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Selective Processing of Affective Pictures:
A Study with the Attentional Blink Design

Wissenschaftliche Arbeit zur Erlangung des Grades einer Diplompsychologin
vorgelegt von

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DANKE!

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I. INTRODUCTION

The present thesis focuses on emotion-attention interaction. Basics have been demonstrated in studies of emotional perception as well as in studies of attention. In the first part of this introduction, I will introduce some influential models of emotional processing. After a brief historical insight into the development of emotion research, an important approach for this thesis, the bioinformational theory (Lang, Bradley, & Cuthbert, 1998), will be highlighted. Therein, Lang and Bradley concentrate on observable outputs of emotion, consisting of language, motor behavior, and physiological responses mediated by the somatic and autonomic systems. Finally, some neurophysiological approaches of emotional perception will be discussed. In the second part of this introduction, I will concentrate on attentional effects of affective stimuli and their impact on behavior. Empirical findings are often inconsistent, proposing either facilitation or inhibition of behavioral responses to pleasant or unpleasant stimuli. These discrepancies are discussed emphasizing the employed stimulus material, the response mode to the stimuli, as well as inter-individual differences. The human defense cascade model (Lang, Davis, & Ohman, 2000), a theoretical approach, explains some of the observed behavioral variance. In the last part of this introduction the design of the conducted study will be addressed.

The aim of this thesis is to examine the selective processing of affective pictures as a function of available attentional resources. Laboratory investigations have provided several paradigms to examine the cognitive system underlying limits. In the presented study, affective pictures are shown within a rapidly displayed stream of distractors at a given spatial location. The central question is whether highly affective pictures (pleasant and unpleasant) are better recognized, and whether they facilitate readiness for action, than low affective pictures (neutral).

Models of emotional processing

Early views on emotion

In the following paragraph I will provide a short insight into some selected concepts defining emotion that have influenced the progression of emotion research. Finally, I will give a working definition of emotion.

For long, emotion was nearly left out of scientific investigations, even though some important papers had been published by the end of the nineteenth century. Spinoza (Nadler, 2005) was among the first ones whose ideas influenced today's research. He divided affects into actions and passions. As actions he considered changes that have their source in people's nature, whereas passions are those changes that originate outside of people. The latter affects are constantly directed outward, toward things and their capacities to affect people in one way or another. Spinoza further regarded any emotion as a variant of one of three primary affects involving joy, sadness, or desire. Then, at the end of the nineteenth century, William James published his emotion theory 'What is an emotion' (James, 1884). It sets out that emotion follows, rather than causes, its bodily expression, which themselves follow the perception of the 'exiting fact' [page 190]. According to James, the importance of this view is that our emotions are tied in with our bodily expressions. Around the same time the Danish physiologist Carl Lange published a book about emotional states with a similar essence (De Sousa, 1987) like James' article. Thus, both positions were later called the James-Lange theory of emotion. Wundt (Wundt, 1924) disagreed with this theory, because he assumed that all mental activities involve emotion. He pointed out that the emotion comes first followed by physiological and behavioral consequences, whereas James believed that people first respond to a situation and then experience the emotion. Wundts' assumption was mainly based upon his method introspection. He further assumed, accepting some of Spinoza's ideas, that emotions might be organized by overcharging motivational factors: pleasure - displeasure, high - low arousal, strained attention - relaxed attention. This division into separate dimensions strongly influenced today's research (Lang, Bradley, & Cuthbert, 1997; Russell & Barrett, 1999), although it remains unclear what affects our subjective emotional experience. The motivational perspective of emotion was also considered by Troland (Troland, 1928). Evolutionary, organisms have to respond to stimuli according to their motivational significance. Survival depends on effective attentional selection and response processes. Hereby, motivation is considered to comprise two general systems: a preservative appetitive and a protective aversive/defense system. The activation of these systems depends on the intensity of stimulation. Troland suggested that pleasure is linked to beneception contributing to the survival of organisms and pain is linked to nociception with undesirable consequences for the organism. Later, this approach emphasizing hedonic processes in the regulation of behavior lost influence, although variations have occasionally been investigated among motivational psychologists and biologists (e.g. Schneirla, 1959; Young, 1959).

Despite these early investigations, studies on behavior have focused more on the higher level processes of the mind discarding emotions for several decades. A reason for this lack of interest might have been the failure to distinguish between emotions and feelings (the conscious experience of emotion) that led to mistrust of emotion as an adequate topic of scientific investigation (Damasio, 2000). Since the late eighties an increasing interest to work on emotion has come up among neuroscientists and cognitive scientist (e.g. Adolphs, Tranel, Damasio, & Damasio, 1995; Davis, 1992; Lang, 1995; LeDoux, 1994). Nevertheless, the definition of the emotional construct is still varying depending upon the topic of interest. I will consider emotions as an evolutionary product that helps various species to survive. This broad statement offers the possibility to include different aspects of emotion as well as differing perceptual channels available to humans: language, motor behavior, and physiological responses mediated by the somatic and autonomic system. There are many more defining accounts about what an emotion is, but for this thesis this characterization will be sufficient.

The Lang – model

Lang characterized emotions as motivationally tuned states of readiness (Lang, Bradley, & Cuthbert, 1998). His *bioinformational theory* became very influential in emotion research. It forms the basis for this thesis because it emphasizes motivational aspects of emotional behavior. Besides the motivational components, it also includes behavioral and cognitive components in line with evolutionary theories of the defensive and approach systems.

Two dimensional affective space

Lang and colleagues consider emotions as action dispositions organized around two motivational systems: An appetitive system and a defense/aversive system. This means that any emotional behavior is affected by the output of the appetitive or defensive system. Appetitive motivation concerns approach related behavior directed toward goals which are usually associated with positive hedonic processes (e.g. food intake, sexual intercourse), while aversive motivation promotes behavior such as escape from a hedonically unpleasant condition to ensure survival or prevent harm. The activation level of these motivational systems can be derived from the amount of arousal elicited by a stimulus (Bradley, Codispoti, Cuthbert, & Lang, 2001). It is suggested that these motivational systems are associated with a two-dimensional model of emotion: the affective dimensions *valence* and *arousal*. Both dimensions (valence and arousal) have been obtained in analyses of emotional stimuli. The valence dimension points out the direction of behavioral activation, either toward (appetitive motivation) or away (aversive motivation) from a stimulus. The arousal dimension indicates the amount of emotional activation or intensity. Both dimensions are proposed to be orthogonal, spanning a two-dimensional affective space (valence and arousal).

Neuroanatomical animal research sustains this approach. Both motivational systems on the valence dimension are found to involve different cortical structures (LeDoux, 1994; Shi & Davis, 2001). No separate neural system is proposed for the arousal dimension. Arousal is considered to reflect changes in terms of activation within the two motivational systems. Evidence is also provided by the ‘startle response paradigm’ (Cuthbert, Bradley, & Lang, 1996). In this paradigm one of the valence systems (appetitive or aversive) is preactivated by looking at highly arousing affective pictures of a predefined valence. Then, a burst of white noise or a flash of light is presented, initiating the startle response, a complex reflex through the whole body. It is found that this response is enhanced when participants are looking at unpleasant pictures, whereas the reflex is reduced while looking at pleasant ones. In the latter, the new stimulus is incompatible to the behavioral disposition of the person.

Standardized affective pictures

Assuming that emotion can be defined by the dimensions valence and arousal, the Lang group compiled a set of normative emotional stimuli for experimental investigations of emotion and attention. They obtained the normative ratings of a representative sample of colored pictures using their own rating scale (Self-Assessment Manikin, SAM; (CSEA, 1999). Thereby, participants had to rate the affective picture material on each dimension (valence and arousal). A picture set (International Affective Picture System, IAPS) was obtained which currently contains over 800 pictures. Figure 1 shows a distribution of a representative sample of those pictures. Each dot represents participants' mean valence and arousal ratings for the corresponding picture. Plotted in such a Cartesian coordinate system, a boomerang-shaped distribution of the pictures emerges. In the center of the distribution cluster the neutral pictures. With increasing distance from the center of the affective space pictures are rated as progressively more pleasant or unpleasant. At the same time they also receive higher arousal ratings. Ito and colleagues (Ito, Cacioppo, & Lang, 1998) assumed that the coupling of arousal and valence ratings is more prominent for unpleasant pictures as these show a steeper slope for the aversive motivation.

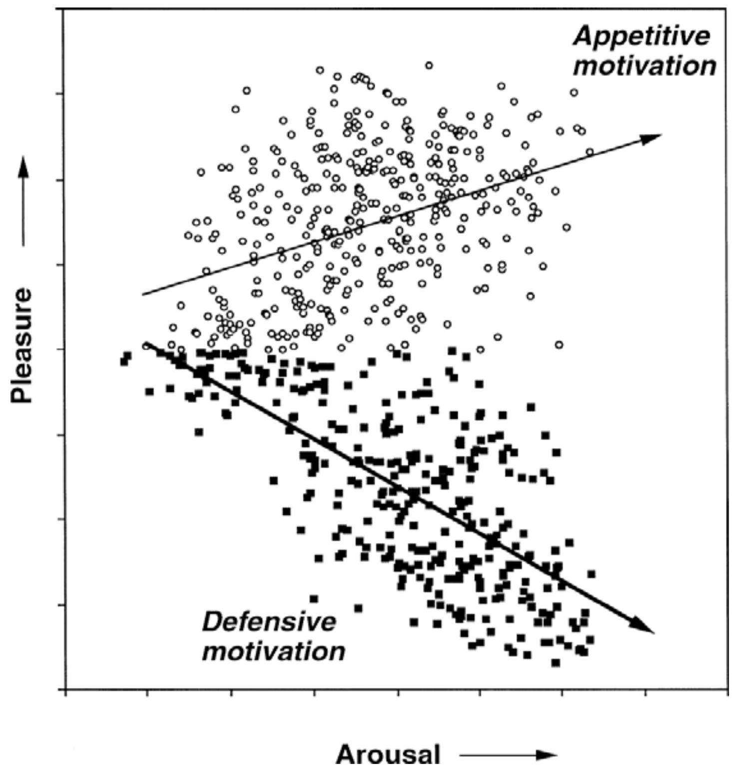

Figure 1: The two-dimensional affective space defined by mean pleasure and mean arousal for pictures taken from the International Affective Picture System (IAPS). Every data point represents a certain picture. Arousal and valence ratings were performed on a 9 point scale (SAM). Taken from Bradley, Codispoti, Cuthbert, & Lang (2001).

The distribution of the affective ratings supports the biphasic organization of emotion along the hypothetical appetitive and defensive motivational systems. Furthermore, the subjective ratings co-vary with activity in the autonomic and central nervous system, which are associated with the appetitive and aversive motivational system (Bradley, Codispoti, Cuthbert, & Lang, 2001). Thus, it is assumed that emotions can be triggered by visual stimuli such as pictures (Hamm, Greenwald, Bradley, & Lang, 1993; Lang, Greenwald, Bradley, & Hamm, 1993).

Cognitive component

Lang and coworker further proposed that human emotions are mentally represented as propositional networks. These networks are considered as information structures in memory which are activated when any element of it is enabled. They contain information about affective stimuli related features and behavior. Simple features can be embedded in a network such as possible reactions, language and behavioral elements, as well as past experiences and stimulus contingencies. A common example is the snake fear network (see figure 2).

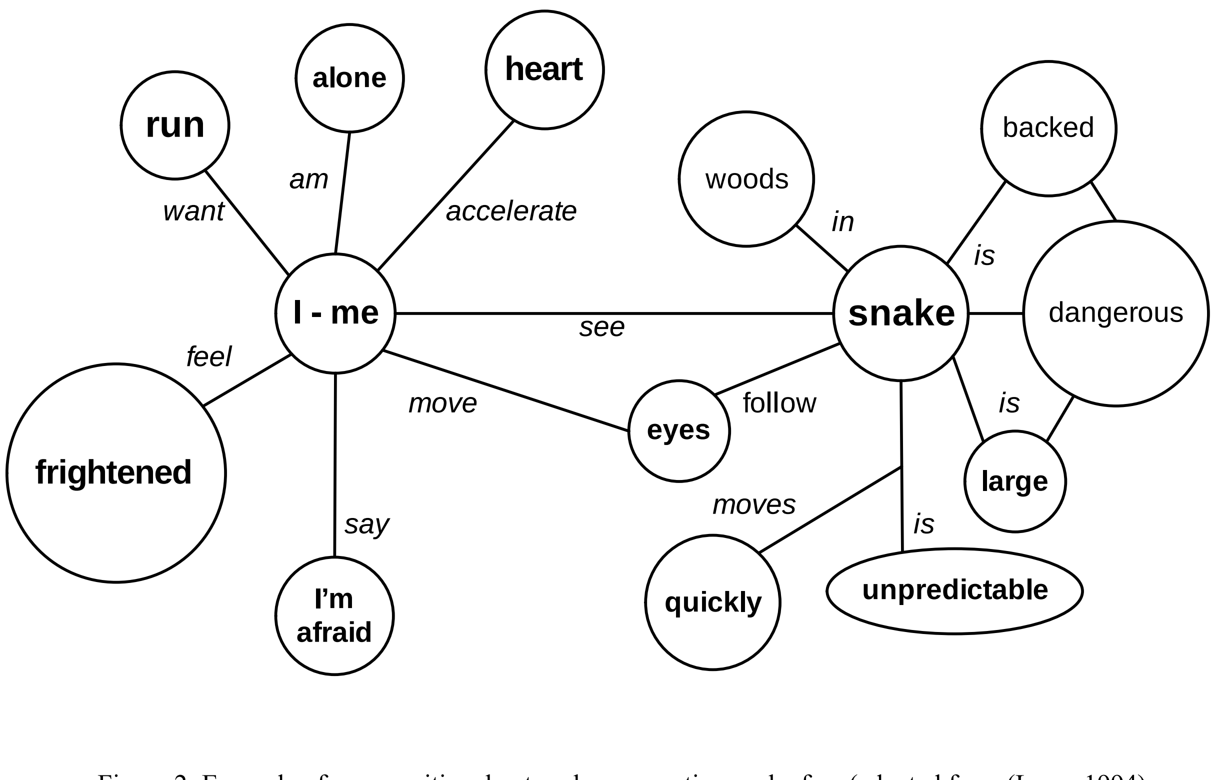

Figure 2: Example of a propositional network representing snake fear (adapted from (Lang, 1994).

Accordingly, fear responses (e.g. highly autonomic arousal, reported distress) can be triggered by cognitive representation of any stimulus associated feature. This semantic model allows the assumption that there is no specific cortical structure for emotion processing, but that propositional networks are activated during affective stimulus processing influencing the motivational systems.

Behavioral/physiological components

In terms of the bioinformational model the emotional state of a person is not necessarily congruent with his/her overt reactions. In some situations it is not adaptive for a person to perform an action that has been triggered by the motivational systems. Thus, at the level of human emotions physiological measures, language, and behavioral reactions of emotional states are not necessarily synchronous. Overt responses vary across different contexts (e.g. perception and imagery) and are oriented on situational requirements. Additionally, they can vary considerably within a person. Lang discriminated between 'strategic' (long-term dispositions of an organism) versus 'tactical' (short-term demands) influencing factors. In each situation these factors are balanced on multiple levels. Lang assumed that affective responding is predominantly tactical, influenced by situational demands.

Lang's model provides consistent explanations for empirical results in experimental, social, and clinical psychology (Bradley & Lang, 2000; Cacioppo & Gardner, 1999; Cuthbert, et al., 2003; Hamm, et al., 2003; Lang, Bradley, & Cuthbert, 1997; Öhman, Flykt, & Lundquist, 2000) and it is one of the fundaments of this thesis.

A neurophysiological approach to affective perception

A substantial insight into the nature of brain mechanisms involved in affective processing is LeDoux's work on fear conditioning in rodents (LeDoux, 1995). He concentrated upon the neurophysiological mechanisms of affective evaluation in the auditory area. Although the focus of my study is more on the behavioral aspects of visual affective stimuli processing, his model provides important insight into the processing of briefly presented affective material and thus will be shortly described.

The model of LeDoux and coworkers is based on the fear-potentiated startle reflex in rodents (LeDoux, 1995). They found that the core structure involved in affective processing is the amygdala. Additionally, their research provided evidence for the role of two afferent routes involving the amygdala mediating fear conditioning (LeDoux, 1995; LeDoux, 2000). The first route, a direct one, connects the sensory thalamus with the amygdala, processing sensory aspects of incoming stimuli which are instantaneously transferred to the amygdala. This pathway is very fast. The second route, an indirect route, relays the incoming signals from the thalamus over the sensory cortex to the amygdala. This pathway is slower than the direct route but permits a more complex analysis of the sensory stimuli. The first one, delivering only a crude representation of the incoming stimuli, is nevertheless very important for a fast identification of aversive/dangerous stimuli. An instant reaction is evolutionary pivotal when potential danger occurs. Although most of these findings were obtained in the auditory domain and in studies with nonhuman mammals, LeDoux assumes that analogous brain regions and mechanisms are involved in human sensory stimulus processing and that these principles also apply for other sensory modalities (e.g. visual).

