checkerboard patterns in the baseline and in the extinction block. In the two conditioning blocks, we observed bigger bP1, bN1 and P3 components for the unpleasant pictures, compared to the neutral ones, replicating previous studies on affective processing (Keil et al., 2002; Lang et al., 1998b; Palomba, Angrilli, & Mini, 1997; Schupp, Junghofer et al., 2003). Surprisingly, however, these effects were lateralized and depended on the presentation site of the preceding grating stimulus. Even though the UCSs were presented centrally, participants were fixating on a small cross in the middle of the stimuli and no evidence for lateralized eye movements was found, the affective pictures and the neutral checkerboards elicited a lateralized bP1, bN1 and P3 responses across all recording blocks. It appears that the CSs were implicitly attracting participants' attention, even before conditioning. During the two conditioning blocks, however, the general hemifield effects were stronger than during baseline and extinction, suggesting increasing attraction of attention by the CSs when learning was taking place or in the context of affective stimuli presentation. In addition, we found lateralized condition differences for the bP1 and bN1 components. The differentiation between unpleasant and neutral pictures at the bP1 was greatest, when the gratings preceding them were presented in the left hemifield. The opposite applied to the bN1 component where differences between the affective categories were found only when the CSs were presented in the right hemifield. At the P3 the general interaction of hemifield with hemisphere was also significant. The condition differences, however, were independent from the presentation site of the gratings, although they were found predominantly over the right hemisphere. As our epoch ended at 400 ms after onset of the UCS and we were only able to record the beginning of the P3 component, these results should be considered with caution. In summary, regarding the ERP response following the UCS presentation, we replicated results previously observed using affective pictures and showing amplified amplitude of the bP1, bN1 and P3 components to highly arousing (here in particular unpleasant) stimuli. We also found laterality effects, increasing with continuing conditioning.

3.4.4. General effects of the recording blocks

In addition to the condition-specific differentiations, we found stable effects of recording context for all analyzed ERP components. When comparing the same condition across the four experimental blocks, the elicited responses during baseline and extinction were very similar to each other in morphology and topography (see Figure 12), although recorded on two consecutive days. The same similarity was found for the responses elicited during the two conditioning blocks. This held true for all four conditions. When presentation of affective pictures (as opposed to checkerboards) was expected, the electrophysiological response to the grating stimuli (CS+ and CS-) preceding those pictures was characterized by enhanced C1 and N1 amplitudes and reduced P1 amplitude. Less surprising were the block effects following the UCS presentation, whereby the high contrast checkerboards elicited greater bP1, bN1 and P3 components than the affective pictures. The context effects, specifically for the early components elicited by the grating stimuli, provide evidence that the observed condition differences cannot be attributed to time course effects. They also suggest that the extinction procedure was effective. In addition, they might indicate a general arousal or attention induced activation during the conditioning blocks, as suggested for example for behaviorally relevant context characteristics in a fMRI study by Downar and collaborators (2001). This, however, needs to be investigated further in future experiments.

3.4.5. Conclusions

With the present study we provide direct evidence for a modulation of the C1 visual component by conditioned stimuli. The aversive conditioning occurred within the visual system and might have led to a short-term reorganization of the early sensory processing, allowing for a differentiation between CS+ and CS- 65-90 ms after stimulus onset. Conditioned stimuli can be considered threat-related and thus belong to a class of stimuli likely to capture attention automatically (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; J. LeDoux, 2003). It has previously been shown that perception for motivationally or emotionally relevant stimuli is associated with increased cortical activity, as well as sub-cortical activation, for fear-related stimuli for example, in the limbic regions (Keil et al., 2002; Krolak-Salmon, Henaff, Vighetto, Bertrand, & Mauguiere, 2004; Phan et al., 2002; Schupp, Junghofer et al., 2003; N. K. Smith et al., 2003). It has been hypothesized that the increased activation in perceptual cortices might be due to feedback-related networks, linking sub-cortical and higher cortical structures with perceptual areas (Amaral et al., 2003; Martinez et al., 2001; Vuilleumier & Schwartz, 2001). While this is likely in the initial stages of contingency acquisition, we think that, with increasing consolidation, a direct involvement of the primary visual areas in arousal or valence differentiation is possible. We demonstrate that conditioned stimuli can modulate the initial sensory component in the human visual cortex. Even though this component is not modulated by spatial attention tasks, it appears sensitive to affective connotation of visual stimuli. Because of its short latency, it is unlikely to be directly influenced by cortical or sub-cortical feedback loops. This points to the important role of sensory plasticity in early attention for emotional stimuli. Our findings suggest that early sensory processing can also reflect affective information or motivational relevance. Whether the involved neural networks have come to expect affective components or simply tag the importance of the incoming information is an important question for future studies.