Michael Davis and Changjun Shi (Shi & Davis, 2001) support LeDoux's position. They also state that thalamo-amygdalafugal pathways enable the amygdala to perform a fast evaluation of stimuli without complex routes in the neocortex. Electrophysiological studies affirmed the presumption that early discrimination of emotional stimuli takes place in time windows of about 100-200 ms (Junghöfer, Bradley, Elbert, & Lang, 2001; Keil, et al., 2002). Nevertheless, LeDoux's assumption about the existence of a fast direct thalamo-amygdalafugal route that differentiates between affective stimuli without a higher-level analysis has been met with criticism. Rolls (Rolls, 1995), in the tradition of classical models of hierarchical visual analysis, proposes in his *learning theory* that emotional stimuli are differentiated at late stages. He states that emotional responding is due to states of the organism which are produced by reinforcers. Primary (unlearned) reinforcers biologically produce emotional states while other stimuli become reinforcers by learning (classical conditioning). According to his view, visual stimuli have to be processed in all stages of the ventral pathways in the temporal lobe before afferents project information to the amygdala. There, in the amygdala, affective stimuli are evaluated. A possible assumption is that both a fast and a slow evaluation route exist.

LeDoux further divided affective phenomena into evaluation, expression, and experience. From his point of view, all three constructs are functionally separated and should be investigated with distinct empirical approaches. He emphasizes evaluation as a preconscious mechanism that is essential for building up affective experience in response to external stimuli, whereas emotional feeling or experience is viewed as a conscious process.

Summarizing, the model proposes two pathways for affective stimuli processing: an early, fast evaluative component and a slower, later response component that accounts for consciously formed experiences. In the presented study the focus is on fast evaluative processes and their correlated behavioral responses.

Processing of affective stimuli

Attentional effects of affective stimuli and their impact on motor responses

Affective stimuli are not just an artificial product of laboratory research but have biological significance. Affective cues regulate people's behavior and are perceived by different senses (e.g. sense of smell, touch, or acoustic). In the following, I will concentrate on the visual domain. An example for solely visual processing in daily life is leafing through some magazine or newspaper. Responses, physiological as well as overt behavior, are primarily results of perception. Attention, an important mechanism for feature integration (Treisman & Kanwisher, 1998), plays a role in analyzing emotional stimuli which are important for the organism.

Attentional mechanisms have been extensively studied in the past 40 years (e.g. Allport, Antonis, & Reynolds, 1972; Deutsch & Deutsch, 1963; Posner & Snyder, 1975; Shiffrin & Schneider, 1984). A review of the relevant literature is provided by Allport (Allport, 1993). Attentional selection is assumed to be guided in great part by the affective significance of stimuli (Lang, Bradley, & Cuthbert, 1997; Öhman, Flykt, & Esteves, 2001). An important question is whether emotional stimuli can be encoded automatically. Barrett (Barrett & Ochsner, in press) argues in her latest article that three kinds of behavioral evidence support this idea. The first confirmation is provided by behavioral studies employing subliminal presentation of affective stimuli. These are said to generate autonomic responses, change the activity of the facial musculature and behavior, and to bias the perception of subsequently presented material in a valence congruent way. Further, Barrett explains that briefly supraliminal presented stimuli facilitate access to valence congruent behavior, which seems to be affective in nature. Finally, behavioral and autonomous responses to affective stimuli may implicitly show changes in the evaluation of these events, which are not necessarily experienced consciously. These findings indicate that affective stimuli are processed rapidly and influence subsequent behavior. Nevertheless, there is no firm foundation whether specific affective cues are automatically encoded. If so, then processing is less susceptible to distraction and information load (Treisman & Souther, 1985; Treisman & Gelade, 1980). Despite differences in the definition of 'automatic' processing (Bargh, 1997; Logan & Compton, 1998; Öhman, 1997), various approaches confirm the notion that affective significant stimuli are rapidly and preconscious detected (Compton, 2003).

Some studies show that in tasks where attentional resources are limited, salient stimuli (e.g. faces, human bodies, threat stimuli) are prioritized for attentional selection (Downing, Bray, Rogers, & Childs, 2004; Lavie, Ro, & Russell, 2003; Mogg, Bradley, de Bono, & Painter, 1997). Using a dot-probe paradigm, Mogg (Mogg, Bradley, de Bono, & Painter, 1997) showed that emotional stimuli facilitate further instructed attentional processes. In the study of Hartikainen (Hartikainen, Ogawa, & Knight, 2000) highly arousing affective stimuli allocated attentional resources and thereby interfered with a visual discrimination task.

Given that, an intruding question is, why some affective stimuli are better processed than others? Various definitions of emotion are tied to the concept of goal-relevance (Ellsworth & Scherer, 2003; Smith & Kirby, 2001). When a stimulus or event has potential consequences for either furthering or inhibiting a person's goals, it is classified affective. These goals can be immediate such as avoiding danger, or more complex and long-sighted. Goals can differ from individual to individual, but there are also types of events which are consistently emotionally significant across people (Ellsworth & Scherer, 2003; Öhman, 1986). If only some information can be attended, it is adaptive to prioritize those stimuli and events that affect goals in either a positive or negative way. A quick decision whether an events is good or bad is essential for identifying potential threats and orienting attention to goal relevant stimuli (LeDoux, 2000; Öhman, Flykt, & Esteves, 2001). Thus, stimuli gain significance by top down properties (driven by the state of the organism) as well as by bottom up properties (stimulus driven). I will concentrate upon the stimulus driven properties. Three theories, investigating attentional facilitation of consistently significant affective stimuli across people, are outlined in the following:

Categorical negativity theory (Pratto & John, 1991): This theory proposes that people constantly evaluate stimuli in their environments. This evaluation is assumed to be outside of conscious awareness. Thereby, stimuli are categorically classified as positive or negative. Negative stimuli automatically attract attention because of their pivotal aspects, although not all negative stimuli threaten survival. Thus, the theory makes two predictions. First, attention is guided by an initial evaluation of valence and only stimuli that are evaluated as negative attract attention. Second, the evaluation process provides only categorical information about valence and does not differentiate between the degrees of unpleasantness of negative stimuli along the valence dimension.

Evolutionary threat theory (Öhman, Flykt, & Esteves, 2001): In this theory, the detection of fear-relevant stimuli which threaten people's lives is seen as more adaptive than the detection of other stimuli. The authors assume a specific detection mechanism for stimuli that threatened survival during the evolution of the human species. Such stimuli might be snakes, spiders, or angry faces. Empirical evidence for the facilitation of unpleasant stimulus processing is provided by studies applying the visual search task (Hansen & Hansen, 1988; Öhman, Flykt, & Esteves, 2001). For example, highly arousing fear pictures in a spatial array are detected more quickly and more accurately than control pictures (Öhman, Flykt, & Esteves, 2001). Thus, evolutionary relevant threatening stimuli are effective in capturing attention. Unfortunately, this theory makes no predictions about the influence of other affective stimuli on attention (e.g. pleasant stimuli).

Both in the negativity bias theory and the evolutionary threat theory the authors did not include the arousal dimension. Nevertheless, it is possible that their found effects are due to arousal, as strong negative / unpleasant stimuli are normally highly arousing.

Arousal theory (Lang, 1995): This theory is widely accepted (e.g. Anderson, 2005; Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001; Keil, et al., 2002). It proposes that responses to affective stimuli vary with their level of arousal and valence. Experiences of pleasure and displeasure, facial expression, the startle probe, as well as the heart rate vary with the valence-level. Skin conductance, the P300 in the event-related potential and activation of the occipital cortex in fMRI scans is associated with the arousal-level. Thus, it seems that the level of arousal of affective stimuli is closely connected to its influence on attention. There is no published evidence that the valence level of stimuli is critical for attentional processes. Evidence that highly arousing emotional stimuli modulate attentional processes is provided by some studies (e.g. Hamm, Greenwald, Bradley, & Lang, 1993). Lang (Lang, Greenwald, Bradley, & Hamm, 1993) stated 13 years ago that highly arousing pictures automatically draw people's attention. Neurofunctional studies confirm this prediction by showing that motivationally significant stimuli can elicit greater activation in the sensory cortex (Keil, et al., 2002; Schupp, et al., 2000; Schupp, Junghöfer, Weike, & Hamm, 2003). Thereby, parameters of perceptual processes are modulated by the arousal of a visual stimulus. Further affirmation for the arousal theory comes from studies using affective word stimuli or affective pictures. Highly arousing words of both valences (pleasant and unpleasant) attract attention when limited attentional resources are available, compared to low arousing neutral words (Anderson, 2005; Keil & Ihssen, 2004). Facilitation effects for highly arousing picture stimuli (strong unpleasant pictures and pictures of opposite sex models) are found in a study by Bradley and coworkers (Bradley, Codispoti, Cuthbert, & Lang, 2001). Summarizing, it seems that attentional modulation is related to the level of arousal.

Studies examining both valence and arousal contributions to visual activation controlling one at a time are rare, as the arousal and valence dimensions are correlated. A study (Mourao-Miranda, et al., 2003) investigating these contributions of both valence and arousal created a new stimulus category: highly arousing, but neutral in valence. They found that both stimulus valence and arousal contribute to visual activation.

Inconsistencies of behavioral findings in studies of emotional perception

Empirical findings of studies investigating the processing of affective stimuli are controversial. They either found facilitation or inhibition of behavioral responses to pleasant or unpleasant stimuli. This inconsistency may be due to the employment of different stimulation material (e.g. words, faces, scenes) as well as to the diversity of employed tasks.

The stimulation material used in experiments varies as well as their findings. For instance, visual word stimuli have been associated with facilitation for pleasant and unpleasant highly arousing compared to neutral low arousing targets (Anderson, 2005; Keil & Ihssen, 2004). Also, Harris and Pashler (Harris & Pashler, 2004) found that if highly emotionally word stimuli (e.g. the participant's own name or negative words) are presented within a math task, responses to this task slow down. Opposed to these findings, Leppänen and Hietanen, using faces as stimulus material, found that positive facial expressions are recognized faster than negative ones (Leppänen & Hietanen, 2004). As a possible explanation for this controversial pattern, the authors consider the higher frequencies of pleasant faces. Kindt argued that faces as well as other pictorial materials are more realistic to natural environment than words (Kindt, Brosschot, & Boiten, 1999). Faces and pictures might be more difficult to process than words. Therefore it is uncertain whether results obtained in studies using a specific kind of stimulus material can be generalized to other ones.

Another reason for the inconsistencies found in literature is the diversity of the employed tasks. The data of behavioral tasks applying differing response modes are not conclusive. Some authors suggested facilitation, others inhibition of behavioral responses in the presence of highly arousing pleasant and unpleasant stimuli. For simple and choice response tasks, it has been argued that only pleasant targets facilitate response time and accuracy (Leppänen & Hietanen, 2003), whereas in visual search tasks (Hansen & Hansen, 1988; Öhman, Flykt, & Esteves, 2001) aversive stimuli are detected faster than pleasant or neutral targets. Leppänen also assumes that a predominance of positive emotions in normal contexts may partly explain this effect. Opposed to these findings, Buodo and coworkers (Buodo, Sarlo, & Palomba, 2002), employing a choice task, showed that reactions to some aversive and appetitive stimuli (blood/injury and erotic couples) were slower compared with other stimuli of the same hedonic valence (threat and sport/adventure scenes), rated as equally arousing. They assumed that the first ones required a greater amount of attentional resources.

Additionally, some effects may also depend upon the examined population. It has been shown that effects are caused by inter-individual differences (Bradley, Mogg, White, Groom, & de Bono, 1999; Mogg & Bradley, 1999). Mogg, applying a probe detection task, found that anxious people show an attentional vigilance for threat stimuli, rather than for neutral ones. This pattern was not found in healthy, low anxious controls (Mogg, Bradley, de Bono, & Painter, 1997).

The human defense cascade model

The variance in behavioral literature is mostly found for unpleasant highly arousing material. A theoretical model making predictions about the nature of unpleasant stimuli is the *human defense cascade model* (Lang, Davis, & Ohman, 2000). On the basis of physiological reactions evoked by aversive stimuli in humans, Lang suggested a cascade of reflex responses, which is to some extend analogous to the reaction pattern found in animals. This model proposes a typical dynamic of the aversive system, ranging from a state of initial perceptual facilitation and motor inhibition to a flight/fight state associated with facilitated behavior and reduced sensory intake (see figure 3).

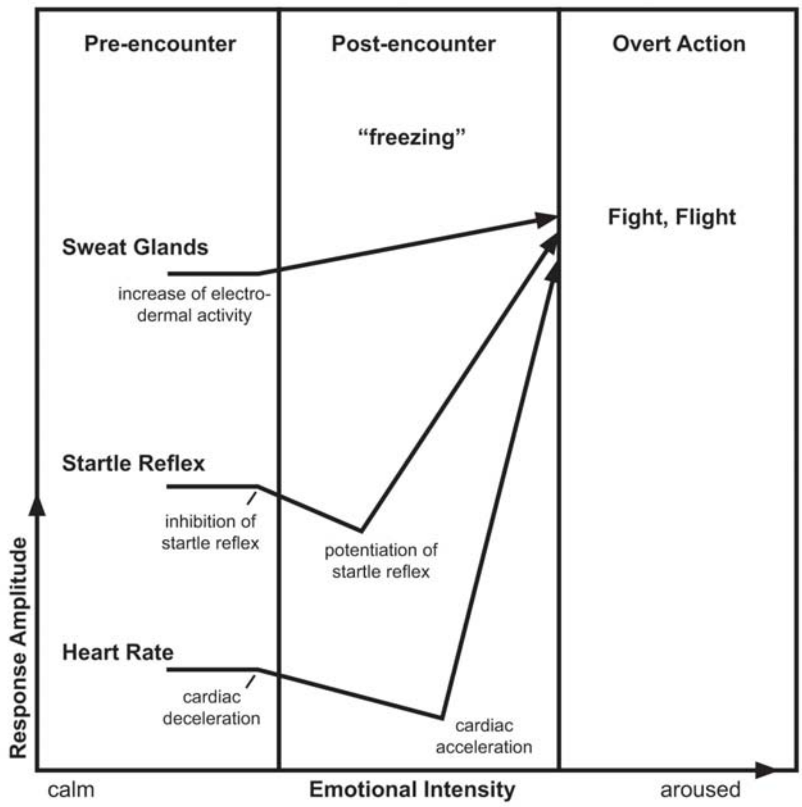

Figure 3: The defense cascade model (adopted from (Bradley, Codispoti, Cuthbert, & Lang, 2001).

In the figure a schematic diagram of the defense cascade is illustrated. It describes possible consequences on the level of physiology, behavior, and self-reports. The post-encounter stage reflects the physiological responses visible in humans during picture viewing. Naturally, looking at pictures is not the same as experiencing real life events. Therefore overt actions are very seldom, but aversive pictures still provide enough threat to activate the defensive motivation system. Thereby, the different reflex systems change at a different level of motivational engagement. Bradley (Bradley, Codispoti, Cuthbert, & Lang, 2001) suggests that defensive responding to unpleasant pictures is organized sequentially, reflecting the degree to which pictures evoke the activation of the defensive system. Moderate aversive cues typically trigger a slight increase of electrodermal activity, cardiac deceleration, and a relative inhibition of the startle reflex, at least if these stimuli are detected and processed. This reflects an orienting response, where attentional resources are directed towards the stimulus and perceptual processing is facilitated. Highly aversive cues, correlated with a higher level of arousal, prompt more pronounced reaction patterns measurable in greater electrodermal activity, potentiation of the startle reflex, and cardiac acceleration.

Alterations of physiological parameters are also found for the appetitive motivational system. Viewing highly arousing pleasant pictures causes more pronounced activation than viewing low arousing ones.

The assumption that responding to unpleasant stimuli is organized sequentially adopts findings from animal research. The defense cascade proposes a typical sequence of affective and behavioral states (reflex reactivity), depending on the proximity and intensity of the threat. Azevedo and coworkers show in a recently presented study that humans show analogous behavior of freezing (Azevedo, et al., 2005) when a series of mutilation pictures is presented. Nevertheless, it remains unclear which processes mediate between stimulus detection and the following motor response while looking at unpleasant pictures.

The Attentional Blink paradigm

What is the Attentional Blink?