4. Synthesis and implications

The present dissertation demonstrated different ways to investigate the temporal characteristics of affective perception. With a series of behavioral studies employing an Attentional Blink design we touched upon the interaction of attention and emotion and demonstrated the importance of the temporal dynamic in affective processing. Emphasis was placed on the output dimension under perceptual overload conditions. We were able to show that response time and response accuracy are modulated by different design variations, thus are likely mirroring different processing dimensions. Rather than showing a general processing facilitation for highly arousing affective stimuli, we observed specific influence of valence depending on the kind and the time of the different output measures. The electrophysiological conditioning study, presented in the second half of this dissertation, provided evidence for a learning dependent sensory plasticity in affective meaning acquisition and emphasized the importance of the timing and the perceptual context for the attainment of affective connotation. The behavioral and electrophysiological results of all five studies presented here, accentuate the significance of timing and dimension for the perception and processing of and the response to affective stimuli. As stated earlier in the introduction, three theoretical approaches make different predictions with regard to the preferential attention allocation to affective stimuli, suggesting arousal dependent modulations (Lang et al., 1997), specific preference for pleasant material (Herbert et al., 2006; Juth et al., 2005; Lehr et al., 1966; J. M. Leppänen & Hietanen, 2004; Jukka M. Leppänen et al., 2003), or processing facilitation for unpleasant threatening stimuli (Öhman & Mineka, 2001). The present data do not allow for an ultimate decision in favor of one of the introduced models. Rather, they support the assumption that different stages and dimensions of affective processing are influenced by distinct characteristics of the affective stimuli. Below, an attempt is made to pinpoint some of the phases of affective processing selectively susceptible to different characteristics of emotional stimuli, and to suggest directions for future research.

The electrophysiological study reported here, adds to an existing and expanding body of conditioning literature (J. LeDoux, 2003). It expands the present knowledge by focusing on the earliest measurable electrophysiological response and providing evidence for learning induced changes of an otherwise very stable component, which has been shown to be independent of instructed attention allocation manipulations. The results provide additional evidence that affective learning is a fast process, possibly leading to reorganization in perceptual cortices and building a base for appropriate responses to visual affective stimuli.

We used only affectively negative highly arousing stimuli in order to achieve conditioning, and thus we do not know, if a comparable manipulation with highly arousing pleasant pictures would have led to similar results. This is an important question to answer in future research in order to clarify the influence of valence and arousal on early affective perception. However, we assume that the generally higher arousal and not the specific unpleasant content, leads to perceptual amplification. A variety of electrophysiological and imaging studies showing arousal dependent modulations of early evoked components[1] as well as of the steady-state response, support this hypothesis (Bishop et al., 2004; Bradley et al., 2003a; Coull, 1998; Cuthbert et al., 1996; Cuthbert et al., 2000; Derryberry & Reed, 2002; Hartikainen et al., 2000; Junghöfer et al., 2006; Lang et al., 1990; Sabatinelli et al., 2006; Schupp et al., 2000; N. K. Smith et al., 2003). We think that early perceptual mechanisms serve to give preferential gain to arousing stimuli. One possible mechanism could be the tagging of deviant stimuli, as the perceptual norm constitutes of low arousal material. Recurrence of similar events, which are still deviant from the norm, could be causing facilitated learning and plasticity, allowing for an even faster and more efficient differentiation. Studies comparing groups of people with different perceptual norms, as well as developmental studies in affective neuroscience could help put this working hypothesis on a more stable foundation.

Allocating more attention to deviant arousing pictures allows them access to deeper perceptual levels where the hedonic valence of the stimuli might begin to play a decisive role. The AB-results presented in this dissertation suggest selective influence of the kind of motor response with regard to the facilitation reaction to certain picture categories, depending not on their arousal, but on their valence. It is possible, that in the later response preparation stages of affective processing, when an unspeeded reaction is required, a full analysis of the presented stimulus has taken place, the stimulus's valence has found complete expression, and an appropriate „defense cascade" answer is taking place. The often reported finding summarized under the term "failure to disengage" (Compton, 2000)**,** might well reflect deeper analyses of unpleasant stimuli. A response that causes a small delay in motor response, but enables more thorough consideration, could be an evolutionary reasonable reaction. Possible consequences often reported in experimental research might be higher memory performance (Kensinger & Corkin, 2003a, 2003b), better recognition out of an array (Öhman, Lundqvist et al., 2001), and the general notion that "negative information weights more heavily on the brain" (Ito et al., 1998), a response pattern falling under the "negativity bias" hypothesis.