A useful way to study the allocation of attention to affective stimuli when attentional resources are limited is applying a ‘rapid serial visual presentation’ (RSVP) in an ‘Attentional Blink’ (AB) design. Therein, two highlighted targets are presented among distractors forming a RSVP stream. The task is to detect and report or recognize both targets. To study the temporal course, the lag between the two targets is varied systematically. With a fast presentation rate of around 10 stimuli per sec, the report of the first target (T1) is nearly error free, but the report of the second target (T2) is impaired if it appears within 200 – 500 ms after the onset of T1 (Raymond, Shapiro, & Arnell, 1992). After this time T2 is likely to be reported accurately. The interval during which T2 response is interfered is called an AB. The impairment of the AB increases with a decreasing interval between T1 and T2 and shows a maximum around 200ms – 300ms. The time course of a typical AB experiment is illustrated in figure 4.

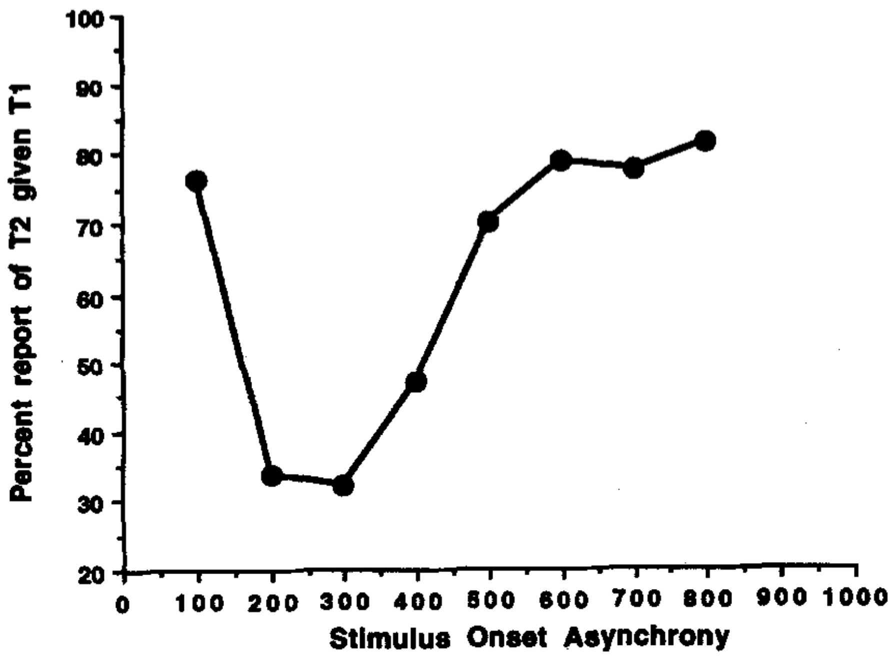

Figure 4: A typical distribution of the AB. The vertical y-axis displays the percentages of correct reports of T2, given a correct report of T1. Apart from the first 100 ms, report performance is a function of the temporal distance (lag) between T1 and T2. (Taken from (Chun & Potter, 1995).

The AB dual task requirement offers a possibility to study the processing of affective stimuli in conditions with limited attentional resources. Thereby, the time course of the AB seems to be an analogy of available attentional resources. In this design all stimuli are presented at the same spatial location in a rapid sequence. The temporal relationship of target stimuli can be varied within certain time limits as well as their affective connotations (Di Lollo, Kawahara, Shahab Ghorashi, & Enns, 2005).

Although the AB produces a stable T2 interference effect and thus, is a reliable instrument for the study of attentional interference processes, the magnitude and the time course of the AB can differ depending on the examined population. Hollingsworth found that adults with an attention deficit hyperactivity disorder show a prolonged AB blink interference (Hollingsworth, McAuliffe, & Knowlton, 2001). Moderately to severely dysphoric individuals have sustained and enhanced magnitudes of the AB (Rokke, Arnell, Koch, & Andrews, 2002). Further, the AB is found to be larger among older adults as compared to younger ones (Lahar, Isaak, & McArthur, 2001).

Theoretical approaches

After the first experiments of Raymond et al. (Raymond, Shapiro, & Arnell, 1992) deploying the AB design, several theoretical accounts of the AB have been proposed. Two of them can be assigned to the class of the inhibition theories. In the first one, the *interference model,* it is said that resources are allocated to T1 and only in diminishing amounts to the following stimuli. This model was first published in 1992. Two years later a revised version followed called the *similarity model* (Shapiro, Raymond, & Arnell, 1994). It assumes that the AB deficit occurs because of limited capacity in the visual short term memory. A second class belongs to the bottleneck theories. The *two-stage model* of Chun and Potter (Chun & Potter, 1995) proposes that the AB deficit occurs while some resources at a high-level stage are preempted by T1. This theory is commonly used to explain neurophysiological AB findings. In the *Psychological refractory period (PRP) model* it is assumed that resource limitations lead to a bottleneck at late processing stages (Jolicoeur & Dell'Acqua, 1998). Another theory is the *attentional dwell-time hypothesis.* Its leading assumption is that some kind of limited attentional resource is allocated to T1 at the expense of T2. This resource is required by both targets, but as long as T1 is processed it is unavailable for T2 (Ward, Duncan, & Shapiro, 1996).

All of the theories agree that processing of T1 depletes a limited resource with a consequent T2 deficit. This deficit is greatest at shortest inter-target lags and diminishes progressively with longer inter-target lags. Therefore, with increasing time the resource is available again as processing of T1 is nearly finished. One problem is that some studies report a lag 1 sparing. This means that identification of T2 is unimpaired if it is presented in the shortest lag 1, directly after T1. The identification impairment of T2 reappears in the following lag 2. Trying to find a solution, an attentional gate is postulated (Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992), which opens rapidly when T1 is detected but closes slowly allowing the next stimulus (in lag 1) to gain entrance. Several studies gave evidence of this early gating of perceptual features reaching awareness. Another explanation is given by the *temporary loss of control (TLC) model*. In their theory Di Lollo, Kawahara, and coworkers (Di Lollo, Kawahara, Shahab Ghorashi, & Enns, 2005) state that a temporary loss of perceptual control occurs in the process of target identification and not a depletion of a limited resource. The limitation in their model does not exist because of the amount of available attention but on the number of tasks which can be performed at the same time. In this view, the restricting factor is the type of configuration of the stimuli, not the number of them.

Recent studies examining affective processing have successfully applied the paradigm. The AB is diminished by factors that increase perceptual salience (Anderson & Phelps, 2001; Chun & Potter, 1995; Jiang & Chun, 2001; Raymond, Shapiro, & Arnell, 1995). This design affords a characterization of stimulus salience in terms of the degree of attentional resources necessary for perceptual report. Another example of recent research is a study by Keil and Ihssen using affective words as targets (Keil & Ihssen, 2004). They found that the AB impairment is significantly alleviated for affective highly arousing words used as target stimuli and this effect is not attributable to other stimulus factors. In their experiment it is the arousal and not the valence of the stimuli that is responsible for the AB sparing. Anderson (Anderson, 2005) also points out that the level of arousal determines increase or decrease of attentional premises for awareness and thus determines perceptual experience.

In the presented study, the AB design is employed to vary the temporal proximity of the targets as well as the valence and arousal level of the T2s. As stimuli are colored pictures and T2s particularly depict humans, it is interesting to see whether the AB impairment is diminished by highly arousing T2s of both valences as found in studies using verbal material.

Memory for briefly glimpsed pictures

Examining the attentional interference of affective pictures, I will further outline some important findings of picture processing and memory. People's average eye fixation frequency can be as fast as 3 per sec (Yarbus, 1967) studying a picture of a scene. With each fixation only a partial view of a picture is scanned. Biederman (Biederman, Mezzanotte, & Rabinowitz, 1982), asking participants to identify objects within a scene, even found that meaning and layout are assessed at durations as fast as 50 – 150 ms. Potter (Potter, 1976; Potter & Levy, 1969), using a picture presentation rate of 3 per sec, similar to the scanning rate of Yarbus, demonstrated that recognition memory for pictures is a positive function of exposure duration of the stimuli during initial viewing. He also found that the content of complex visual scenes can be extracted by untrained participants even if these are presented with a high frequency of more than eight pictures per second. Additionally, he examined differences in picture identification employing both a detection task and a recognition task (Potter, 1976). In the former, participants had to view a sequence of pictures and to press a button when the target picture appeared. In the latter, the target picture had to be detected amongst others after the sequence. He found that more information processing is needed to remember a picture for a recognition task than to identify a picture in a distractor stream. This means that detection can be accomplished with only partial picture processing while in recognition tasks the stimuli have to be processed more extensively. Intraub (Intraub, 1999) also assumes that poor memory retrieval following rapid presentation is caused by limitations on memory rather than on perception.

Goal of the present study

The main goal of the present study is to further the understanding of how affective cues are processed. Empirical findings are often inconsistent proposing either facilitation or inhibition of behavioral responses to pleasant or unpleasant stimuli. The approach of this study is to extend findings by adding behavioral measures of affective stimuli.

The AB design is used as a tool. Thereby, the temporal proximity of the targets as well as their valence and arousal level will be varied. First targets (T1s), depicting neutral pictures, should be reported nearly error free (Raymond, Shapiro, & Arnell, 1992; Shapiro, Raymond, & Arnell, 1994). The report of second targets (T2s) is normally impaired if they are presented within 200 – 500 ms after the onset of T1 (Raymond, Shapiro, & Arnell, 1992). It is of interest, whether the impairment remains as T2s depicting human beings vary in their hedonic valence and arousal level. If affective stimuli are privileged for processing, then affective significant events should modulate the magnitude and time course of the AB, attenuating the impairing effects of the decreasing interval between T1 and T2. The arousal theory would predict that interference of T2 processing diminishes with the arousal-level of affective pictures.

Furthermore, the design disentangles the perception of the affective stimuli from immediate speeded motor response to target stimuli. The role of ongoing affective stimulation on attentional processes and dual task-interference is examined in a non-speeded recognition task following each picture stream. Affective pictures have to be processed extensively in order to memorize them for the following retrieval task (Potter, 1976).

Hypotheses

[1] According to theoretical assumptions and the results of previous studies, resources are limited when two stimuli have to be processed in close temporal proximity. T1 being the first target to process will be unimpaired by this fact. I expect that T1 will be identified without any constraints and reproduction accuracy rates will be high and similar across lags.

[2] Across lags (lag 2, 4, and 6), I hypothesize to find an overall increase in T2 accuracy rate as well as a decrease in response time. This tendency reflects the AB deficit that increases with a decreasing interval between T1 and T2.

[3] I assume that highly arousing visual stimuli, which have high motivational relevance, will facilitate sensory processing (higher hitrate values and shorter response times). By manipulating both the valence and arousal level of the second target (T2), it is possible to examine the targets influence on the AB. If high arousal is associated with reduced dependence upon a resource limited encoding stage, then both pleasant and unpleasant highly arousing pictures show an attenuated AB relative to neutral low arousing pictures. If the valence level is critical, then the degree of AB sparing should be greatest for either pleasant or unpleasant pictures.

[4] Additionally, it is expected that regardless of affective category and lag there will be no effect of T2 position within the recognition matrix (for T2 accuracy as well as for T2 response time).

II. METHOD

Participants

Forty-four volunteers, recruited at the University of Konstanz, participated in two similar versions of the experiment. They either received course credit or were paid € 5.00 per hour for participation. After the testing of fourteen women (first data set), an additional variable was introduced in data collection. Thirty students were tested with the modified version of the experiment (second data set). The data of four students from this modified version was excluded from further analysis because of technical problems during data collection. Preliminary data analysis showed no significant effects between the two versions, therefore both data sets were combined again for analyses (see design and results). The run of the experiment was the same for participants in both versions. The remaining 40 students, 27 women and 13 men, constitute the final sample. Their ages ranged from 19 to 49 years (M= 24.5, SD= 4.8). All except one student were right-handed. Participants reported normal or corrected-to-normal vision. None had participated in a similar experiment before, nor seen the stimuli.

Materials, stimuli and display parameters

Both versions of the experiment used the same materials, display and stimuli.

An informed consent form provided information about data-processing and reminded participants about the possibility to discontinue any time during the experiment. In a personal information questionnaire age, gender, handedness, and vision of the participants were assessed, as well as neurological and psychiatric disorders and incidences of epilepsy of family members and the participants themselves. Only participants without a family history of photic epilepsy were allowed to participate. The State and Trait Anxiety Inventory (STAI; (Laux, Glanzmann, Schaffner, & Spielberger, 1981) was used in the German paper and pencil version.

The experiment was conducted on a PC running Presentation ® software (Version 0.76 built 11.30.03, www.neuro-bs.com). Stimuli were displayed centrally on a grey screen of a 19 inch monitor with a refresh rate of 75 Hz. Color setting was True color (32 bit). Participants viewed the display binocularly at a viewing distance of approximately

45 cm. Target stimuli and distractors were colored photographs. They were edited to fit the same size of 326 pixels width and 244 pixels height with a screen resolution of 1024 x 768 pixels subtending visual angles of 14° in width and 11° in height.

In the experiment, two target pictures were embedded in a stream of distractors.

- First targets (T1s) were 78 neutral pictures, each displaying one or two hands. Thereby one to maximum five outstretched fingers were shown on each picture. All T1 photos had a unicolored background. They were either self-made (55 pictures) or chosen from public digital picture libraries (23 pictures).
- The 180 second targets (T2s), showing people in different situations, were exclusively selected from the International Affective Picture System (IAPS) based on their valence and arousal ratings (CSEA, 1999). This T2-pool consisted of three affective categories: unpleasant highly arousing pictures, neutral low arousing pictures and pleasant highly arousing pictures. Each category consisted of 60 pictures. The 60 unpleasant highly arousing T2s depicted mutilated bodies and people involved in dangerous and/or unpleasant situations (mean valence = 2.4, SD = .7; mean arousal = 5.9, SD = .9), the 60 neutral low arousing pictures showed people in every day situations (mean valence = 5.9, SD = .9; mean arousal = 4.0, SD = .9) and the 60 pleasant highly arousing stimuli included images of happy adults and children, as well as erotic photographs (mean valence = 7.3, SD = .5; mean arousal = 5.3, SD = .9). The three affective groups were matched with respect to luminescence and complexity.
- In addition, 143 distractors were used showing landscapes, objects, art work, and food, but no people. They were also selected from the IAPS and other public digital picture libraries.
- Other 360 pictures were used as distractors in a 3 x 3 recognition matrix at the end of each trial. They matched the T2s in size, complexity, image formation, content, affective connotation, and arousal and depicted people as well. They were selected from public digital picture libraries.

Examples of pictures from the used categories are shown in figure 5.

After the experiment, the dimensions valence and arousal of a computerized version of the Self-Assessment-Mannequins (SAM; (Bradley & Lang, 1994) were used to rate the target pictures.

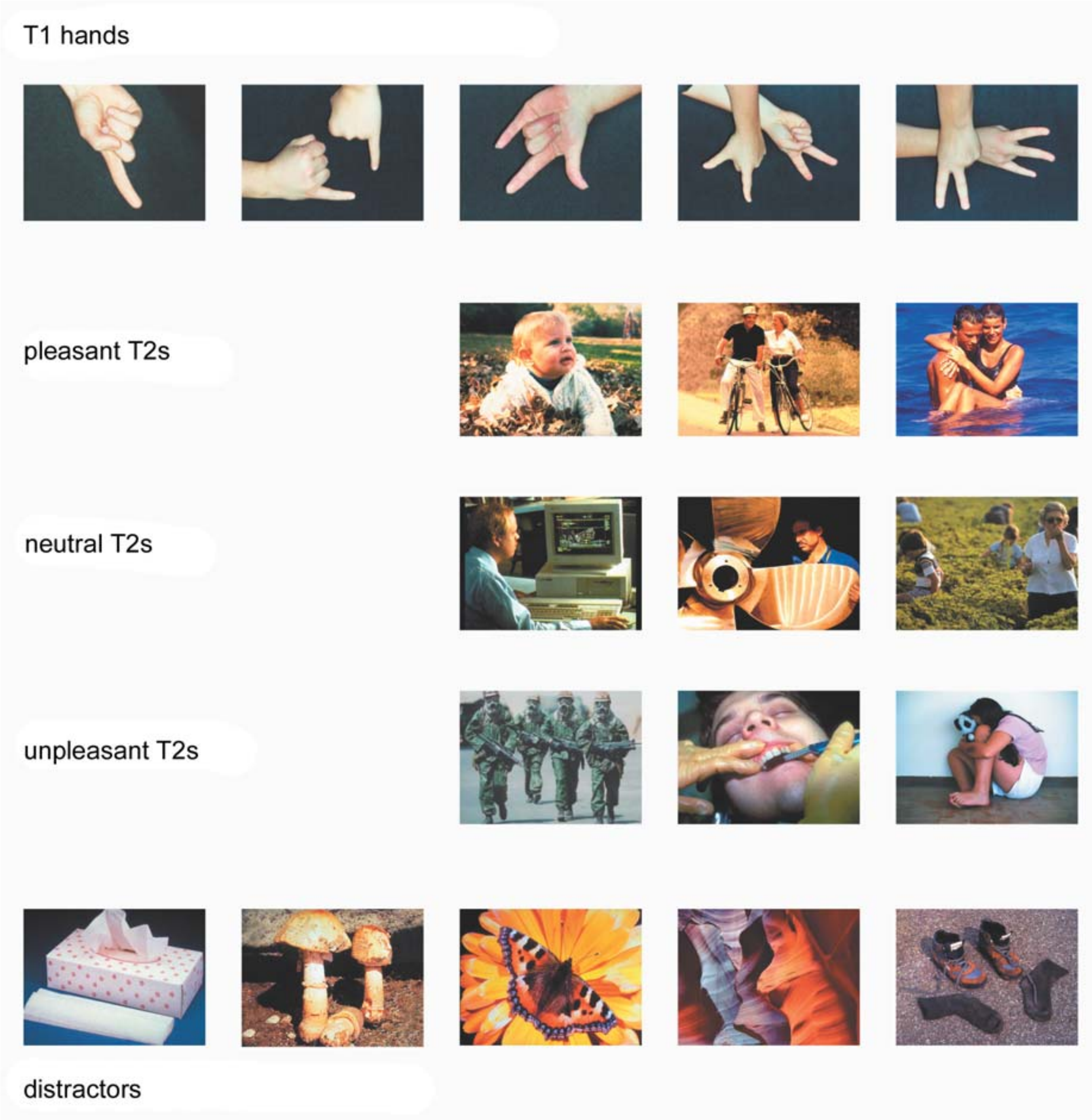

Figure 5: Examples of pictures used as T1s, T2s, and distractors in both versions of the experiment.

Design

For both variations of the experiment a rapid-serial-visual-presentation (RSVP) technique was employed. In a stream of distractors, a target 1 picture (T1) and a target 2 picture (T2) were included, in which T2 always occurred after T1. Each item was displayed for 93.3 ms, yielding a presentation rate of 10.7 Hz. In each trial a minimum of 17 pictures and a maximum of 35 pictures were presented. The number of distractors preceding T1 was determined randomly in each trial and varied between 5 and 15. This randomization was used to minimize expectancy effects of the presentation of T1. T2 was presented after one, three, or five intervening distractors after T1, resulting in three lags. The stimulus onset asynchronies (SOAs) between T1 and T2 were:

- 186.6 ms in lag 2 (one distractor between T1 and T2)
- 373.2 ms in lag 4 (three distractors between T1 and T2)
- 559.8 ms in lag 6 (five distractors between T1 and T2)

T2 was never the last item in the RSVP stream. It was followed by a random number of distractors varying between 9 and 13. A schematic outline of the display sequence of stimuli in each trial is illustrated in figure 6.

After each trial, participants had to recall T1 and afterwards to select T2 out of a recognition matrix. (For detailed description see procedure.) T2 was randomly positioned in one of the eight possible places within the matrix. Both experimental versions were identical until the T2 selection. In the first version the recognition matrix disappeared after the selection process, whereas in the second version the matrix remained. In the latter, participants had time to take a look at the pictures after the selection process. The purpose of this modification was to separate the reaction time of selecting T2 from the mere watching time of the pictures. In both versions the centered blue box remained in the middle of the screen, asking participants to start the next trial per mouse click.

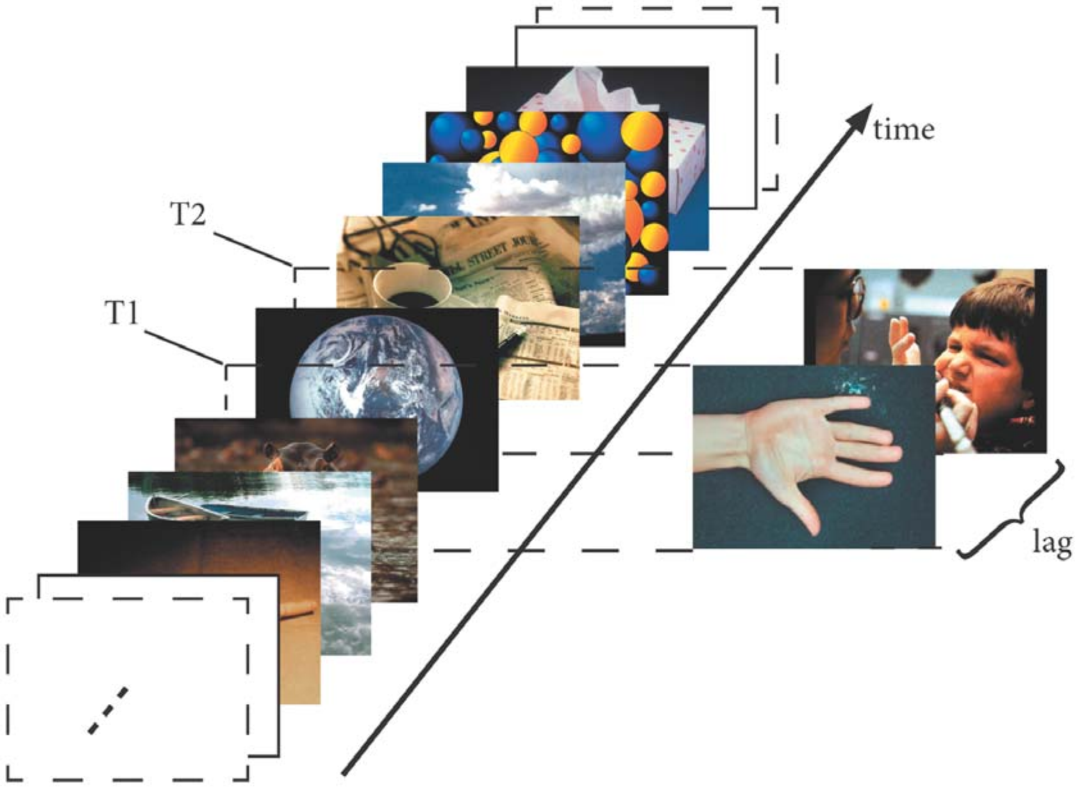

Figure 6: Schematic representation of the display sequence of events in a single trial.

The experiment consisted of two blocks. In each block the 60 pleasant, the 60 neutral, and the 60 unpleasant pictures displaying people were used as T2s. They were presented in one of the three lags (SOAs: 186.6 ms, 373.2 ms, and 559.8 ms) after the onset of T1. Thus, 20 pictures from each affective category were shown per lag. Additionally, 60 trials without a T2 were added for manipulation check. In these control trials T2s were replaced by distractors. Including theses 60 control trials, one block consisted of 240 trials. For illustration see figure 7. Presentation order of the affective categories was randomized across trials. Pictures from each affective category were selected randomly as well, without replacement within a block. T1s were also selected randomly.

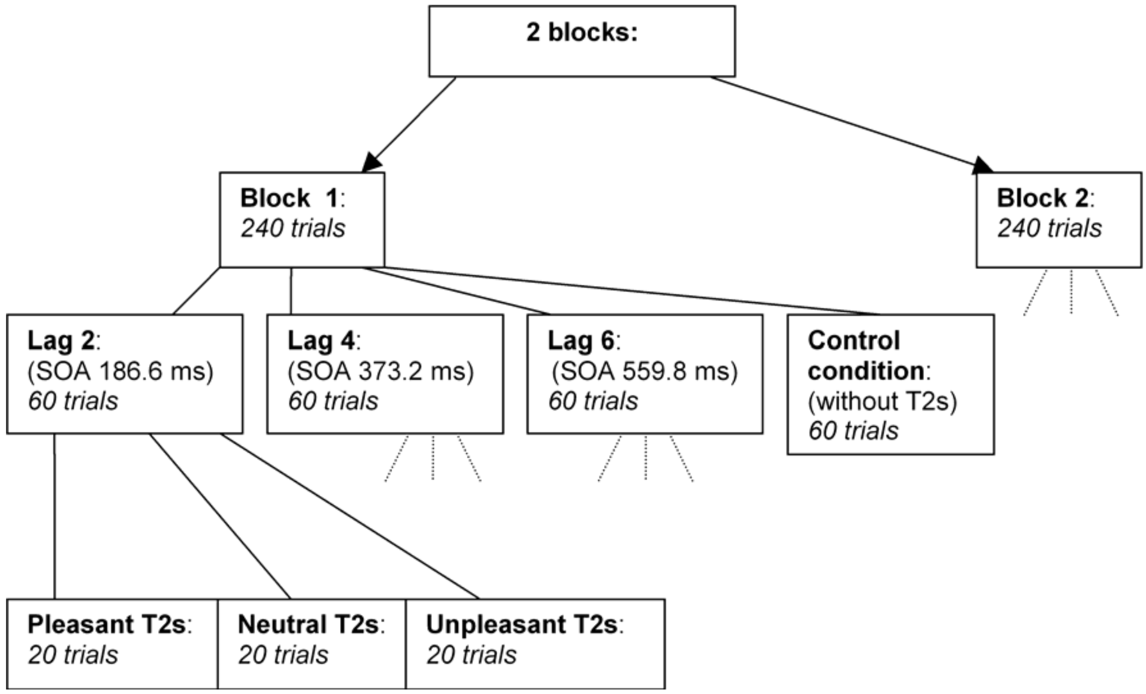

Figure 7: Schematic illustration of the experimental design of the study.

Procedure

Participants were tested individually and completed all tasks in a single session lasting about two hours, depending on participants' speed. Upon arrival in the laboratory, participants signed an informed consent form and completed a personal information questionnaire, as well as the STAI. The STAI records the state and trait anxiety of participants. State anxiety is seen as a temporary emotional state, whereas trait anxiety defines a stable personality trait. Participants received spoken and written instructions. They completed six RSVP test trials to familiarize themselves with the task. Target pictures in these practice trials were not used in the experiment. The experimenter started the first block and left the room when participants had no further questions regarding the procedure. Participants had a dual task in each trial. They had to monitor the RSVP stream for the two targets as instructed. At the end of each trial they were asked to recall the number of fingers (T1) seen in the stream and to press the corresponding key (1, 2, 3, 4, or 5) on the keyboard. If they couldn't remember, they pressed the left mouse button. Next, a 3 x 3 recognition matrix appeared displaying eight affective pictures placed around a centered blue box with the inscription "I didn't see a picture with people". Participants had to detect and select the picture with people (T2) seen in the RSVP stream among the eight pictures in the matrix or to choose the centered blue box. Selection was performed with a mouse click. Participants were told that each trial would contain a picture with one or two hands (T1), but there would not always be a picture showing people (T2). In the first version of the experiment, the recognition matrix disappeared after the selection process, whereas in the second version it remained. The centered blue box remained in both versions. Merely its inscription changed through the selection process into “Click here to start the next trial”. Participants initiated each trial without any time constraints. After 240 trials a grey text field appeared with the note “You have reached the middle of the experiment. Please call the experimenter.” Participants were allowed to take a short break. When ready, they started the next block with a mouse click. Altogether, participants completed two blocks, each consisting of 240 trials. They needed about 40 minutes per block.

After the experiment, participants were asked to rate the 120 T2s and 15 randomly selected T1s on the dimensions valence and arousal using a computerized version of the SAM. Initially, participants read a short instruction and viewed an example on the computer monitor together with the experimenter. The pictures were displayed above the SAM-scales. First, the valence scale was shown for each picture, and afterwards the arousal scale. In SAM the various states of valence are indicated by five graphical Mannequins with facial expressions ranging from a frown (unpleasant) to a broad smile (pleasant). The arousal scale depicts the five Mannequins in states of agitation varying from low to high. For illustration see figure 8. Participants selected one section of the 9-point scale (five figures and four boxes in between) for each dimension by moving a green dot with the mouse. The final selecting mouse click changed the color of the dot to red. Each selection could be corrected by pressing the right mouse button. The next picture appeared through a further mouse click. Participants rated the target pictures without any time constraints. They needed approximately 20 minutes.

Finally, participants’ questions regarding the experiment were answered and they were paid.

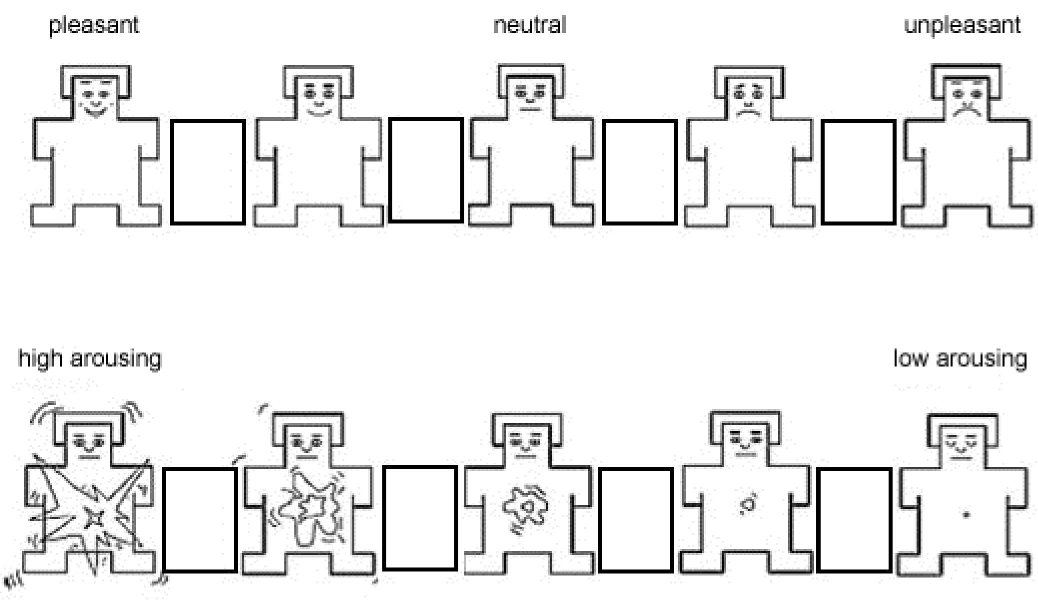

Figure 8: The valence-scale (above) and the arousal-scale (below) of the Self-Assessment-Mannequins (SAM; (Bradley & Lang, 1994). One section on every 9-point scale (five Mannequins and four boxes in between) had to be selected by participants. This rating procedure was performed for every target picture.

Data analysis

Data from 40 participants was retained for analyses. A 3 (affective category: unpleasant highly arousing, neutral low arousing, and pleasant highly arousing) x 3 (SOA: 186.6 ms, 373.2 ms, and 559.8 ms) within factorial design was conducted.

The following independent variables were varied within each participant:

- Time difference (*lag*) between the onset of T1 and the onset of T2 (SOAs: 186.6 ms, 373.2 ms, and 559.8 ms)
- *Affective category* of T2 (unpleasant highly arousing, neutral low arousing, and pleasant highly arousing) and c*ontrol condition* (no T2 was shown)
- *Position of T2* within the recognition matrix (left, middle, right)

Dependent measures were:

- *Display time:* The display time of the picture recognition matrix was measured as the time difference between the selecting mouse click of T2 and the mouse click, starting the following trial. This variable was only assessed in the modified version of the experiment. Display times (ms) were calculated for affective category, lag, and control condition.

- *Identification accuracy of T1*: Percentages of correct responses for T1 were calculated for affective category, lag, and control condition.
- *Identification accuracy of T2*: T2 accuracy was measured as a function of lag and affective category that required the report of T1 and T2. Therefore data from trials with inaccurate responses to T1 were excluded from analysis. Percentages of correct responses for T2 were calculated for affective category, lag, and correctly identified control condition
- *T2 response time*: Response times were measured as the time difference between the onset of the recognition matrix and the selecting mouse click. Response times below 150 ms and above 10s were regarded as incorrect and excluded from analysis. Decision times (ms) for correctly selected T2 were computed for affective category, lag, and correctly identified control condition.
- *Identification accuracy of T2 dependent on left, middle, or right display position within the recognition matrix*: Percentages of correctly selected T2 were averaged for position within the recognition matrix (3; left, middle, and right) and calculated for each affective category.
- *T2 response time dependent on left, middle, or right display position within the recognition matrix*: Response times were measured as the time difference between the onset of the recognition matrix and the selecting mouse click. The criterion for included responses was the same as for T2 response time: Response times below 150 ms and above 10s were regarded as incorrect and excluded from analysis. Decision times (ms) for correctly selected T2 were averaged for position (3; left, middle, and right) and calculated for each affective category.