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[1] The C1 component has to our knowledge so far not been investigated specifically in the context of affective perception. Thus "early" means here P1, N1 following immediately after the C1.

The selective facilitation for the pleasant category, often found in immediate fast response tasks (Feyereisen, Malet et al., 1986; Hugdahl et al., 1993; Schult, Zeller, Stolarova, & Schupp, 2007) and when the response is delivered in the absence of the unpleasant stimulus, as demonstrated in the immediate fast response condition of the AB-experiments, could be a characteristic for a situation when a deeper analysis is not possible or is not considered necessary. Then, the learning promoting mechanisms of the “positivity offset” might foster approach and have a higher adaptive value. In a similar vein, in a generally safe situation, such as a laboratory experiment, a better accuracy rate for the pleasant category and a linear decrease from pleasant through neutral to unpleasant stimuli, as demonstrated in the four AB-experiments, might be a sign that the influence of the approach system prevails. This does not necessarily mean that the evaluation of a stimulus, or even any given point in time of affective processing, is characterized by a clear advantage of one of the two regulating systems: avoidance and approach. It also does not necessarily imply that pleasant stimuli per se activate the approach system, while processing of unpleasant information always necessarily relies on withdrawal mechanisms. Rather, a dynamic view (in time and space) is proposed, allowing for differential influence of approach and avoidance strategies on different stages (e.g. perception, evaluation and output) and dimensions (e.g. output dimensions such as response time and response accuracy or input dimensions such as verbal and pictorial material) of affective processing. A hint in this direction is provided by the AB-data, showing that accuracy rate of and response speed to the very same stimuli show dissimilar response patterns and are sensitive to different experimental manipulations. The fact that small manipulation in the experimental design, for example showing a matrix of schematic faces, versus a matrix of realistic portrait photographs, changes the response pattern in favor of one or the other valence (Juth et al., 2005), also points in this direction. Similar conclusions were drawn by Vuilleumier and Pourtois (2007) in a recent article, emphasizing the importance of an “interactive network with distributed activity in time and space” in emotional face perception and recognition. Furthermore, this is the place where selective attention comes into play; influencing different levels at different stages in a specific and adaptive way.

This argumentation is supported by a recent SSVEP potential study (Kim, Grabowecky, Paller, Muthu, & Suzuki, 2007), showing that attention operates simultaneously on different levels increasing single neuron responses to certain features and increasing synchronization of the responses in general and providing a possible electrophysiological base. This could be an underlying mechanism also responsible for a different aspect with regard to the dynamic of affective processing and the interaction of valence, arousal and attention. When considering the explicit influence of the context on the early electrophysiological response demonstrated in the conditioning study (the mere expectation of complex visual material of negative or neutral valence, as opposed to checker boards, led to a category unspecific response modulation), we assume that not only the specific arousal of the stimuli, but also the situational arousal, influence learning, affective meaning acquisition and probably evaluation. It is likely that a situation with a higher frequency of arousing or deviant material (maybe a distinctive feature of an interesting as opposed to a boring situation) modulates the reactivity of early perceptual systems, captured here by means of ERPs, and evaluated in other studies by means of SSVEP (Keil et al., 2003; Kim et al., 2007). The "context" can be created through outside variables, as in the presented study. It could, however, also be determined by personal characteristics, such as age, gender, rearing environment or psychiatric conditions.

The studies presented here support the notion that none of the existing theoretical models in affective neuroscience can explain the perception and processing of emotional stimuli and the interaction between attention and affective content as a whole. All three main models briefly described in the introduction, as well as "the „defense cascade"", "the failure-to-disengage", "the negativity bias" and "the positivity offset" hypotheses explain certain aspects of affective processing. When timing and dimension are considered it is possible to reconcile the apparently conflicting positions. Promising candidates for providing the neuropsychological foundations enabling appropriate and adapting responses to affective stimuli are distributed networks, capable of fast, learning dependent reorganization, possibly by means of increased response synchronization (Keil et al., 2007; Kim et al., 2007; K. Taylor, Mandon, Freiwald, & Kreiter, 2005). Before putting together the affective processing puzzle into a coherent picture, it is necessary to first sort out the parts from all the other puzzles mixed together in the box named "Emotion and Attention" by clearly defining their characteristics. This dissertation attempted to find that box, open the lid and begin the sorting by pointing out some of the possible sorting criteria.

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