Because of software problems, some trials were incompletely recorded. These fragmentary trials were excluded from analysis. The remaining trials were monitored for potential systematic effects. The number of intact trials per lag and category were subjected to repeated measures ANOVA. No effects of lag or affective category were found. A mean number of 430 trials (SE = 8.58), with a minimum of 289 and a maximum of 480 trials, were intact across participants and included in analysis. The mean number of intact trials per affective category and lag are shown in table 1.

A	Affective category of T2	Mean	Std. Error
	pleasant highly arousing	108.23	2.08
	neutral low arousing	106.55	2.30
	unpleasant highly arousing	107.63	2.15

B	Lag	Mean	Std. Error
	lag 2 (SOA: 186.6 ms)	108.40	3.08
	lag 4 (SOA: 373.2 ms)	107.33	2.14
	lag 6 (SOA: 559.8 ms)	106.68	2.42

C	control condition (without T2)	107.63	2.18

Table 1: Mean and standard error of intact trials across participants (N = 40). A: Intact trials per affective category of T2 (pleasant highly arousing, neutral low arousing, unpleasant highly arousing). B: Intact trials per lag (SOAs: 186.6 ms, 373.2 ms, and 559.8 ms). C: Intact control condition trials.

Dependent measures (see above) were averaged across participants. For all, a repeated measures ANOVA with Greenhouse-Geisser correction was conducted with the within factors lag (3 SOAs: 186.6 ms, 373.2 ms, and 559.8 ms) and affective category (3: unpleasant highly arousing, neutral low arousing, and pleasant highly arousing), and the between factor gender. All follow-up pair wise comparisons were corrected with Bonferroni. Follow-up ANOVAs, computed for significant interactions, were corrected with Greenhouse-Geisser as well.

Data of control conditions, used for manipulation check, were compared with the data of affective categories averaged across lags using the paired-sample T-test. Thus three comparisons were conducted (unpleasant T2 group – control condition, neutral T2 group – control condition, and pleasant T2 group – control condition).

The SAM - *ratings of the target pictures* (T1s and T2s) were averaged across participants' responses on the dimensions valence and arousal. Mean values of the two dimensions were subjected to a One-Way ANOVA with the within subject factor affective category (4; unpleasant highly arousing, neutral low arousing, and pleasant highly arousing T2s, and neutral T1s).

To control for effects produced by the emotional state of participants, *STAI values* of each participant were calculated, for state and trait anxiety separately. The higher the values in the STAI parts, the higher the corresponding anxiety. Further, a response quotient for participants' T2 accuracy rates and T2 response times was calculated by dividing results of unpleasant T2s by results of pleasant T2s, for each lag separately. This ratio between unpleasant and pleasant responses should disclose differences in response pattern of both highly arousing categories. Then, STAI values for state anxiety as well as for trait anxiety were correlated with the response quotients of T2 accuracy and T2 response time, for each lag separately. For correlation a two-tailed Spearman's rho was computed.

Statistical significance for all tests was evaluated at the .05 level.

III. RESULTS

Display time of the recognition matrix – The reason for combining both experimental versions

This variable was assessed only in the second version of the experiment ($N = 26$), and not in the first version ($N = 14$).

No effects were found regarding the mean display times averaged across participants. This variable was the only difference between both versions of the experiment. Therefore it was possible to combine both versions for further analysis ($N = 40$).

Identification accuracy of T1

There was a significant main effect of LAG ($F(2,76) = 3.261$, $p<.05$). No effects of T2-category or gender were observed regarding the identification accuracy of T1 (figure 9). The test of within-subjects contrasts showed a linear tendency for lag ($F(1,38) = 6.45$, $p<.05$). The mean accuracy rate for T1 across affective categories differed significantly ($p<.05$) between the shortest lag 2 ($M = 72.29\%$, $SE = 1.40$) and the longest lag 6 ($M = 75.21\%$, $SE = 1.04$). Lag 4 ($M = 74.31\%$, $SE = 1.45$) did not differ significantly from lag 2 or 6.

T1 identification rate was high in the control trials with a mean identification rate of 75.49% ($SE = 1.17$). No significant effects were found for the control condition.

Résumé: The main effect of lag for T1 identification accuracy was carried by the difference between lag 2 and lag 6. Across categories and control condition identification accuracy of T1 was consistently high.

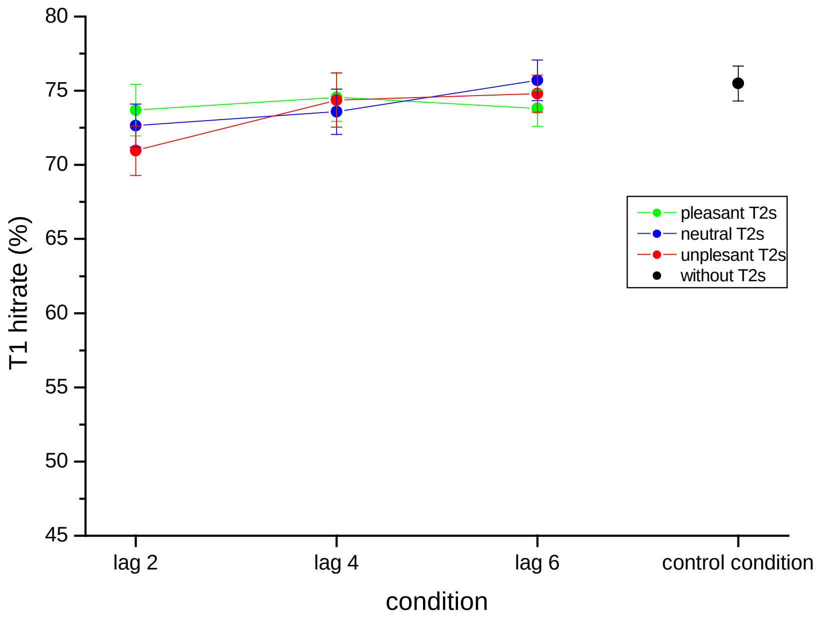

Figure 9: Mean percentages (%) of correctly reported T1s as a function of lag and picture category. Error bars represent standard error. For better inter-scale comparison, all hitrate scales of this study are presented with the same scale resolution (45% - 80%).

Identification accuracy of T2

With T2 performance conditional upon a correct response for T1, 24.51% of trials had to be excluded.

Figure 10 shows that the identification of T2 was impaired ($p<.001$) in all affective categories across the three lags (SOAs: 186.6 ms, 373.2 ms, and 559.8 ms) compared to the control condition. Correct selection rates of “no seen T2” in the control condition had a mean of 72.35% (SE = 1.61). The impairment of T2 selection was greatest in the unpleasant highly arousing group and smallest in the positive highly arousing group.

There was a significant main effect of affective CATEGORY ($F(2,76) = 41.34$, $p< .001$), with lowest accuracy for the unpleasant pictures (M = 52.23%, SE = 2.12), followed by the neutral pictures (M = 59.23%, SE = 2.05) and the positive ones (M = 62.21%, SE = 2.11). Recognition rates were significant between all three affective groups (pleasant / neutral, $p<.05$; pleasant / unpleasant, $p<.001$; neutral / unpleasant, $p<.001$). The test of within-subjects contrasts showed a linear tendency for category ($F(1,38) = 74.92$, $p<.001$).

Another significant main effect was observed for LAG ($F(2,76) = 7.24$, $p<.01$), with the shortest lag 2 ($M = 55.62\%$, $SE = 2.06$) differing significantly from the longest lag 6 ($M = 59.82\%$, $SE = 1.88$) ($p<.01$). Lowest identification rates were observed in the shortest lag 2. Lag 2 and lag 4 ($M = 58.24\%$, $SE = 2.32$) failed to differ significant from each other, but nevertheless showed a tendency ($p=.057$). The test of within-subjects contrasts showed a linear contrast for lag ($F(1,38) = 14.68$, $p<.001$).

There was also a significant two-way interaction of LAG x affective CATEGORY ($F(4,152) = 3.73$, $p<.01$). Follow-up ANOVAs for each lag revealed significant differences between the pleasant and the unpleasant highly arousing T2s in lag 2 ($p<.001$), lag 4 ($p<.01$), and lag 6 ($p<.01$). The neutral low arousing and the unpleasant highly arousing T2 groups differed significantly in lag 2 ($p<.001$), as well as in lag 6 ($p<.05$). Further follow-up ANOVAs within the affective categories showed significant effects only for the unpleasant T2 group between lag 2 and 4, and lag 2 and 6 ($p<.001$).

Résumé: All affective T2 groups differed in their identification accuracy significantly from each other. Correct control condition responses were significantly higher than for the affective groups. The main effect for lag was mainly influenced by the difference between lag 2 and lag 6. The interaction between lag and category was carried by the unpleasant T2 group, differing significantly from the pleasant T2 group in all lags, and from the neutral T2 group in lag 2 and lag 6. Furthermore the unpleasant group was the only affective group differing significantly between lags (lag 2 & 4, and lag 2 & 6).

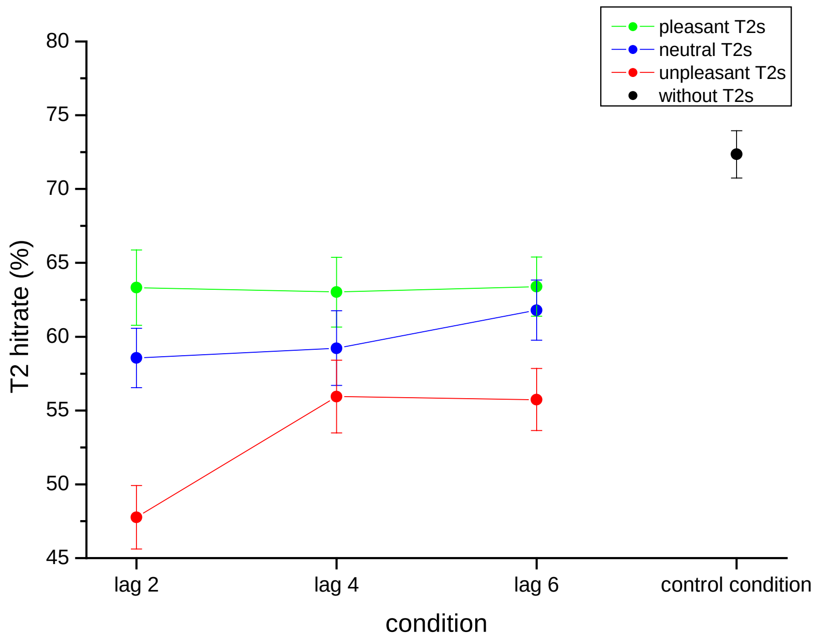

Figure 10: Mean percentages (%) of correct T2 selections, given a correct report of T1 as a function of lag and picture category, and mean percentage of correct control condition responses, given a correct report of T1. Error bars represent standard error.

T2 response time

The repeated measures ANOVA revealed significant main effects of affective CATERGORY (F(2,76) = 34.74, p<.001) and LAG (F(2,76) = 4.67, p<.05). The test of within-subjects contrasts showed a linear tendency for lag (F(1,38) = 8.37, p<.01).

Figure 11 shows that the unpleasant highly arousing T2s (M = 2041.12 ms, SE = 70.44) elicited longest response times, followed by the pleasant highly arousing pictures (M = 1810.04 ms, SE = 55.95) and the neutral low arousing ones (M = 1724.02 ms, SE = 70.44). Pairwise comparisons showed significant differences between all three affective categories (pleasant from neutral at the p<.05 level; all others at the p<.001 level). Participants responded slower in the shortest lag 2 (M = 1919.09 ms, SE = 61.49) than in the longest lag 6 (1813.81 ms, SE = 59.12) (p<.05). Lag 4 (1842.28 ms, SE = 59.12) did not differ significantly from lag 2 or lag 6.

Responses for the control condition (M = 1614.80 ms, SE = 129.99) were faster than responses for the unpleasant highly arousing group (p<.01). The other affective groups did not differ from the control condition in terms of response time.

Résumé: All affective groups differed in their response times significantly from each other. Significant impairment compared to the control condition was only found for the unpleasant T2 group. The main effect of lag for T2 response time was carried by the difference between lag 2 and lag 6.

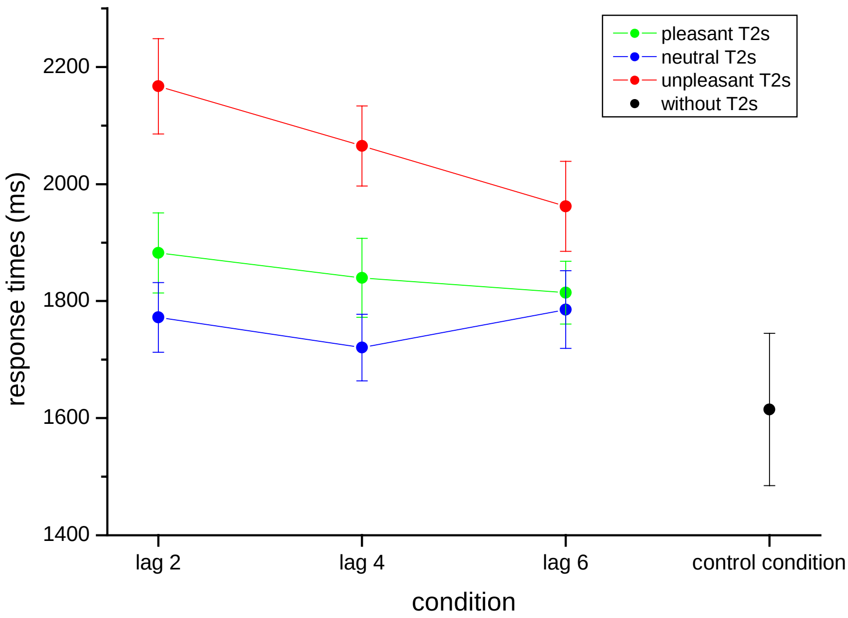

Figure 11: Mean response times (ms) of correct T2 selections, given a correct report of T1 as a function of lag and picture category, and mean response time of correct control condition responses, given a correct report of T1. Error bars represent standard error. For better inter-scale comparisons, all response time scales of this study are presented with the same scale resolution (1400ms – 2200 ms).

T2 accuracy dependent on left, middle, or right display position within the recognition matrix

Percentages of correct T2 responses were averaged for the left, middle and right position within the matrix for each affective category.

The found significant main effect of affective CATEGORY ($F(2,76) = 33.15$, $p < .001$) confirms the main effect reported in *Identification accuracy of T2*. [The test of within-subjects contrasts also showed a linear tendency for category ($F(1,38) = 59.43$, $p<.001$) underlying previous findings. Lowest accuracy rates were shown for the unpleasant picture group (M = 53.44%, SE = 2.04), followed by the neutral picture group (M = 60.34%, SE = 1.93) and the positive ones (M = 53.44%, SE = 2.04). Pair wise comparison showed that the unpleasant picture group differed significantly from the pleasant and the neutral picture group (p<.001). (In *Identification accuracy of T2*, all affective picture groups differed significantly from each other.)]

No significant main effect was observed for POSITION, only a tendency was found (F(2,76) = 2.97, p=.061). Left position showed a mean identification rate of 58.59% (SE = 1.97), the middle position a mean of 60.49% (SE = 2.07), and the right position a mean hit rate of 58.06% (SE = 1.87) (see figure 12). No interaction was found between affective category and position.

Résumé: The category effect found for T2 identification accuracy dependent on position within the picture matrix confirmed the effect found for T2 identification accuracy. The factor position showed only a tendency for the left and right position slightly differing from the middle one.

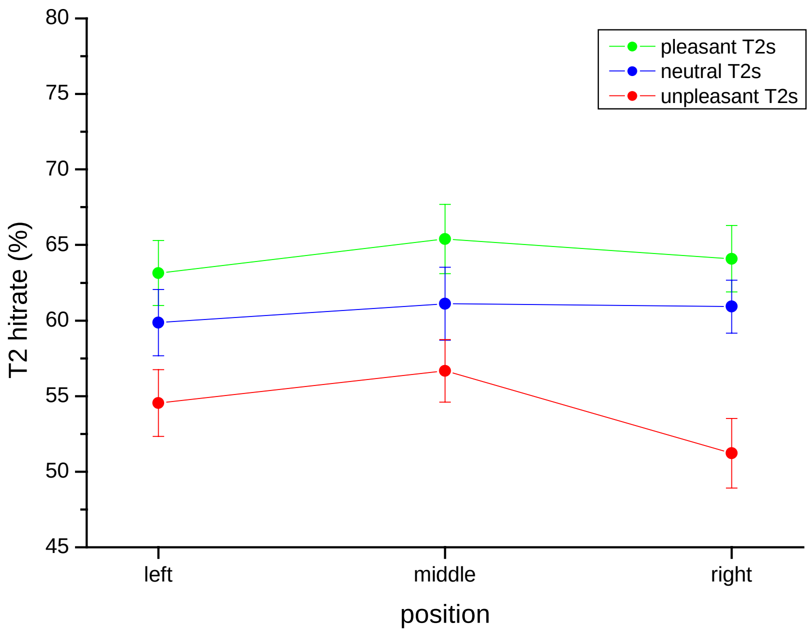

Figure 12: Mean percentages (%) of correct T2 selections separated for position, given a correct report of T1 as a function of lag and picture category. Error bars represent standard error.

T2 response time dependent on left, middle, or right display position within the recognition matrix

The repeated measures ANOVA revealed a significant main effect of affective CATERGORY ($F(2,76) = 32.08$, $p < .001$). This confirms the category effect found for *T2 response time*. [The unpleasant highly arousing T2s ($M = 2029.49$ ms, $SE = 68.45$) elicited longest response times, followed by the pleasant highly arousing pictures ($M = 1826.29$ ms, $SE = 58.25$) and the neutral low arousing ones ($M = 1733.07$ ms, $SE = 54.84$). Pairwise comparisons showed significant differences between all three affective categories (pleasant from neutral at the $p<.05$ level; all others at the $p<.001$ level), thus underlying previous findings.]

Another significant main effect was observed for POSITION ($F(2,76) = 59.00$, $p<.001$). The middle position ($M = 1630.02$ ms, $SE = 60.12$) elicited shortest response times differing significantly from the left position ($M = 1938.98$ ms, $SE = 61.76$) as well as from the right position ($M = 2019.85$ ms, $SE = 60.51$) at the $p<.01$ level (see figure 13).

Résumé: The category effect found for response time dependent on position within the picture matrix confirmed the effect found for T2 response time. All affective groups differed in their response times significantly from each other. The main effect found for position was carried by the left and the right position differing significant from the middle position.

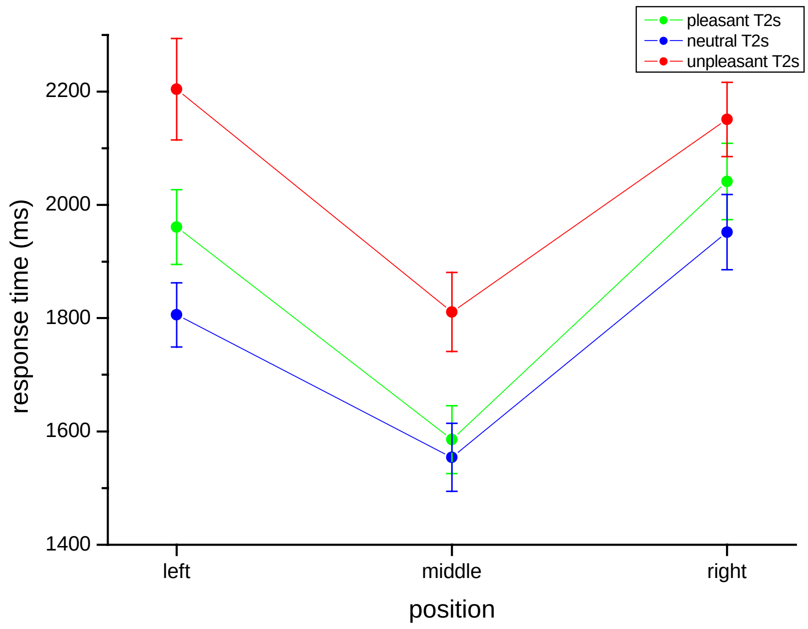

Figure 13: Mean response times (ms) of correct T2 selections separated for position, given a correct report of T1 as a function of lag and picture category. Error bars represent standard error.

Subjective Ratings

All 180 affective pictures used as T2s were rated by participants (N = 40). The ANOVA revealed significant effects for VALENCE ($F(3,191) = 534.6$, $p< .001$) and AROUSAL ($F(3,191) = 149.6$, $p< .001$). A linear decrease in self-rated valence for pleasant, neutral, and unpleasant pictures was observed. All follow-up pair wise comparisons corrected with Bonferroni were significant at the $p< .001$ level. Regarding the arousal dimension, the expected quadratic distribution was found. Participants rated the neutral pictures as less arousing than the pleasant pictures and the unpleasant ones. Pair wise comparisons were significant at the $p<.001$ level as well.

Participants also rated 15 randomly selected T1s. The valence ratings of the hand pictures differed significantly from the pleasant and unpleasant T2 categories ($p<.001$), and even from the neutral T2 picture category ($p<.01$). The arousal ratings of the hand pictures differed significantly from the pleasant and unpleasant T2 categories ($p<.01$), but not from the neutral T2 category.

The mean valence and arousal ratings of T1s and T2 groups are shown in table 2 and figure 14 and 15.

	Valence		Arousal	
Targets	**Mean**	**Std. Error**	**Mean**	**Std. Error**
pleasant highly arousing T2s	6.97	.06	4.10	.13
neutral low arousing T2s	5.66	.11	3.48	.09
unpleasant highly arousing T2s	2.33	.09	6.44	.12
neutral T1s	4.97	.02	3.27	.08

Table 2: Valence and arousal ratings (mean and standard error) of the target pictures (T1s and T2s) averaged across participants (N = 40).

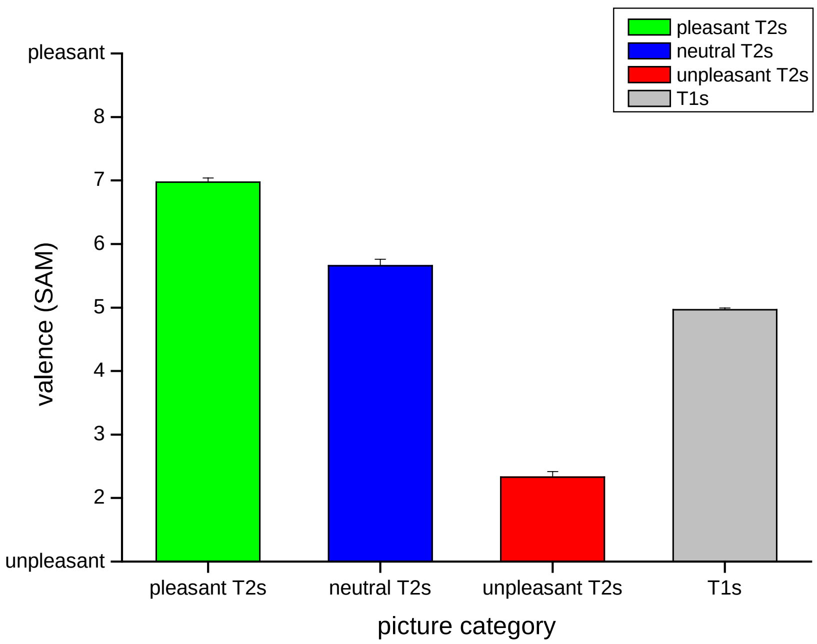

Figure 14: Mean valence ratings of the target picture categories (T1s and T2s). Error bars represent standard error.

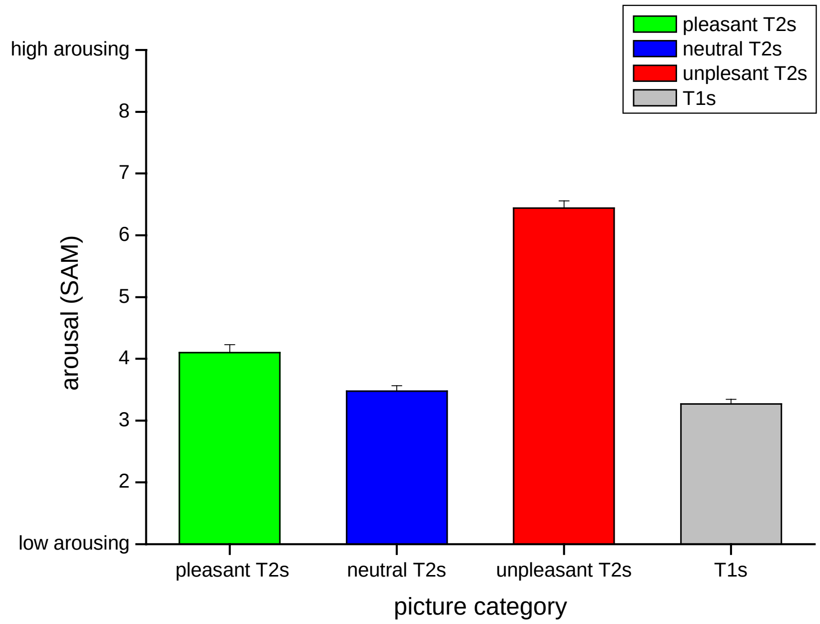

Figure 15: Mean arousal ratings of the target picture categories (T1s and T2s). Error bars represent standard error.

For better illustration of the distribution of the rated pictures see figure 16. The ratings are shown on both dimensions valence and arousal spanning the two-dimensional affective space. They are arranged in three separated clusters: one with low valence and high arousal ratings – the unpleasant T2 category, one with medium valence and low to medium arousal scores – the neutral T2 and T1 categories, and one cluster with high valence and a wider distribution of medium arousal scores – the pleasant T2 category. A polynomial regression with the arousal values dependent on the valence ratings showed a significant quadratic relationship between the parameters valence and arousal ($F(2,194) = 225.95$, $p<.0001$). This regression explains 70% of variance (R square = .70). This rating data suggests that our participants perceived the target pictures according to their affective categories, i.e. pleasant highly arousing, neutral low arousing, and unpleasant highly arousing T2 categories, and a neutral low arousing T1 group.

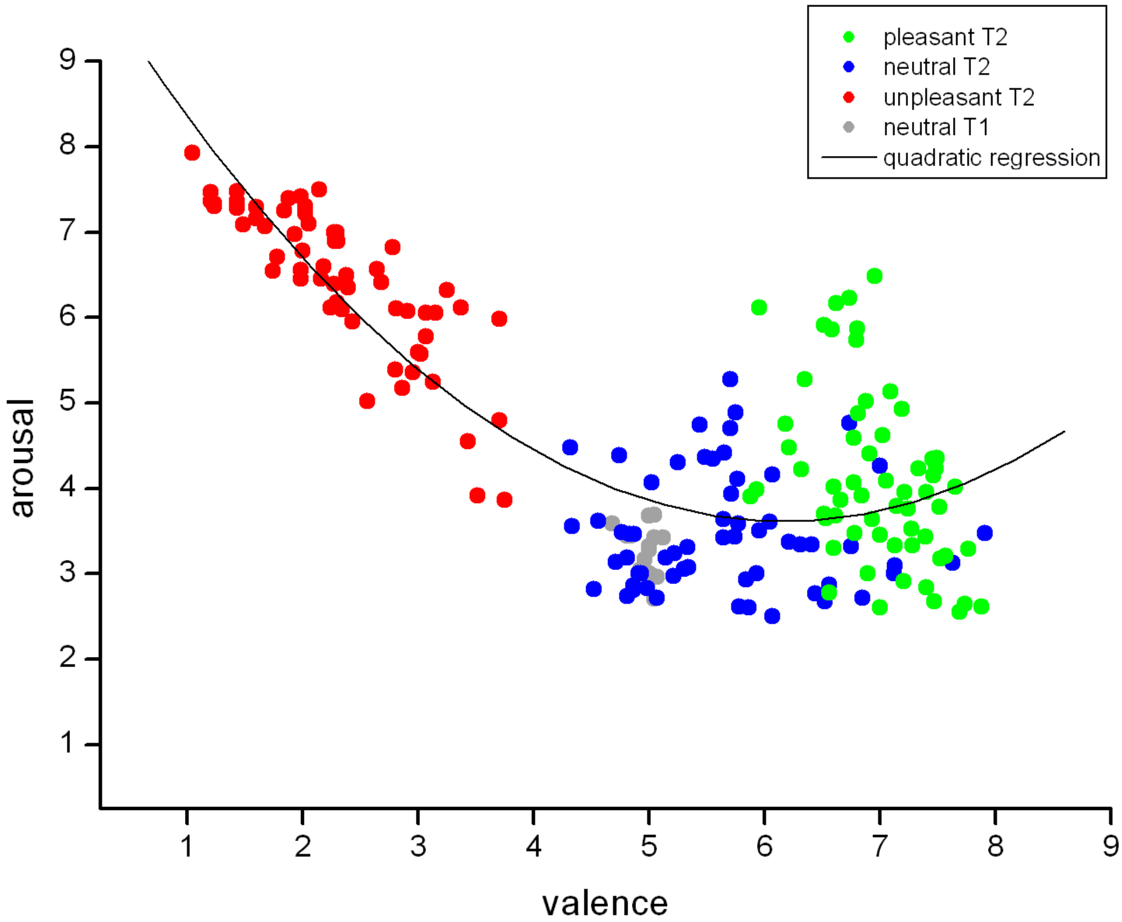

Figure 16: The affective space of T2s and T1s as rated by participants on the dimensions valence and arousal and their quadratic regression. Each dot represents a target picture with a specific hedonic valence and arousal level. Target groups used in the experiment are highlighted with different colors.

STAI values

For each participant, state and trait anxiety values were calculated. The higher the value in one of the STAI parts, the higher the corresponding anxiety. Across participants, state anxiety ranged between a minimum of 26 points and a maximum of 56 points and trait anxiety between a minimum of 25 points and a maximum of 59 points. The mean state and trait anxiety values are shown in table 3.

	State Anxiety		**Trait Anxiety**	
participants	**Mean**	**Std. Deviation**	**Mean**	**Std. Deviation**
N = 40	37.2	6.8	40	9.3

Table 3: State and trait anxiety points (mean and standard deviation) of the participants (N = 40).

Significant two-tailed Spearman correlation was only found for the T2 response time quotients in lag 2 and state anxiety values ($r = .39$, $p<.05$). This correlation suggests that the higher the scores in state anxiety the slower the response times to unpleasant T2s compared to pleasant T2s in lag 2. For illustration see figure 17.

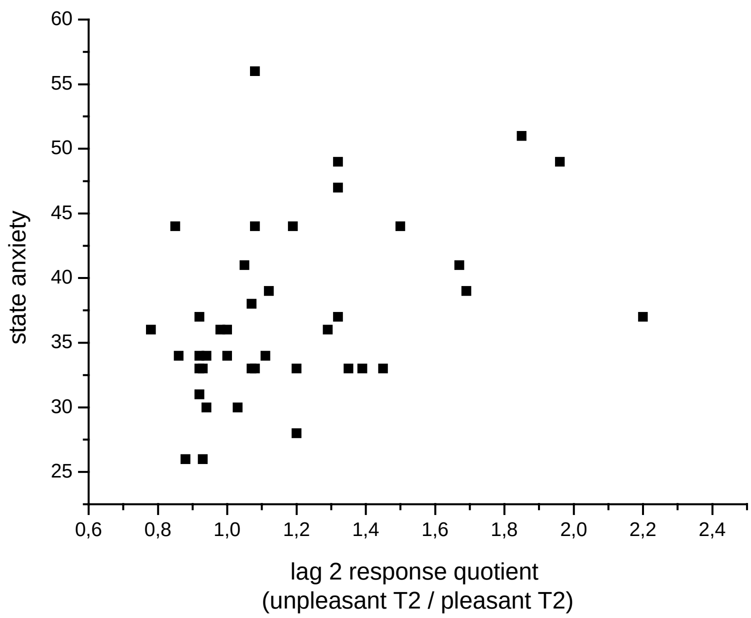

Figure 17: Distribution spanned by state anxiety values (STAI) and T2 response time quotients (unpleasant T2 response times divided by pleasant T2 response times) in lag 2. Each data point represents the response pattern of a participant.

IV. DISCUSSION

The aim of the present investigation was to provide information and to further understanding about the allocation of attentional and processing resources to affective pictures. The central question was whether affective arousing stimuli enhance or impair post-perceptual processing. This was examined in a behavioral experiment applying the attentional blink (AB) paradigm. Therein, the detection and recognition of a second target (T2) is interfered for approximately 200 - 600 ms after the successful processing of a first target (T2). It has been shown that this T2 impairment is reduced for salient stimuli (e.g. the own name Shapiro, Caldwell, & Sorensen, 1997). Thus, the AB was an adequate tool to examine the post-perceptual processing of affective stimuli. Additionally, it offered the possibility to vary the temporal proximity between the target pictures (SOAs: 186.6 ms, 373.2 ms, 559.8 ms) as well as their valence and arousal degrees. First targets (T1s), showing hands, were neutral low arousing pictures. Second targets (T2s), depicting human beings, were selected from the IAPS library based upon their valence and arousal level. Thus, it was possible to directly compare three hedonic categories: pleasant highly arousing pictures, unpleasant highly arousing pictures, and low arousing neutral ones. Participants' task was to detect both targets within a picture stream. Behavioral measures were recorded after the picture sequence. T1 had to be reproduced in a free recall task, whereas T2 had to be recognized and selected within distractors in a recognition matrix. Some picture sequences were presented without a T2. This control condition made it possible to account for effects of simple perceptual interference caused by distractor display.

Validity of stimulus material

As expected, the T2 ratings of the participants revealed three hedonic picture categories. Self-rated valence of pictures decreased linearly from pleasant to neutral and unpleasant. Self-rated arousal showed the expected quadratic distribution with the unpleasant pictures achieving highest arousal levels. Neutral pictures were less arousing than pleasant and unpleasant ones. Pleasant and unpleasant pictures also differed in terms of arousal. Thus, the ratings showed a steeper slope for unpleasant pictures indicating that the coupling of arousal and valence ratings was more pronounced for the unpleasant picture category than for the pleasant one.

The valence ratings for the T1s differed from all T2 categories, even from the neutral ones, indicating that they were less pleasant than the neutral T2s. T1s were rated as equally arousing as the neutral T2 group, differing from the pleasant and unpleasant categories.

Altogether, the rating data suggests that all T1s and T2s were experienced according to their affective category. They showed a typical distribution in a two-dimensional affective space spanned by the dimensions valence and arousal, as has been reported in previous studies for pictorial (Bradley, Codispoti, Cuthbert, & Lang, 2001), verbal (Keil & Ihssen, 2004), and auditory stimuli (Bradley & Lang, 2000).

In order to reduce variance caused by nonaffective parameters, all pictures were matched with respect to luminescence and complexity. Evidence that this matching was an important factor came from selective attention tasks: stimuli that were colorful and/or high in contrast were at a competitive advantage. Image compression (e.g. JPEG) is one visual complexity metric for complexity estimation (Buodo, Sarlo, & Palomba, 2002). The assumption is that the larger the file format after compression, the more complex the image. Thus, all target as well as distractor pictures had similar file (JPEG) sizes and luminescence. Therefore, behavioral measures in the experiment should be unimpaired by these variables.

Processing of target pictures within the AB

T1 accuracy

As hypothesized, T1 accuracy rates were consistently high and similar across all lags. Thus, the temporal proximity between T1 and T2 as well as the affective connotation of T2 had no effect on T1 processing.

The attentional blink effect

I found a modest increase of T2 accuracy ($F = 7.24$) and a modest decrease of T2 response time ($F = 4.67$) across target categories. Differences were found between the shortest lag 2 and the longest lag 6. A T2 accuracy interaction for lag and affective category revealed that these differences were carried by the unpleasant group. Accuracy rates of unpleasant T2s were more reduced in the shortest than in the longest lag, and response times were much slower in the shortest than in longest lag. This impairment for the unpleasant group lasted for all lags. Even in the longest one, the difference between the unpleasant and the other groups remained for accuracy rates.

Similar to AB studies using verbal stimuli (Anderson, 2005; Anderson & Phelps, 2001; Keil & Ihssen, 2004), I expected a high impairment across categories in the shortest lag 2 and a more obvious recovery of the behavioral measures in lag 4 and 6. Instead, mean accuracy responses were only 4% reduced for the shortest lag 2 compared to the longest lag 6 and mean response times were only 105 ms slower in lag 2 compared to lag 6. Keil and Ihssen (Keil & Ihssen, 2004) found in three studies a mean reduction of at least 30% of correct response for a short lag (SOA: 232 ms) compared to a longer lag (SOA: 696 ms). Thus, the results of the conducted study revealed an AB effect but did not show the expected robust AB interference for T2 accuracy as well as for T2 response time across categories.

T2 accuracy and response time - a valence or arousal effect?

The major question of the study was whether highly arousing pictures, which have high motivational relevance, facilitate sensory processing (higher hitrate and shorter response time within the AB interval). Therefore, three picture groups were employed as T2s: pleasant highly arousing, unpleasant highly arousing, and neutral low arousing pictures.

Recognition accuracy rates of all affective T2 groups were significantly lower than correct control condition responses (no seen T2), which showed a mean accuracy rate of 72%. This T2 impairment was smallest for the pleasant group with an average reduction of 10%, followed by the neutral group with an average reduction of 13%, and strongest for the unpleasant group with an average reduction of 20%. This reduction in recognition accuracy of all affective groups indicates that the impairment of the affective T2 groups was not only influenced by perceptual interference caused by distractor display. Further, all three affective groups differed significantly from each other, showing a linear trend with highest recognition rates for pleasant T2s and lowest rates for unpleasant T2s. These results suggest that recognition accuracy rates of T2 varied as a function of valence. Additionally, recognition accuracy rates of unpleasant T2s were still reduced in the longest lag 6, compared to the other groups. In previous studies, employing verbal stimuli, the AB interference diminished with longer lags (Anderson, 2005; Keil & Ihssen, 2004). Altogether, the data suggests a processing amplification as a function of valence, with highest accuracy rates for the pleasant stimulus category, followed by the neutral and the unpleasant ones, irrespective of their arousal degree.

Response times were significantly reduced only for the unpleasant T2 group compared to the control condition (no seen T2). Nevertheless, all affective groups differed from each other in their response times. Slowest responses were recorded for unpleasant T2s, followed by pleasant and neutral ones. Thus, evidence suggests that T2 response times were influenced by the arousal level. With longer lags, recognition times of the unpleasant picture group enhanced but were still slower in the longest lag 6 compared to the other groups. I would like to point out that the variable response time measured the decision time of participants and not a reaction time, as participants did not have any time constraints selecting T2 within the recognition matrix.

To sum up, pleasant pictures as a function of valence were processed more accurately than unpleasant ones, regardless of their arousal level. Neutral pictures were in between both groups. This suggests that the facilitation of the AB effect was specifically related to the appetitive (pleasant) content of the pictures, irrespective of a picture's emotional intensity. Response times were instead influenced by the arousal level of T2s. The distributions of the affective categories for both behavioral measures (T2 accuracy and response time) were arranged similar to the distributions of the affective categories in the corresponding dimension (valence or arousal) of the rating data. The linear valence decrease found for T2 ratings was also observable for T2 accuracy rates. Even the average distances between the affective categories seemed equidistant. The quadratic arousal distribution observed for T2 ratings was also seen in the T2 response time data. The average distances between the affective categories seemed to be alike. Additionally, for both T2 accuracy and response time, the unpleasant picture category may have played a crucial role. Defensive (unpleasant) content was associated with a high impairment of recognition and response time, with the strongest reduction of recognition accuracy and slowest response times at the shortest T1-T2 lag. This impairment gradually diminished to some degree with increasing lag but was still detectable in the longest lag 6 compared to appetitive and neutral picture content.

This special role of the unpleasant pictures category may be due to the arousal level of this category. Evidence arises from studies applying the startle response paradigm (Cuthbert, Bradley, & Lang, 1996). Therein, the startle reflex was enhanced if participants viewed unpleasant stimulus material, whereas the reflex was reduced if they viewed pleasant material. This pattern was only found for highly arousing affective stimuli with arousal scores of at least 6 points on the nine point SAM scale (CSEA, 1999). Thus, this threshold was crucial for the activation of the stimuli congruent motivational systems (defensive or appetitive). In the presented study all three affective groups differed significantly from each other in terms of arousal. Pleasant T2s had a mean arousal level of 4.1, neutral T2s a mean arousal of 3.5, and unpleasant ones a mean arousal of 6.4. Only the unpleasant picture group showed scores above the threshold, and respectively, it may be that only the defensive motivational system was activated in the conducted experiment. From this point of view, it remains questionable whether the pleasant picture group would have shown the same facilitation pattern of recognition times, if this picture category had met the arousal threshold.

T2 accuracy and response time dependent on left, middle, or right display position within the recognition matrix

Analysis confirmed the above reported effects found for T2 accuracy and response time, independent of T2 position.

As expected, no effect of T2 position was found for accuracy rates. This means that T2 accuracy rates were uninfluenced by the display position within the recognition matrix, irrespective of affective category or lag. However, a response time effect was detectable for the left and right position, differing from the middle one. Selections in these border positions were slower than the ones for the middle position. Responses to T2s in the right position were in average 390 ms slower than responses to the middle position, and responses to T2s in the left area were in average 309 ms slower compared to those in the middle position. Thus, my hypothesis to find no response time effect of T2 position was not confirmed.

Two reasons may be accountable for this effect. First, the mouse pointer always appeared in the center of the recognition matrix. This may have directly influenced the response times, as T2s in the middle were faster to reach because of the close spatial distance of those stimuli compared to pictures in the upper and lower left as well as pictures in the upper and lower right area. Second, all stimuli in the experiment were displayed centrally on the monitor and participants' eyes were adjusted at this position. This may have affected the retrieval strategy for T2s, starting the searching processes in the middle of the recognition matrix.

STAI values and their implications for behavioral responses

STAI scores for state and trait anxiety were assessed prior to the experiment to control for effects produced by the motivational state of participants. Scores of both scales can range between 20 and 80 points. Their values are directly interpretable: high scores on their respective scales mean more trait or state anxiety and low scores mean less.

Participants' state anxiety ranged between 26 and 56 points and their trait anxiety between 25 and 59 points. A correlation was found between the state anxiety values and T2 response time quotients (response times of unpleasant T2s divided by response times of pleasant T2s) in lag 2. No correlation was found for the other lags or for trait anxiety values. This means that participants with high scores in state anxiety responded slower to unpleasant T2s compared to pleasant T2s in the shortest T1-T2 lag, than participants with low state anxiety scores.

The data suggests that participants which were in an anxious mood, possibly caused by the unfamiliar experimental setting, showed an enhanced response time sensibility to the unpleasant stimulus material in the shortest lag 2.

General Discussion

With respect to theoretical accounts of the AB effect, the interferences at post-perceptual stages has been found to be crucial for the AB occurrence (Isaak, Shapiro, & Martin, 1999). According to the two-stage model (Chun & Potter, 1995), both highly arousing pleasant and unpleasant stimuli gained entrance into stage one and thus, both groups are detected fast at this early stage. In the second stage, the data indicated that appetitive content facilitated elaboration and consolidation in memory to make the information available for behavioral responses, as pleasant pictures as a function of valence were associated with greater accessibility in memory. Jolicoeur (Jolicoeur & Dell'Acqua, 1998), adopting a more general perspective, suggested that short-term consolidation processes are responsible for interference effects such as the AB. He further assumed that in addition to the consolidation of T1, other processes such as response selection and retrieval from long-term memory can cause the interference of T2 consolidation. In terms of the present data, it seems that pleasant affective stimuli as a function of valence were processed more efficiently. Nevertheless, it remains debatable why the consolidation of pleasant pictures as a function of valence at later stages was facilitated.

Comparing the present data to findings of previous studies employing affective verbal stimuli in an AB design, the results are contradictory (Anderson, 2005; Anderson & Phelps, 2001; Keil & Ihssen, 2004). In the latter, it was found that affectively arousing pleasant and unpleasant T2s were associated with an enhanced accuracy compared to low arousing neutral stimuli within the AB interval. This facilitation pattern of affectively arousing verbal material was assumed to reflect the well learned nature of word material of both valences with respect to representational network models of affective perception (Lang, Bradley, & Cuthbert, 1998). Pictures in contrast, being more complex and realistic to natural environment (Kindt, Brosschot, & Boiten, 1999), may require a more elaborated processing and thus show other processing patterns than verbal stimuli.

Another reason for the recognition impairment of the unpleasant T2 category compared to the other ones may be due to poorly distinguishable picture content of the unpleasant T2s. Although the affective groups were matched with respect to luminescence and complexity, it may be possible that the unpleasant pictures were more diffuse and thus more difficult to detect.

The presented study found an enhanced processing of pleasant pictures as a function of valence compared to unpleasant T2s. This pattern seems contradictory to an evolutionary facilitated detection of significant affective stimuli (e.g. Lang, Bradley, & Cuthbert, 1997; Öhman, Flykt, & Esteves, 2001) but considering the employed experimental designs, this difference unravels. In the presented study a recognition task was used. Studies employing other experimental designs (e.g. visual search tasks), found a superior attention grabbing effect of unpleasant stimuli (Hansen & Hansen, 1988; Öhman, Flykt, & Esteves, 2001). Therein, defensive contents were detected faster and were more accurately processed than appetitive contents. This detection facilitation effect of evolutionary relevant stimuli is not inconsistent to my findings, as for a detection task the stimulus material does not have to be processed in detail (Pratto & John, 1991). More information processing is needed to remember a picture for a recall or recognition task than to identify a picture in a distractor stream by immediate motor response (Potter, 1976). Also, Intraub (Intraub, 1999) assumed that poor memory retrieval following rapid presentation is caused by limitations on memory rather than on perception. Thus, unpleasant stimuli may be detected faster, but in a recognition task, when detailed cognitive analysis is required, unpleasant content may need a prolonged processing.

Regarding the response time impairment of unpleasant T2s, a study of Leppänen and Hietanen (Leppänen & Hietanen, 2004) seems to be in line with the results of the conducted study. Applying a choice reaction time task, they found a recognition time advantage of pleasant (happy) faces. Admittedly, they did not find a difference regarding the recognition accuracy between happy and disgusted faces, reasoning that their results reflected a faster processing of happy faces rather than a response bias toward them. In contrast, my data indicated a recognition bias toward appetitive content as these stimuli were better recognized and faster processed than defensive picture content. Still, Leppänens' assumption may be transferable to my findings as in his study pleasant content was also processed faster than unpleasant ones. The authors assumed that pleasant stimuli are more often encountered in everyday life and thus more effectively processed than low frequency stimuli, due to higher baseline activation of the corresponding processing unit (McClelland & Rumelhart, 1981). Taylor (Taylor, 1991) observed a similar response time slowing for unpleasant cues, proposing the mobilization-minimization hypothesis. Therein, he argued that the mobilization of the organism, evoked by negative events, is followed by complex response patterns minimizing the impact of these events. Thus unpleasant stimuli required a more detailed and delayed cognitive processing than pleasant ones, which may have deferred the recognition of unpleasant pictures.

The human defense cascade model (Lang, Davis, & Ohman, 2000) can account for this response time impairment of unpleasant T2s. Therein, delayed responding for unpleasant pictures in a recognition task reflects a post-encounter motor inhibition. This indicates an orienting behavior to gain more information. Bradley and collaborators observed that human responses to unpleasant pictures is analogous to the freezing behavior of animals, when these are confronted with potential threats (Bradley, Codispoti, Cuthbert, & Lang, 2001). In this state an orientation to the sensory input takes place. Contextual details are processed, as well as a retrieval of relevant information from memory, implicitly preparing for a possible action. By contrast, responding should not be impaired due to the high amount of attention allocated to unpleasant stimuli in the pre-encounter phase. Thus, highly arousing unpleasant T2s may have prompted a freezing analog state in participants, indicated by the slow recognition times of unpleasant T2s. Also, Jolicoeur and Dell'Acqua (Jolicoeur & Dell'Acqua, 1998) assumed that defensive content may require a more detailed processing, including response selection and retrieval from long-term memory. As overt emotional actions rarely occur in laboratory, the unpleasant pictures primarily initiated orienting processes, which is signaled and measurable by skin conductance and cardiac changes, a potentiation of the startle reflex, and self reports (Bradley, Codispoti, Cuthbert, & Lang, 2001). According to the defense cascade model similar processes were predicted for the appetitive motivational system. The absence of an analog pattern may be due to the missed arousal threshold for the pleasant pictures category, as this seemed to be crucial for the activation of the motivational systems (Cuthbert, Bradley, & Lang, 1996).

Affirmation for a freezing analogous behavior in humans is also provided by a study of Azevedo and collaborators, in which participants' body sway was recorded during picture viewing (Azevedo, et al., 2005). She observed this behavior when participants were confronted with threat pictures. A similar reaction to unpleasant pictures of the conducted study could be due to the specific picture content depicting human beings. This property had a naturalistic relevance for participants. Bradley and colleagues (Bradley, Codispoti, Cuthbert, & Lang, 2001) stated that pictures representing primary reinforcers were presumed to strongly activate the motivational systems. The more pronounced coupling of arousal with the unpleasant picture category compared to the pleasant one may be an indicator that the defensive content of pictures could enhance the freezing behavior. Also Buodo and collaborators (Buodo, Sarlo, & Palomba, 2002), employing a choice task, found slower reaction times to some pleasant and unpleasant stimuli (blood/injury and erotic couples) compared to other unpleasant or pleasant scenes, rated as equally arousing. He assumed that specific contents required more attentional resources than others within the same valence category. This may indicate that unpleasant pictures depicting humans lead to a pronounced attentional occupation.

Thus, the freezing analogue behavior (Azevedo, et al., 2005), reflecting orienting processes, offers an explanation for the slowing of response times for unpleasant pictures (Lang, Davis, & Ohman, 2000). The unpleasant pictures group, arousing enough to activate the defensive motivational system, needed a more elaborated processing than the other T2 groups. This pattern seems affirmed by the correlation between the state anxiety scores and the response time quotient in the shortest lag 2. Participants with high scores on state anxiety showed a pronounced response time slowing for unpleasant pictures compared to pleasant ones.

An important aspect of the conducted experiment, which may be relevant for the understanding of the data, was the passive viewing task. Initially, participants only had to scan the RSVP picture streams for the two targets. This passive perceptual intake of cues offered little demand for behavioral output. As according to Lang, situational requirements are adjusted on multiple levels, the actual behavior may be shaped on the 'tactical' (short term) demands of the respective situation (Lang, 1995). This means that, as there was no pivotal need to respond fast to the T2s, response times for all picture groups were respectively slow and showed a high variability. However, responses to the unpleasant group were especially slowed down. This indicates that some post-perceptual factor influenced the processing and / or the recognition of this unpleasant group. It may be that participants searched for additional orienting cues, suppressing the seen target picture.

Bradley and colleagues suggested that affective responses serve different functions (e.g. mobilization for action, attention), reflecting the motivational system that is engaged (defensive or appetitive), its intensity of activation, as well as the specific emotional context (Bradley, Codispoti, Cuthbert, & Lang, 2001). For instance, studies examining anxious individuals found that these were more likely than controls to display attentional biases toward threatening information (Mathews, Ridgeway, & Williamson, 1996; Mogg & Bradley, 1999; Williams, Mathews, & MacLeod, 1996). Nonpathological individual differences in personality have also been linked to differences in attentional bias (i.e. introverts compared to extraverts) (Compton, 2003). Thus, attentional biases have been found to be strongest for stimuli most closely related to an individual's concern (e.g. MacLeod & Rutherford, 1992; Mathews & Klug, 1993). To sum up, the naturalistic emotion regulation strategies of participants which are influenced by short term and long term demands play a crucial role in understanding the behavioral responses of people. Some goals and concerns, such as avoiding danger, are shared among individuals. Thus, similar attentional biases will be observed among individuals. Likewise, to the extend that there are individual differences in concerns, such as the preoccupation with specific threats among people with anxiety disorder, there will be individual differences in attentional biases toward those respective threat stimuli. The results of the conducted study suggest some additional factor may have influence the processing of affective stimuli (e.g. state anxiety). There may have been also other influencing factors, which I did not access. The facilitated processing of pleasant picture content and the pronounced impairment of unpleasant picture content, for recognition accuracy as well as for response time, may reflect an interaction of several complex factors (e.g. emotional and cognitive factor), guiding behavioral responses.

Conclusion and Outlook

The present results support the view that emotional picture processing involves a variety of influencing variables and levels. I found that pleasant highly arousing pictures as a function of valence interfered with the AB phenomenon in terms of recognition accuracy, suggesting amplification for this stimulus category. As neutral low arousing pictures had accuracy scores in between both highly arousing categories, the amplification as a function of valence is irrespective of pictures' arousal level. This finding suggests that affective picture material demands other processing capacities than previous used stimuli (e.g. words, faces), which showed an attentional facilitation for highly arousing material. This inconsistency may be due to differences in the elaboration of the corresponding representational networks and to the specific human related content of target pictures. Recognition response times varied instead as a function of arousal with slowest responses for the unpleasant picture category. This response time reduction of the unpleasant T2s was strongest in the shortest lag 2. Additionally, a correlation was found in lag 2 between participants' state anxiety scores and response times of unpleasant T2s compared to response times of pleasant T2s. This selective processing of affective cues may reflect an evolutionary pattern. This possibility is highlighted by the data with respect to the human defense cascade model. Thus, slow responses to defensive cues in the post-encounter stage may indicate an orienting behavior to gain more information.

Future research directed towards the understanding of these valence and arousal patterns of pictures should provide a better understanding of the processing of realistic picture material, especially of those depicting human beings. It should be noted that the presented study employed both a recall task for T1s and a non speeded recognition task for T2s. These tasks may demand different processing pathways and resources. It may be helpful to restrict future studies to one type of task, as the understanding of how affective pictures guide attention has to include an understanding of how affective stimuli are detected, selected, and modulated. Thereby, an essential focus should be on the employed task modus, as this one defines the situational demands to which participants have to respond. It would be also reasonable to use more T1-T2 lags as well as longer ones, to better track the development of category impairment and / or enhancement. Individual differences such as state anxiety can influence response patterns. The complex manner in which this variety modifies selective attention will be an exciting avenue for future research.

V. SUMMARY

The aim of the present investigation was to examine the selective processing of complex affective pictures as a function of available attentional resources. To determine the affective attributes of pictures that amplify post-perceptual processing within the underlying limits of the cognitive system as well as to gain insight into the temporal dynamics of these processes, an attentional blink (AB) paradigm during rapid serial visual presentation (RSVP) was employed. The AB, a temporal visual attention deficit, appears after the successful processing of a first target (T1) for approximately 200 – 600 ms. During this interval the detection and processing of a second target (T2) is impaired. T2 was presented in three different T1-T2 lags (SOAs: 186.6 ms, 373.2 ms, and 559.8 ms) after the onset of T1. T1s depicted hands in differing positions. Pleasant highly arousing, neutral low arousing, and unpleasant highly arousing pictures showing humans were used as second targets (T2) in a 9.3 Hz RSVP stream. Behavioral measures were recorded after the picture streams. T1 had to be reproduced in a free recall task, whereas T2 had to be recognized and selected within distractors in a recognition matrix.

The processing of T2 was impaired for all affective groups showing reduced recognition accuracy rates in all lags, but only the unpleasant stimulus category showed a pronounced AB effect. Response times were significantly reduced only for the unpleasant picture group compared to the other ones. Performance of T1 was unaffected by the affective category of T2 or lag.

Pleasant highly arousing pictures in terms of valence, irrespective of their arousal degree, were associated with enhanced accuracy rates compared to the unpleasant highly arousing ones during all lags, suggesting amplification for the pleasant stimulus category. Neutral low arousing pictures showed scores in between both highly arousing groups. Recognition times of T2 instead varied as a function of arousal with slowest responses for the unpleasant picture group. This response time reduction of the latter category was strongest in the shortest lag 2. Additionally, a correlation was found in lag 2 between participants' state anxiety scores and response times of unpleasant T2s compared to response times of pleasant T2s. The results are discussed with regard to the AB underlying processes as well as compared and contrasted to previous findings of studies. The human defense cascade model, suggesting that unpleasant picture content can prompt a human analog of "freezing" behavior, as well as inter-individual emotion regulation strategies are proposed to explain some of the found data.

VI. ZUSAMMENFASSUNG

Ziel der vorliegenden Arbeit war es, die Verarbeitung von komplexem affektiven Bildmaterials unter Berücksichtigung von vorhandenen Aufmerksamkeitsressourcen zu untersuchen. Es sollte festgestellt werden, welche affektiven Attribute die Verarbeitung von Bildern in Situationen reduzierter Aufmerksamkeit erleichtern. Zur Untersuchung dieser Frage, als auch zur Bestimmung der zeitlichen Dynamik der affektiven Verarbeitung beim Menschen, wurde das Attentional Blink (AB) Paradigma innerhalb eines Rapid-Serial-Visual-Presentation (RSVP) Designs herangezogen.

Der AB, eine Periode reduzierter Bewusstheit, äußert sich in einem Verarbeitungsdefizit, wenn zwei Zielreize in kurzem zeitlichem Abstand von ungefähr 200 - 600 ms dargeboten werden. Dafür wurde eine Reihe von Bildern in schneller Abfolge, im vorliegenden Experiment mit einer Frequenz von 9,3 Hz, am selben Bildschirmort präsentiert. Diese Stimulussequenz enthielt die beiden Zielbilder (T1 und T2), die sich von den übrigen Bildern unterschieden. Für die T1 wurden Abbildungen von ein oder zwei Händen benutzt. Die T2 bestanden aus Fotos von Menschen, die sich eindeutig den Kategorien angenehm hoch erregend, neutral niedrig erregend oder unangenehm hoch erregend zuordnen ließen. Letztere wurden in drei verschieden langen Intervallen nach Präsentation der T1 dargeboten (SOAs: 186.6 ms, 373.2 ms, and 559.8 ms), um die zeitliche Verarbeitung des emotionalen Bildmaterials differenziert untersuchen zu können. Nach jeder Reizkette sollte der T1 wiedergeben sowie der T2 in einer 3 x 3 Matrix wieder erkannt werden.

Die T2 Verarbeitung war beeinträchtigt für alle affektiven Gruppen. Dies zeigte sich in einer reduzierten Wiedererkennungsrate in den T1-T2 Intervallen. Einen ausgeprägten AB-Verlauf zeigte sich jedoch nur für die unangenehme Bilderkategorie. Die T2 Antwortzeiten waren auch nur für die unangenehme Gruppe signifikant verlangsamt. Die Leistung des T1 war gleich bleibend hoch.

Angenehm hoch erregende Bilder wurden ungeachtet ihres Erregungsniveaus besser wieder erkannt als unangenehm hoch erregende Bilder. Die Werte der neutralen niedrig erregenden Bilder lagen in der Wiedererkennungsaufgabe zwischen der angenehmen und der unangenehmen Kategorie. Dies lässt auf einen valenzabhängigen Wiedererkennungsvorteil schließen. Für die T2 Antwortzeiten zeigte sich jedoch ein erregungsabhängiger Effekt mit den höchsten Entscheidungszeiten für die unangenehme Bildergruppe. Diese Verlangsamung war am stärksten im kürzesten T1-T2 Intervall ausgeprägt. Zusätzlich ergab sich für das kürzeste Intervall eine Korrelation zwischen der momentanen Ängstlichkeit der Probanden und den Antwortzeiten für die unangenehmen im Verhältnis zu den angenehmen T2-Reizen. Die Ergebnisse wurden hinsichtlich der dem AB zugrunde liegenden Verarbeitungsprozesse diskutiert und mit Erkenntnissen früherer AB Studien und Studien zur automatischen Aufmerksamkeitslenkung durch affektive Reize verglichen.

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VIII. APPENDIX

Register of IAPS pictures used as second targets with their mean arousal and valence values as rated by participants after the AB experiment using the SAM.

number of **pleasant IAPS**	Ø valence	Ø arousal	number of **pleasant IAPS**	Ø valence	Ø arousal
1340	6,58	3,69	4538	6,52	3,89
2040	7,73	3,31	4572	6,81	3,96
2057	7,18	3,71	4599	6,50	4,04
2058	6,88	4,08	4601	6,96	5,00
2070	7,16	2,84	4603	6,74	4,52
2071	7,04	3,58	4606	6,37	3,93
2080	6,77	4,46	4607	6,82	3,75
2150	7,37	3,63	4608	7,46	4,42
2160	7,08	3,92	4609	7,42	4,31
2165	6,95	3,27	4611	6,74	4,22
2170	6,96	2,63	4623	7,12	3,85
2209	7,48	2,80	4626	6,00	4,48
2216	6,59	2,85	4640	6,54	4,81
2224	7,44	4,20	4641	6,78	3,67
2310	7,04	3,12	4650	6,54	5,58
2311	7,18	3,82	4653	6,63	5,63
2331	7,44	4,26	4659	6,36	5,48
2340	7,15	2,96	4660	6,78	6,22
2341	7,04	3,39	4664	6,36	4,96
2345	7,71	4,32	4669	6,44	6,04
23521	7,07	2,89	4670	6,56	5,70
2360	7,50	3,62	4680	6,61	3,75
2387	7,63	2,58	4687	6,37	6,11
2530	6,46	3,85	4690	6,85	3,04
2540	6,74	4,00	4700	5,70	5,85
2550	7,28	4,16	4800	6,59	3,04
2660	5,95	3,55	7325	7,70	2,48
4220	5,40	3,56	8120	6,31	3,08
4250	5,58	3,65	8200	6,08	4,12
4520	7,16	4,76	8461	7,00	4,28

∑ - MEAN	6.97	4.10
∑ - SE	.06	.13

number of **unpleasant IAPS**	Ø valence	Ø arousal	number of **unpleasant IAPS**	Ø valence	Ø arousal
2053	3,20	5,96	3350	2,43	6,25
2120	3,38	5,92	3500	2,22	6,93
2141	2,44	6,04	3530	1,85	7,42
2205	2,41	5,41	35501	1,96	6,96
23522	2,07	7,30	6212	2,00	7,62
2375	4,04	5,12	6213	2,70	6,48
2490	3,88	3,88	6312	2,21	7,00
2661	3,68	6,25	6313	1,82	7,68
2683	2,36	7,04	6315	2,36	7,00
2691	2,57	6,93	6350	2,00	7,46
2700	3,50	4,73	6360	2,46	6,50
2710	2,96	5,20	6540	1,88	7,04
2800	1,56	7,07	6550	1,85	7,54
29001	3,11	5,61	6560	1,83	7,58
3015	1,21	7,21	65701	2,19	7,08
3022	3,08	6,28	6838	2,15	6,74
3030	2,12	6,64	8230	1,61	7,57
3051	1,36	7,32	9007	2,22	6,26
3053	1,07	8,18	9040	1,81	6,63
3060	1,19	7,31	9041	3,04	6,29
3080	1,22	7,41	9042	2,25	6,14
3102	1,11	7,56	9050	2,26	6,33
3120	1,41	7,22	9160	3,37	6,41
3170	1,48	7,37	9220	3,50	3,69
3181	2,22	6,52	9250	2,19	6,78
3230	2,88	5,46	9400	1,88	6,58
3266	1,31	7,31	9410	1,41	7,89
3280	3,14	5,32	9421	2,92	6,13
3300	2,96	5,93	9582	3,08	5,56
3301	1,56	6,76	9584	3,04	5,82

∑ - MEAN	2.33	6.44
∑ - STD	.09	.12

number of **neutral IAPS**	Ø valence	Ø arousal	number of **neutral IAPS**	Ø valence	Ø arousal
1601	6,41	3,22	2630	4,79	3,43
2190	5,29	2,79	2650	6,56	3,04
2191	5,89	2,26	2655	7,42	3,00
2200	5,78	3,04	27451	5,19	3,08
2210	4,58	3,38	2749	4,54	2,73
2214	5,40	3,00	2830	5,11	4,41
2221	4,89	3,26	2840	5,50	3,15
2240	5,78	3,70	2850	5,26	3,22
2250	6,46	3,19	2890	4,44	3,30
2260	6,77	3,08	4100	5,85	3,46
2320	6,14	2,46	4535	5,61	3,32
2370	5,93	2,79	4605	5,25	3,11
2372	4,69	2,92	4610	6,75	2,75
2383	5,00	2,86	5410	6,80	2,28
2410	4,41	4,22	5831	7,78	3,67
2441	4,67	4,26	5875	6,44	2,63
2442	6,25	3,14	7550	4,81	2,69
2480	4,92	2,96	8010	5,04	4,23
2485	5,19	2,69	8032	5,79	4,04
2487	5,12	2,60	8033	5,86	4,00
2493	4,82	3,39	8034	5,68	4,36
2495	4,92	2,88	8040	5,58	5,31
2500	6,44	2,92	8041	5,73	4,85
2515	5,93	2,70	8090	5,76	4,80
2560	6,04	3,46	8130	5,74	4,37
2570	4,81	3,07	8260	5,76	5,08
2580	5,89	2,36	8280	6,31	4,23
2600	4,96	3,23	8311	5,81	3,63
2616	6,83	5,25	8460	5,31	4,12
2620	7,00	2,93	8465	6,92	4,15
∑ - MEAN	5.66	3.48			
∑ - STD	.11	.09			

Einverständniserklärung

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Ich habe die vorausgehende Erklärung gelesen und verstanden.

Frau ……………………………………………………….................
(Unterschrift der Untersuchungsleiterin und Datum)
hat mir die Untersuchung erläutert und allgemeine Fragen hinreichend beantwortet.
Ich bin damit einverstanden, dass Daten, die im Rahmen dieser Studie erhoben werden und für die Dauer des Projekts auf elektronischen Datenträgern gespeichert werden.

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Datenblatt ABIP_hrecent **VP-Nr:________**

Geschlecht: weiblich___/männlich___

Alter: ____

Staatsangehörigkeit/Muttersprache: Studienfach:

Neurologische und/oder psychiatrische Probleme: Ja / Nein

Epilepsie: Ja / Nein oder jemand in der Familie: Ja / Nein

Rechts- / Linkshänder

Fehlsichtigkeit: Ja / Nein wenn ja, korriegiert: Ja / Nein

Datum, Uhrzeit:

Anmerkungen: