FEAR

-A PROCESS INFLUENCED BY CONCURRENT PROCESSING DEMANDS

Anna Bjärtå
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Anna Bjärtå

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Department of Psychology
Mid Sweden University, SE-831 25 Östersund
Sweden

Telephone: +46 (0)771-975 000

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Till Pappa,

som alltid ser mina strider
men som aldrig tvivlar på att jag fixar det
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Anna Bjärtá
Department of Psychology
Mid Sweden University, SE-831 25 Östersund, Sweden
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ABSTRACT

Fear is a central aspect in mammalian evolution, prompting escape from and avoidance of threat and dangers. Therefore, it is reasonable to believe that we have a well developed system to detect dangers and quickly respond to them. It has been shown that threatening information has an advantage in information processing; it seems to promote a rapid capture of selective attention and puts demand on processing resources. It has been suggested that the elicitation of fear occurs automatically, and that it is independent of and impenetrable to cognition.

The idea with the present research is that fear processing is dependent on all concurrent internal or external processing demands. One visual search study (Study II) and two secondary task studies (Study I & III) have been conducted to investigate if external or internal distraction can interfere with fear processing. In order to provoke fear responses, spider or snake fearful individuals have been exposed to pictures of their feared stimulus. The aim of Study II was to investigate if the selective attention to fear stimuli could be influenced by contextual factors, such as the nature of the distracting stimuli in a visual search. Study I and III aimed to investigate manipulation of resources allocated to fear stimuli. In Study I, task demand was used as the manipulation, and in Study III an internal cognitive directive was used. The results from these studies indicate that fear is susceptible to manipulation by both external and internal means. By changing circumstances in the surrounding or in the individuals’ internal states, responses to threatening stimuli can be altered. This means that processing of threatening stimuli is influenced by other concurrent processing demands, suggesting that a fear response is not occurring as an isolated and impenetrable process. In an evolutionary perspective, a fear system that is easily triggered but has access to cognitive evaluation at all times ought to be far more flexible, thus creating a better chance for survival than a modular and impenetrable fear system.

Keywords: Attention, Fear, Performance, Processing resources.
SVENSK SAMMANFATTNING

Rädsla är centrale i människans evolution då den motiverar undvikande av hot och faror i vår omgivning. Det är därför logiskt att anta att vi har ett välutvecklat system som snabbt detekterar faror och som förbereder organis men att reagera. Hotstimuli har visat sig ha en fördel vad gäller hjärnans informationsbearbetning, det verkar som om att de fångar vår uppmärksamhet snabbt och lägger beslag på hjärnans resurser. Det har föreslagits att rädsla kan utlösas automatiskt och att det är en respons som är oberoende och opåverkad av kognitiva processer.

Tanken med den forskning som presenteras i denna avhandling är att bearbetning av rädsla är beroende av all övrig intern och extern bearbetning som måste utföras samtidigt. För att undersöka hur intern och extern distraktion påverkar rädsloreaktioner har en visual search studie (Studie I) och två secondary task studier (Studie I & III) utförts. Rädsla har genererats genom att läta spindel och områda försökspersoner exponeras för bilder av sitt frukta objekt.

Syftet med Studie II var att undersöka om den selektiva uppmärksamheten till hotstimuli låter sig påverkas av förändringar i kontextuellt avseende, i detta fall avhängigt vilken typ av distraktorstimuli som används i ett visual search experiment. Studie I och III syftade till att undersöka manipulation av bearbetningsresurser som allokeras till hotstimuli. Olika svårighetsgrader av en uppgift användes som distraktion i Studie I medan ett internt krav att fokusera på en uppgift användes i Studie III.

Resultatet från alla tre studier visar att rädsla är påverkad och kan manipuleras med både externa och interna medel. Genom att manipulera förutsättningar i omgivningen eller i individers inställning kan man alltså förändra aspekter av rädsloresponsen. Detta betyder att bearbetning av hotstimuli är beroende av all annan bearbetning som sker samtidigt, vilket tyder på att rädsla inte uppstår som en isolerad och opåverkad process. Ett rädslosystem som har ständig åtkomst till kognitiv utvärdering torde vara mer flexibelt än ett isolerat system, och i ett evolutionärt perspektiv kan man anta att detta borde skapa en ökad chans för överlevnad.
LIST OF PAPERS

This thesis is mainly based on the following papers, herein referred to by their Roman numerals:


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1. PREFACE

I often find myself thinking about who I am in dualistic terms that includes *Me* and *My brain*. I even tell my students about “what the brain does” like it is some kind of machine running the by-product that is me. This is however not the way I see it. Well, I do believe that we have organic machinery which makes it possible for us to live and evolve within our environments, but it is really up to us to set up this machinery all the way down to the smallest mechanical process. For example, our basal bodily functions are dependent on what we eat, as our mental development is dependent on what information we feed the brain; as such, the working of the nervous system is incident to what we expose it to. If we could grasp the full capacity of the brain, Freud’s metaphor of consciousness, as the tip of an iceberg, would probably make more sense. Think about all that the brain does to allow us to work in our environment without having to consider every little movement we are about to make or reflect upon every sound we hear. Most of the times it does everything for our own good, but sometimes it creates behaviours that are maladaptive in the situation. For rather a lot of individuals this can cause problems that may have more or less severe impacts in their daily life. This is the reason why we have to conduct research in psychology; why we need to understand the small processes of the brain underlying the behaviours, thoughts, and emotions, providing the foundation to all that we are.

Me? I am scratching where the ice breaks the surface of the water.

I will finish this preface with a wonderful quote by Santiago Ramón y Cajal, sometimes referred to as the father of modern neuroscience.

“How many interesting facts fail to be converted into fertile discoveries because their first observers regard them as natural and ordinary things, unworthy of thought and analysis! Oh that unlucky mental inertia, the lack of wonder of the ignorant! How it has delayed our acquaintance with the universe!”

(from “Recollections of my life”, 1937, p. 46)

Östersund, December 2012
2. INTRODUCTION

From the moment we wake up our brains commence the work of processing information about our surroundings. Chemical molecules produced during the night will reach sensory receptors on the olfactory bulb in your nose to produce the inconvenient smell from the night's sleep, the creases of your sheets from all your oblivious nightly activities make themselves felt through receptors in the skin, electromagnetic waves arriving from the sun reaches the sensory receptors on the retina letting us understand that dawn has broken, and so on, and so forth. At any given moment our interface with the surrounding – consisting of our sensory organs - is bombarded with a multitude of sensory input. However, our available quantity of processing resources is assumed to be finite, accounting for a limited capacity to process information and a selection for conscious processing (Desimone & Duncan, 1995). Due to this capacity limitation, the brain cannot consciously process all input that the environment and the individual itself has to offer. Therefore certain stimuli are singled out for awareness while most remain unattended. This is, for example, why we don't feel our clothes against the skin all the time or hear the buzzing from the fan in the computer, but we can if we choose to. What is selected for conscious processing is an interaction of the internal goals people have and the stimuli that impinge on them, also referred to as top-down and bottom-up processes (Corbetta & Shulman, 2002; Desimone & Duncan, 1995; Pashler, Johnston, & Ruthruff, 2001; Posner & Petersen, 1990). Stimuli that are attended to, make demands on the individual's processing capacity, which gives rise to a competition for resources (Desimone & Duncan, 1995; Kastner & Ungerleider, 2001). The current view is that this competition is biased towards information that is currently relevant to the individual (Corbetta & Shulman, 2002; Desimone & Duncan, 1995). A category of stimuli that could be viewed as commanding competitors for resources would be those who pose some kind of threat to the individual.

Most people recognize and have experienced the physiological changes that occur in a stressful or threatening situation. This is generally thought of as an evolutionary evolved response, triggered by the autonomic nervous system to prepare the organism for a confrontation or a quick escape – the, so called, fight or flight response. Less obvious to people is that a parallel change occurs in the cognitive system of the human brain (Mathews, Mackintosh, & Fulcher, 1997), causing a disruption of the ongoing attention to facilitate a shift of attention towards the potentially threatening stimuli. Research has shown that threat information does influence attention processing (see e.g., Wilson, MacLeod, & Campbell, 2007; Yiends, 2010, for recent reviews). It has, for example, been shown that stimuli with negative valence, such as angry facial expressions (e.g. Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Hansen & Hansen, 1988; Öhman,
Lundqvist, & Esteves, 2001) or spiders and snakes (e.g. Flykt, 2005, 2006; Lipp & Derakshan, 2005; Lipp & Waters, 2007; Öhman, Flykt, & Esteves, 2001; Soares, Esteves, Lundqvist, Öhman, 2009) are found efficiently during search tasks, and that they engage attention and interfere with continuous processing of other things (e.g. Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Koster, Crombez, Verschuere, & De Houwer, 2004; Yiend & Mathews, 2001). Although these studies have led to a variety of conclusions there is little doubt that threat stimuli do have a special role in human attention processing: stimuli that are relevant to the individual are given priority to attention resources, and even more so in high anxiety individuals (e.g. Bradley & Lang, 1999; Derryberry & Reed, 2003; Fox, Derakshan, & Shoker, 2007; Fox et al., 2002; Mogg & Bradley, 2002; Taghavi, Neshat-Doost, Moradi, Yule, & Dalgleish, 1999; Yiend, & Matthews, 2001; but see Bar-Haim et al., 2007; Mineka, Rafaeli, & Yovel, 2003, for some recent reviews).

The question whether emotions can elicit automatically and guide the attention, or if they are dependent on some cognitive processing to elicit, is a continuous debate in academic discourse. The extensive research by Arne Öhman and colleagues (e.g. Esteves, Dimberg, & Öhman, 1994; Esteves, Parra, Dimberg, & Öhman, 1994; Öhman & Dimberg, 1978; Öhman, Flykt, & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001; Öhman & Soares, 1993, 1994, 1998) have demonstrated that fear of evolutionary fear-relevant stimuli (i.e. spiders, snakes, and angry facial expressions) can be learned (Esteves, Parra, Dimberg, & Öhman, 1994; Öhman & Soares 1998), and elicit (Esteves, Dimberg, & Öhman, 1994; Öhman & Soares, 1994) outside conscious awareness; that it is resistant to extinction (Öhman & Dimberg, 1978; Öhman & Soares, 1993); and that fear-relevant stimuli can attract attention automatically (Öhman, Flykt, & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001). Öhman and colleagues have suggested that attention is automatically biased to focus on threats (Öhman, 1993; Öhman, Flykt, & Lundqvist, 2000; Öhman & Mineka 2001). Öhman and Mineka (2001, 2003) have furthermore proposed a model for an evolutionary evolved fear module. Within this framework it is assumed that threat stimuli draw attention bottom-up, that fear is activated automatically, and that it is an encapsulated system independent of, and impenetrable to cognitive processing.

2.1. Emotion

In a biological perspective on psychology, human brain functions can be viewed as the result of millions of years of natural selection. Therefore, emotions can be understood as adaptive or functional responses shaped by evolution to make us do what our ancestors had to do to survive and successfully pass their
genes on to coming generations (Öhman, 1993; Tooby & Cosmides, 2008). Most researchers seem to agree upon the adaptive value of emotions, however, after over a century of research on emotions there is still no clear cut and unifying definition of what an emotion is comprised of or how they elicit.

Emotion research in the past century has been greatly influenced by the ideas of William James (see e.g. Lang, 1994). He pictured emotions as a sequence of events starting with the stimulus and ending with the conscious emotional experience. His idea was that the conscious evaluation of the bodily changes following perception of an exciting stimulus was the emotion (James, 1884). As such, James was one of the first to emphasize the subjective experience as part of an emotion although he considered them secondary phenomena. One of the main objectives in emotion research has been to map this stimulus-emotion sequence. The idea suggested by James has been much disputed ever since, and the question of what comes first, the physiological response or the cognitive evaluation of stimulus, seems to be a difficult problem to solve. This can be exemplified with a recent and well known discussion between Robert Zajonc and Richard Lazarus, sometimes referred to as the affective versus cognitive primacy controversy (Lazarus, 1984; Zajonc, 1984). Zajonc (1980) conducted a series of experiments where he showed that emotional reactions, or affect, to a stimulus could be formed without any conscious registration of the stimulus content. His conclusion was that affect has primacy over, and is independent of cognition. An emotion, in other words, can exist before and without any cognitive processing. In contrast, Richard Lazarus (1982) claimed that emotional responses are dependent on a cognitive evaluation of stimulus content, asking the question what remains if we dissociate the different components of an emotion. Today many researchers acknowledge several different characteristics as being part of a full emotional reaction, such as physiological changes, mental processes, and behaviours.

The scope of the definition is however still problematic. Some researchers view emotions purely as states of the brain triggering collections of specific physiological and biochemical responses (e.g. Damasio, 2000; Ekman, 1992; Panksepp, 1998) while others are more prone to also include, or put more emphasis on, the cognitive and evaluative (or appraisal) aspects of an emotion (e.g. Arnold, 1960; Barret, 2005; Clore & Ortony, 2000; Lazarus, 1982; Leventhal & Scherer, 1987). Another definition causing much imbroglio is that of cognition; some researchers view cognition as the non-automatic processes available for conscious processing (e.g. Öhman, 1993; Öhman & Mineka, 2001; Zajonc, 1980), while others argue that cognitive processing can be automatic as well and that implicit cognitive evaluations of stimuli is part of how we process all information (e.g. Lane, Nadle,
Allen, & Kaszniak, 2000; Lang, 1979, 1994; Lazarus, 1982). Lane et al. argued that any boundaries between emotion and cognition depend on the definition of cognition. Since these definitional problems are so closely intertwined, the same could obviously also be said about the definition of emotion.

2.1.1. Emotion and information processing

Since the mid 20th century the information processing paradigm has been applied in many different areas in cognitive psychology, such as attention, memory, language etc., and it has gained considerable impetus due to the high degree of congruence between information processing models and cognitive neuroscience (see e.g. Corbetta & Shulman, 2002; Desimone & Duncan, 1995; Posner & Petersen, 1990, regarding models of attention). In the contemporary cognitive view of information processing, the brain is an organ for storing and processing information and the core idea of this approach is to make systematic observations in order to “analyze the mind in terms of different subsystems that form, retain, and transmit representations of the world” (Pashler, 1998, p. 7). Many emotion researchers have also taken an information processing approach to emotions (see e.g. Dalgleish, 2003; Derryberry & Reed, 2003; Eysenck, Derakshan, Santos, Calvo, 2007; Foa & Kozak, 1986; Lane et al., 2000; Lang, 1978, 1984; Mathews et al., 1997; Öhman, 1993; Power & Dalgleish, 1999, and many more). Some of them (e.g. Lane et al., 2000; Lang, 1994) have had the idea that this approach would provide a solution to the controversy between emotion and cognition, arguing that if emotions are viewed as a consequence of information processing it ought to be reasonable to conclude that emotion to a certain extent is cognitive. Peter Lang (1994) reasoned:

As the century nears its end, information-processing models should be at least carrying us past these issues. Only if the definition of cognition is arbitrary restricted to rational conscious thought can it be placed in opposition to emotion – and even then, only weakly (p. 219).

Lang’s own definition of cognition is not restricted to conscious thought. He views the brain as a thinking machine for processing information, integrating it, and creating responses; and that all processing required for central representation and expression of a response is considered to be cognitive (Lang, 1984; also Lazarus, 1984). However, some researchers argue that cognitive processing is merely one example of information processing, and that there are non-cognitive biological information processing systems, such as genetics and the immune system (Zajonc, 1984; Izard, 1993). An interesting thought by LeDoux (1995), concerning the neural underpinnings of emotions, is whether the information processing rules and
transformations (i.e. neuronal functioning) are fundamentally different in areas of the brain involved in emotion versus areas involved in cognition, or if these areas simply perform different things on the basis of similar processing functions. Two structures that merit mentioning in this context is the amygdala, which has been pointed out as a central structure in emotion processing (e.g. LeDoux, 1995, 1998; Phelps & LeDoux, 2005; Sander, Grafman, & Zalla, 2003; Sergerie, Chocho, & Armony, 2007), and hippocampus, which is involved in the memory system and has been more related to cognitive processing (e.g. LeDoux, 1998; Squire & Candel, 2008). Although much is known about the physiology of the hippocampal neurons (e.g. Squire & Candel, 2008), broad advances in research are still required before the function of neurons in amygdala is fully understood. However, many researchers are turning their focus to the role of amygdala in memory formation (e.g. Cahill & McGaugh, 1998; McGaugh, 2002, 2012; Paré, Quirk, & LeDoux, 2004; Phelps & LeDoux, 2005). It has been shown that amygdala influences plasticity in other brain regions, such as hippocampal areas and cortical sensory processing systems (e.g. McGaugh, 2002, 2012; Phelps & LeDoux, 2005). Findings also indicate that the same type of plasticity that can be found in hippocampus is also occurring in nuclei of the amygdala, but there is yet no consensus whether amygdala is a site for memory storage per se (e.g. Cahill & McGaugh, 1998; LeDoux, 1995, Paré et al., 2004).

Even though Lang’s expectations (1994, see quote above) have not yet been met, his dimensional bioinformational model of emotion is a very prominent and influential integrative contemporary view (see e.g. Lang, 1979, 1984; Lang, Bradley, & Cuthbert, 1990, 1998; but also Barlow, 2002, pp. 54-57 for an overview of the theory). He argues that emotions are response dispositions, or action sets, located along a biphasic appetitive-aversive motivational dimension that can vary in activation and arousal. The representation of a stimulus is not just an image in the brain; it is a conceptual network associated with an action set, or a pattern of verbal, behavioural, and physiological responses. Lang (1984; Bradley & Lang, 2000) has emphasized that an emotional response ought to be considered and investigated in such a way respecting all three of these components.

2.1.2. Fear

Some researchers have suggested a set of basic (or standard/primary/core) emotions which are considered to be innate, to be shared globally and with lower species, and to have distinctive physiological and behavioural expressions (e.g. Ekman, 1992; Panksepp, 1982, 1998; Plutchik, 1980, 2001; Izard, 1993; 2009; James, 1884). Although theories differ in the number of basic emotions that are supposed to exist, fear is an emotion which is always included. Fear is a central aspect in the
evolution of many species; it is pervasive and expressed similarly in all mammals, with respect to defensive behaviours and physiological responses (LeDoux, 1998; Panksepp, 1998). The emotion of fear is an aversive state that is associated with a defence system motivating avoidance from threat and danger (Lang, Bradley, & Cuthbert, 1998; Öhman, 1993). Thus, in a functional perspective, fear can be viewed as an important and normal human reaction that mobilises individuals to deal with the threats they face. However, fear can also become dysfunctional and it is considered a central component in many psychopathologies (c.f. Öhman, 1993, 2008; Barlow, 2002).

2.1.3. Clinical anxiety

Fear and anxiety are closely related emotional phenomena. They are aversive states centred on threat, both involving intense negative feelings and strong bodily manifestation (Öhman, 2008). Pathological fear and anxiety are also subjects of the same nosological category (anxiety disorders) within the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR, American Psychiatric Disorders, 2000). Anxiety disorders, which encompass many different sub-disorders, are more prevalent than any other class of disorders (Barlow, 2002). The manual states that the primary feature of this class of disorder is abnormal or inappropriate fear or anxiety; that is, if fear/anxiety is frequently elicited in inappropriate contexts, in which the responses are inappropriate or dysfunctional and the intensity of the response is unreasonable to the extent that it causes impeded psychological or physiological functioning to the individual, it can be considered dysfunctional in a clinical sense (c.f. Öhman, 2008). Even if fear and anxiety have many common denominators, Öhman (1993, 2008) has described a number of aspects in which the two are distinguished. The main notion emphasized is that fear is a coping emotion that activates avoidance behaviour from an eliciting stimulus or event, while anxiety is the anticipation of threat/disaster. As such, fear has an external focus, for example to a specific stimulus or a situation, as in phobias.

2.1.4. Common fears and phobias

Phobias are the most common among anxiety disorders (Barlow, 2002). A phobia is characterized by an intense and persistent fear cued by the presence or anticipation of a specific object or a situation (DSM-IV-TR, 2000). The fear is typically recognised as irrational or disproportional to the actual threat, and individuals suffering from phobias go through great lengths to avoid the situation or object. Alternatively it is endured with intense anxiety or distress. Phobias are mainly divided in 3 subtypes: Social anxiety disorder, characterized by an excessive fear of an interpersonal event where embarrassment can occur; specific phobias that have a specific eliciting factor, such as an animal, a natural environment event,
blood or injury, or a specific situation; and *agoraphobia*, which is a fear of being in public spaces where it is difficult to escape or get help, typically also related to the fear of having a panic attack.

The specific phobias belong to the largest class. The point-prevalence of a specific phobia has been estimated to 19.9% (26.5% for women, and 12.4% for men) in a Swedish survey by Fredrikson, Annas, Fischer, & Wik (1996). Another extensive study by Eaton, Dryman, and Weissman (1991, in Barlow, 2002, p. 21) estimated the lifetime prevalence to 11.25%. An earlier diagnostic interview study by Agras, Sylvestre, and Oliveu (1969) showed a point-prevalence of 7.7% for specific phobias, but over 50% reported an intense fear for a specific situation or object (i.e. a specific fear that did not reach the criterions for a phobia). Even though these studies exhibit some differences, they all demonstrate a high occurrence of specific fears in the population (see also LeBeau et al., 2010, for a recent meta-study). LeBeau et al., also demonstrated that the most common of the specific fears are animal fears and natural environment fears (such as heights).

The targets of human fear seem to be clustered around a restricted sample of factors which can be considered to have been significant in human evolution (e.g. Arrindel, Pickersgill, Merckelbach, Ardon, & Cornet, 1991; Öhman, 1993, 2008; Öhman et al., 2001, Öhman & Mineka, 2001, 2003). Originating from Seligman’s theory of preparedness (c.f. Seligman, 1970, 1971), Öhman and Mineka (2001) have argued that these types of fear are shaped by evolution, and they reflect evolutionary prepared defence systems. That is, evolution has equipped humans with a propensity to associate fear to certain stimuli (e.g. spiders, snakes or angry faces) or situations (e.g. heights or water) that threatened the survival of their ancestors (Öhman & Mineka, 2001; but see Seligman, 1971, for the original theory). These archetypal representations are furthermore assumed to be hard-wired or integrated in the so called fear module.

### 2.1.5 Assessment of fear

A fear reaction causes a cascade of changes in the individual, such as a shift in attention, negative evaluations, facial expressions, avoidance behaviour, impaired or enhanced performance, increased heart rate, muscle tension, and so on and so forth (e.g. Lang, Davis, & Öhman, 2000). The assessment of fear and anxiety has changed dramatically during the past few decades. This is mainly due to the advent of modern brain imaging techniques but also to other advancements, both technical as well as the ‘new’ behavioural assessment techniques provided by the information processing approach. There are a number of different ways to measure fear, of which only a few will be attended to herein. Measurements and results of
relevance for this thesis will briefly be considered. For the sake of some coherence, these will also be presented in accordance with Lang’s three-system approach (physiological, subjective, and behavioural responses; Lang, 1984; Bradley & Lang, 2000). But first, to measure fear in a laboratory setting a fear response has to be provoked. There is a variety of ways to accomplish this, but one very simple method is to have individuals who are afraid of an object (e.g. a fear of spiders) view pictures of that object. Picture viewing is a very useful, and frequently used, experimental method to induce different emotional states. Lang and colleagues (Lang, Bradley, & Cuthbert, 2005; Bradley & Lang, 2007) have developed a standardized set of picture material with over 1 000 pictures that have been rated on the basis of pleasure and arousal. Other methods will not be treated here but the interested are recommended to read the Handbook of Emotion Elicitation and Assessment (Coan & Allen, 2007), which is a very readable work for the experimentalist.

Physiological measures. The underlying assumption for all measures (including behavioural and subjective) in the present view, is that all output is a result of brain processing. With psychophysiological methods we can investigate brain activity directly, for example through brain imaging procedures, or indirectly, with peripheral measures from autonomic and somatic branches of the nervous system (e.g. Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008). There are also the ‘wet’ methods, measuring for example hormonal levels from the blood or other bodily fluids, which will not be considered any further here.

Even though direct measures of brain activity in humans are very difficult to achieve – considering the massive activity that occurs in the whole brain (especially during a fear response) and the current available methods (see e.g. Cacioppo et al., 2003) – many researchers have, as LeDoux (1998, p. 73) put it, joined the crusade “through the cerebral promised land in search of the emotional Holy Grail”. That is, in this case, the search for the brain region or network of fear. As stated previously, the amygdala is central in emotion processing. Due to the pioneering animal studies on fear conditioning and fear potentiated startle, by researchers like Joseph LeDoux and Michael Davis; the amygdala has gained a special status within the field of fear research on humans (see e.g. LeDoux, 1995, and Davis, 2006, for overviews). Through their research a great deal has been learnt about the crucial function of the amygdala in, for example, the acquisition, elicitation, maintenance, and extinction of fear in rats. However, measuring brain activity in humans is a quite different story; for ethical reasons and for the reasons introducing this paragraph. To be more precise, the human brain is much larger and much more complex than the brain of a rat, and the humane methods available
are not as robust, or precise, as some of the methods that have been used on animals.

Some of the most ‘usage-friendly’ methods are positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and electroencephalography (EEG). These methods, as stand-alone, are not necessary the most precise measures, with regard to both temporal and spatial solution (see e.g. Wager, Hernandez, Jonides, & Lindquist, 2007), but they are applicable to human subjects (in contrast to in-depth electrodes, or ablation) and they have frequently been used to investigate, for example, lateralisation, activity in specific structures, emotional states, attention, resource allocation, and much more (see e.g. Kok, 1997; Phan, Wager, Taylor, & Liberzon, 2002; Sergerie et al., 2008; Vuilleumier, 2002, for some reviews). Enhanced activity has been demonstrated in the amygdala, for example when viewing pictures associated with fear or threat (see e.g. Öhman, 2005; Phelps & LeDoux, 2005, for some reviews), and a study by Carlsson et al. (2004) has shown an enhanced activation of amygdala when spider and snake phobic subjects viewed pictures of their feared animal on a supraliminal (conscious) level. When presented on a subliminal level (i.e. outside/before visual awareness), pictures of both spiders and snakes (fear-relevant) elicited stronger responses (compared to neutral mushrooms) in the left amygdala in both groups. That is, all individuals had larger responses to their feared object as well as the non-feared but fear-relevant object, in comparison the mushrooms.

The peripheral measures mainly originate from activity in the sympathetic and parasympathetic branches of the autonomic nervous system (ANS); sometimes also referred to as ‘fight or flight’, and ‘rest and digest’ systems respectively. During a fear response, a surge of sympathetic innervation occurs, which causes, for example, a redirection of the blood flow to striate musculature in preference of areas not necessary for a quick escape, such as the digestive system. Some frequently used peripheral psychophysiological measures are electrodermal activity (EDA), electromyography (EMG), and electrocardiography (ECG). When exposed to pictures of a feared object (i.e. spider or snakes), people with animal fears (i.e. to spiders and snakes) have shown distinct changes in peripheral physiological activity (Globisch, Hamm, Esteves, & Öhman, 1999). Globish et al. found stronger eye-blink startle potentiations (measured with facial EMG), larger skin conductance responses (measured with EDA), and a faster heart rate acceleration (as measured with ECG), in spider and snake fearful individuals when exposed to pictures of their feared animal, compared to neutral and pleasant pictures.

EMG is frequently used to measure startle potentiation, but multiple studies have also investigated facial muscle tension (i.e. facial expressions/facial feedback)
during picture viewing (e.g. Dimberg, 1982, 1986; see Dimberg, 1990 for a review. Measurements from the electrodermal response system are also widely used in psychological research. EDA is thought to reflect activity only from the sympathetic branch of ANS and is therefore a good measure of arousal level, but a worse separator between different emotions (Dawson, Schell, & Filion, 2007). It is also a measure strongly connected to attention, and activity in the electrodermal system is generally considered as a component of orienting and habituation (e.g. Siddle & Spinks, 1992). For example, Öhman and Soares (1993, 1994, 1998) have measured SCR to demonstrate autonomic activation to feared and fear conditioned stimuli (spiders and snakes) presented outside the frames of conscious awareness, and also, conditioning to subliminally presented fear-relevant stimuli.

The cardiovascular system is innervated from both the sympathetic and parasympathetic branches, which makes it useful when measuring, for example, stress levels (Bernston, Quigley, & Lozano, 2007). There are several possible ways to calculate data from an ECG signal including heart rate variability (HRV) and sustained heart rate (HR) which are frequently used in research on stress and anxiety. HR has also often been used to measure reactions to discrete stimuli. Viewing unpleasant pictures usually causes a relatively larger deceleration, compared to neutral pictures, while viewing feared stimuli causes an acceleration of the heart rate. This has been interpreted as indicative of an orienting response and a defence response respectively (e.g. Bradley & Lang, 2000). Some researchers consider HR insufficient as an index of emotional states (e.g. Bradley & Lang, 2000; Lang et al., 1990). It is, for example, sensitive to individuals’ physical and mental condition, such as height, weight, stress levels, cognitive operations, and so on. Nevertheless, in a controlled setting using within-subjects comparisons, HR can be a good indicator of a fear response. For example, when phobic individuals are exposed to pictures of their phobic object or situation, they exhibit a relatively larger HR acceleration and peak value, compared to neutral stimuli and compared to non-fearful controls (Elsesser, Heuschen, Pundt, Sartory, 2006; Globisch et al., 1999). Moreover, in accordance with above, Dimberg (1986) showed that non-fearful individuals exhibited a larger deceleration and a generally lower HR when exposed to pictures of spiders and snakes, compared to mushrooms and flowers, which could be interpreted as a mildly negative valence (unpleasantness) to spiders and snakes in a non-fearful population.

To summarize, it can be concluded that viewing pictures of feared objects elicits autonomic physiological responses that reliably can be measured from different response systems. It moreover seems that physiological responses to fear-relevant and feared stimuli are elicited at a very early stage, and that conscious
awareness is not a necessity for the brain to differentiate between stimuli and activate the defence system.

**Subjective measures.** Subjective measures refer to self reports of a person’s conscious experiences. This is a very tricky field considering that the goal is usually to assess individuals’ experiences of their ‘raw feeling’, preferably with as little reflection as possible (Nielsen & Kaszniał, 2007). That is, we would like individuals to be objective about their subjective feelings. This is not an easy task because people are always affected by, for instance, their present mood, the task at hand, or various things in our surroundings. An example from our own laboratory comes from calibrating the apparatus for electrocutaneous pain stimulation. Nineteen participants used a visual analogue scale (VAS) for pain rating and we asked them to perform pain ratings from ‘no pain’ to ‘worst pain imaginable’, quantified from 0 to 10, with a stop value at 5 (Günter et al., 2013). First of all, almost all participants had questions regarding what was meant with the worst pain imaginable. Second, the actual stimulation at VAS 5 varied between the participants with 0.6 to 4.0 mA, which is quite a big difference in output. Third, when rating pain during viewing pictures with different emotional valence, ratings differed between the emotional categories, but mean ratings did not correlate with the amperage, nor were they consistent with the calibration measure. Finally, some participants reported afterwards that they had not been true in their ratings, due to things like ‘fear of excessive pain during the experiment’ or ‘playing tough’. This was a small digression that, however, demonstrates how subjective measures can be assessed and that they can be useful in differentiating emotional states. It also demonstrates how precarious and uncontrollable to undue influence these type of measures can be, as shown by the large individual differences and the effect of expectations and attitudes.

Nevertheless, continuous self-rating to pictures during experiments is a commonly used subjective measure of transient emotional states. For example, Lang (1980); Bradley & Lang, 2007) developed an instrument which provides a quick and easy method for individuals to rate their pleasure and arousal to pictures from the IAPS material; the so called Self-Assessment Manikin (SAM). SAM is a visual reporting scale that is easy to understand and has a reporting method that allows for reports to be created without engaging in much conceptual analysis (Nielsen & Kaszniał, 2007).

Another frequently used method for subjective assessments is using questionnaires. Questionnaires are used as diagnostic tools, to infer something about individuals’ states or personality traits, and they are not as direct as continuous self ratings. There are many high quality and validated questionnaires which can provide, for example, a measure of anxiety levels (e.g. the State and
Trait Anxiety Inventory [STAI] from Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), or levels of fear to specific objects (e.g. Spider Questionnaire [SPQ], Snake Questionnaire [SNAQ], and Mutilation Questionnaire [MQ] from Korman, Weerts, Hastings, Melamed, and Lang, 1974). These questionnaires are frequently used in emotion research, both as a criterion for selection and as a dependent measure.

**Behavioural measures.** The behavioural assessment of fear and anxiety has changed considerably during the past decades. This is partly due to the cognitive approach to emotion, introducing a myriad of techniques to operationalize mechanisms of attention, perception, resource allocation and memory, to name a few examples. In particular some of these techniques will be considered in much more detail in the following paragraphs. The progress is also due to the development of refined and advanced computerized techniques; for example, the extensive research on facial expressions, that in the past have been conducted with observational techniques (see Ekman, 1992, for an overview) or EMG (see Dimberg, 1990, for an overview), have now gained some new computerized methods to create and measure facial expressions (e.g. Kemeny et al. 2011; Cohn & Kanade, 2007). Moreover, software manufacturers are creating programs specifically adapted for designing and conducting experiments and collecting, for example, reaction time data with a millisecond precision. Technical advancements aside, there are still plenty of analogue tests used (e.g. behavioural approach/avoidance tests). However, the majority of analogue assessment procedures are not standardized and may best serve as a screening and monitoring of treatment effectiveness (Rosqvist et al., 2006).

To move forward from this rather lengthy brief description, this thesis will henceforward cover attention phenomena and research that has been conducted to investigate the relationship between fear and attention. The concept of attention is closely linked to the discussion of the definition of emotion (see paragraph 2.1); and some would say that attention is the first thing that has to occur for a fear response to elicit, while others would argue that fear can be elicited without attention.

### 2.2. Attention in the presence of threat

It is difficult to refrain from starting this section with the famous quote of William James (1890, p. 403-404) stating: “Everybody knows what attention is. It is taking possession by the mind in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thoughts. Focalization,
concentration, of consciousness are of its essence". This is probably how most people comprehend attention, whilst not having a clear view of the hows and whys. Due to limitations in space and time, only the major concepts and research methods that are of importance for this thesis will be attended, but rest assured that this is an area with an extensive and multifaceted theory and research.

Attention can broadly be divided into two main temporal categories: the early perceptual processes and the later central processes. What James described would today be referred to as a central process; the selective attention, which occurs once a stimulus has been attended to. Selectivity and capacity are perhaps the most central features of attention. As mentioned, there is limitation of the brain’s processing resources that by necessity give rise to a selection for conscious processing (Desimone & Duncan, 1995). From all possible internal and external excitants, our awareness encompasses only a small subset of the available information at a time.

It has been suggested that attention reflexively can be drawn to a stimulus because of certain characteristics that impinge on our sensory systems, such as a flash of bright light or a sting of a needle. This bottom-up process has been said to be involuntary and automatic, and exerts exogenous control of attention, in contrast to the voluntary top-down process that could be seen as non-automatic and endogenous (Posner, 1980). It is reasonable to think of some sensory stimuli as being involuntarily and automatically processed. For example, a visual stimulus presented in the focus of attention will be processed unconditionally, given that the percever has his, or her, eyes open. However, whether or not attention can be guided in the visual space in a purely bottom-up fashion is a question that calls for some further discussion.

The distinction between early preattentive and central attentive processes has been critical in the study of visual attention (e.g. Treisman & Gelade, 1980). It has been suggested that a certain set of stimulus properties, such as a colour, orientation, size, motion, etc., have the propensity to guide spatial attention preattentively (Treisman & Gelade, 1980; Wolfe, 1992b). There is however some uncertainty as to where to draw the boundary between preattentive and attentive processes (see e.g. Cave & Batty, 2006, or Wolfe & Horowitz, 2004, for a discussion of that topic). Some studies have shown, for example, that bottom-up capture is contingent on top down attentional control settings, set by task demands (Folk, Remington, & Johnston, 1992), or primes (Wolfe, Horowitz, Kenner, Hyle, & Vasan, 2003); that search efficiency is dependent upon perceptual salience (i.e. a facilitated figure ground segregation, see e.g. Pashler, 1988; Wolfe, 1992a), and the
relationship between perceptual categories of targets and background distractors (Duncan & Humphreys, 1989); and Jonides and Gleitman (e.g. Jonides & Gleitman, 1972, 1976) have also demonstrated an effect of conceptual categorisations in search tasks. Some researchers have suggested that search rather should be characterized with efficiency than trying to sort them into preattentive and attentive categories (e.g. Duncan & Humphreys, 1989; Wolfe, 2001), and many are emphasizing a much greater role for top-down influences in the deployment of attention (c.f. Pashler et al., 2001; Soto, Hodson, Rothstein, & Humphreys, 2008; Wolfe et al., 2003). Even for processes that could be considered as preattentive, Wolfe et al. (2003) suggested this semi-controlled attention to be an implicit top-down process.

Results from many studies have shown an attentional bias towards threatening facial and animal stimuli. This thesis will continue with some findings, restricted to a small set of methodologies, regarding selectivity to threat, resources devoted to threat, and attention to threat when putting demands on attentional resources. Findings that will be reviewed here are mainly from studies that have investigated effects of fear on attention, mostly by using fear-relevant and feared animal stimuli.

2.2.1. Assessment of selective attention to threat

In an evolutionary perspective, an effective defence system that is quickly activated has obvious survival value (Öhman, 1993; LeDoux, 2000). Therefore, Öhman argues that there also ought to be a premium for early detection of threat (e.g. Öhman, 1993; Öhman et al., 2000; Öhman & Mineka, 2001). To investigate if fear-relevant and feared stimuli can draw attention preattentively, Öhman, Flykt et al. (2001) used an odd-one-out visual search task.

The visual search paradigm is one of the most frequently used methods to investigate aspects of selective visual attention. There are many different types of search tasks, but in the odd-one-out task, subjects are looking for a discrepant target stimulus among a number of distractor items, that are all the same or that are derived from a stimulus category different from the target category. On a percentage of the trials a target is present with the rest being, what are sometimes called, blank trials (Wolfe, 1998), in which a target is not present. The two most important tools that assist in the understanding of this visual search paradigm are measurements of search slopes and search-asymmetry (Treisman & Gormican, 1988; Treisman & Souther, 1985; Wolfe, 2001). The search slope is a function of reaction times as related to the number of items in the search set (i.e. set size). If the search for a specific target is efficient, reaction times do not increase much with an
increased number of items (generally less than 10 ms/item, e.g. Wolfe, 1998), but if
the search slope is steep the search is said to be inefficient (Treisman & Gormican,
1988). Treisman and colleagues (e.g. Treisman & Gormican, 1988; Treisman &
Souther, 1985; Treisman, Vierira, & Hayes, 1992) argue that if a certain feature
produces a search slope with an increase at less than about 10 ms per item, it is
said to “pop-out”, and the processing of that feature is assumed to be preattentive.
The search-asymmetry is assumed to be a mark for a basic preattentive feature
(Treisman & Gormican, 1988; Treisman & Souther, 1985). Given two types of
stimuli, Treisman and colleagues have argued that it is easier to find a target
defined by the presence of a basic feature than by its absence. As such, a search for
stimulus Q on a background of O distractors would be faster than a search for
stimulus O on a background of Q distractors, implying that the Q possesses the
added preattentive basic feature.

In the study by Öhman, Flykt, et al. (2001), pictures of spiders and snakes
served as fear-relevant (FR) stimuli, and pictures of flowers and mushrooms
served as fear-irrelevant (FIR) stimuli. The search-asymmetry between FR targets
on FIR distractors and vice versa (i.e. FIR target on FR distractors), was
investigated over two different set sizes (2 x 2, and 3 x 3). Participants were asked
to look for a stimulus from a discrepant category and to respond on a button with
one hand (usually the right) if a target was present, and the other hand if a target
was absent. Participants in the first two experiments were randomly selected not
based on any fearfulness criteria (i.e. a general sample). In the third experiment
individuals both fearful (of spiders or snakes) and non-fearful conducted the tasks.
The result exhibited both a search-asymmetry and a pop-out of FR targets, with
faster responses and flatter search slopes to FR targets than FIR targets. Fearful
individuals were furthermore even faster to respond to their feared target. These
results supported the hypothesis that FR stimuli draw attention preattentively,
because of some genetically predisposed features that evolutionary threats possess.
These so called feature detectors (see Martin, 1994, for a brief history) are assumed
to draw attention and trigger the fear system automatically. Öhman et al.
concluded that humans share a predisposition for an automatic guidance of the
visual attention towards potential threats.

Many studies have replicated the search-asymmetry between FR spiders and
snakes and FIR flowers and mushrooms found by Öhman, Flykt, et al. 2001(e.g.
Blanchette, 2006; Brosch & Sharma, 2005, Flykt, 2005, 2006; Lipp, 2006; Lipp,
Derakshan, Waters, Logies, 2004), and others have shown a preferential processing
of spiders and snakes using other analyses or methodologies (e.g. Flykt & Caldara,
2006; Lipp & Derakshan. 2005; Lipp & Waters, 2007). However, in a study by Flykt
and Caldara (2006), ERP responses to feared (spider or snake), FR (spider for snake fearful and snake for spider fearful), and FIR (mushroom and flower) target stimuli on FIR distractors during passive viewing and reaction times during a visual search task was measured. The results demonstrated faster reaction times to feared stimuli (spider or snake) but a differentiation between stimuli was evident only in the LPP (late positive potential), suggesting no early differentiations in ERP of the emotional significance of the stimuli. In addition, the studies by Blanchette (2006), and Brosch and Sharma (2005) showed that not only stimuli which could be considered threatening in an evolutionary perspective (i.e. phylogenetic) have a threat advantage, but also ontogenetic threats, such as guns and syringes (see also Fox, Griggs, & Mouchlianitis, 2007, for a similar finding). Thus, it seems like threats in general facilitate attention resources. A suggestion by Fox et al. (2007), was that the so called threat superiority effect (found in Blanchette, 2006), rather should be characterized by an effect of relevance. This theory is moreover supported by neurological findings of activity in the amygdala, showing that activation of the amygdala is not exclusively related to fear processing (see Sander et al., 2003, for a review). Further support can also be found in the studies by Lipp, and colleagues (Lipp, 2006; Lipp et al., 2004), demonstrating that not only spiders and snakes but also animals which cannot be considered fear-relevant in an evolutionary perspective (e.g. cats and horses, see also Tipples, Young, Quinlan, Broks, & Ellis, 2002), are detected faster on a background of flower and mushroom distractors. That is, all animals fear relevant or not, could be considered as more relevant to humans in comparison to flower and mushroom stimuli.

An aspect of particular importance for this thesis (see Study II), has to do with the relation between target and distractor categories. In their theory of visual attention, Duncan and Humphreys (1989) have argued that an increased perceptual similarity between target and distractor stimuli (i.e. simple perceptual features or shapes) causes a decrease in search efficiency, and that an increased homogeneity within target and distractor categories facilitates the search. Studies that involved all combinations of backgrounds and targets (Flykt, 2005, 2006, Lipp et al., 2004) have shown obvious categorization effects. That is, when a target is derived from the same category as the background distractors (e.g. a spider [FR-animal] target on snake [FR-animal] distractors, or a flower [FIR vegetative] target on mushroom [FIR vegetative] distractors) reaction times are much longer than if targets and backgrounds are from different categories (e.g. a spider [FR-animal] on mushroom [FIR vegetative] distractors). Generalizing Duncan and Humphreys' theory in a broader psychological perspective, these results could be due to an effect of conceptual categorizations being made among stimuli in the search set, causing impairment due to an increased conceptual similarity.
Lipp (2006, Experiment 2) also tested a category of FIR bird and fish on FR spiders and snakes to investigate if the increased homogeneity between target and distractor categories would impair the search, but the search advantage to the FR stimuli was still evident. However, a study by Soares, Esteves, and Flykt (2009), using cats and fish as distractors showed no search advantage to FR stimuli in a general sample. In that study a search asymmetry was not investigated but the data provided indicates that a search asymmetry did occur, but in preference of the FIR stimuli. A categorization effect among the FR stimuli was also shown, rendering longer reaction times to an FR target among FR distractors. This effect was not found among the FIR animals. Taken together, these results suggest that FIR animal distractors are more homogenous to the FR category than flowers and mushrooms are, but they also exhibit less homogeneity among the FIR stimuli compared to the FR stimuli. Soares et al. (2009) also tested individuals highly fearful of either snakes or spiders. These individuals exhibited a search advantage (i.e. shorter reaction times) to their feared stimulus compared to both the FR but non-feared (i.e. snakes for spider fearful, and spiders for snake fearful), and the FIR stimuli (cats and fish). In the analysis, all possible combinations of targets and distractors were included; meaning that among FR (but non-feared) and FIR targets search arrays, the feared animal as a distractor was included. These conditions produced much longer response latencies within fearful subjects than any other conditions. This result could actually be due to the fact that a feared object is more resource demanding, resulting in a slower disengagement from the threat; and thus, causing an interference of further processing. For example, Fox and her colleagues (e.g. Fox et al., 2000, 2001, 2002; see also Köster et al., 2004; Yiend & Mathews, 2001) have suggested that a delayed attentional disengagement from threat occurs. Speeded responses could be due to the degree of attentional engagement of distractors rather than to speeded detection of target. That is, if distractors are irrelevant in relation to the target stimulus (for example as mushrooms would be in relation to a spider target), they would not detain attention for long. However, if distractors are interesting or more relevant in relation to the target (for example as spiders would be in relation to a mushroom target), they would take longer time to search through, resulting in an interference of the detection of the target. This kind of interference effect has been found in several studies also among spider fearful individuals searching for a target with a spider distractor present (e.g. Gerdes, Alpers, & Pauli, 2007; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005).

This section has been dealing with measuring the spatial attention, mainly with visual search experiments that are including FR and feared stimuli. As shown,
it is not an easy task to draw any firm conclusions from the data. Nevertheless, it seems like threat stimuli do produce a response bias, but this bias can be dependent on several factors, such as individual levels of fear/anxiety, the categories that are used in the search set, the relation among and between categories, and disengagement effects, and so on. There are also still a lot of ambiguities as to when and at which processing stage a facilitation would occur, and the question of whether attention to a threat, such as a spider or a snake, truly is an automatic bottom-up driven processes or if it is a process that can be influenced by top-down factors, is still open for discussion. Study II was conducted in order to investigate the effects of distractor categories on the frequently reported search-asymmetry between FR and FIR stimuli.

As also mentioned, many studies have shown that threat related stimuli do interfere with task performance; and high anxiety individuals usually perform even worse than controls on tasks in the presence of a threatening stimulus. These interference effects are assumed to be due to that when a threat stimulus captures attention it makes demands on information processing resources (e.g. Yiends, 2010).

2.2.2. Assessment of resources to threat

Processing limitations are clearly present when people perform several tasks simultaneously. If one task requires a large amount of resources, processing of other tasks will suffer due to our limited cognitive capacity to process information. The secondary task technique is one type of dual task method that allows an investigation of resource allocation over time. By presenting two attention demanding tasks close in time, it is possible to measure resources allocated to the first task by performance in the secondary task, given that they rely on the same mechanisms or resources (see e.g. Pashler, 1994, 1998). Processing of the secondary task will be postponed or slowed by the requirements of the primary task, due to the, so called, “PRP effect” (psychological refractory period). It is assumed that the PRP effect is caused by a queuing of processing activity at a central “bottleneck” in some stage of the process. There is some disagreement as to where this bottleneck occurs; for example, Johnston and McCann (2006) have suggested that it occurs at a central conceptual stage, while Pashler (1989) has suggested it to be at a later central stage (i.e. at response selection). Whenever it is located it is assumed that this mechanism cannot begin its processing of a task before the processing of the other tasks is finished. This will also result in longer response latencies the closer in time tasks are presented.
There are relatively few secondary task studies that have been conducted to specifically investigate resources to FR animal stimuli. However, there are many studies that often involve other aspects, as for example spatial cueing experiments also involving spatial attention mechanisms. To isolate the investigation of resources as much as possible, stimuli should be presented in focal attention, and they should preferably also load the same system to enhance specificity and to avoid any crossmodal effects, if there are such.

It has been shown that negative stimuli do consume a larger amount of processing resources. For example, in a conditioning study using a secondary task experiment, colored lights were used as the primary task and response to a tone as the secondary task (Dawson, Shell, Beers, and Kelly, 1982). One of the colors (CS+) was paired with an electrical shock, and the other was not (CS-). The results showed that a tone presented subsequent to the CS+ generated longer reaction times, indicating a larger resource allocation to unpleasant stimuli than when the tone followed the control stimuli (i.e. CS-). In addition, this differentiation remained evident for more than six seconds. In a study by Crombez, Eccleston, Baeyens och Eelen (1998) it was shown that electrocutaneous pain stimulation interferes with processing of task, and that a threat of intense pain allocates increased resources, even though stimulation was the same over groups of participants. Furthermore, an ERP (event related potentials) study by Meinhardt and Pekrun (2003) used visual picture stimuli with emotional valence and emotional imagery as primary task, with the counting of an auditory odd-ball as the secondary task. P3 amplitudes were assessed as a measure of processing resources allocated task-related processes. The results showed smaller P3 amplitudes to both negative and positive stimuli compared to neutral stimuli, indicating that emotional stimuli/imagery required more processing resources than the neutral.

As shown by these experiments, emotional stimuli do demand processing resources and impair processing of other information. One of the aims of Study I was to investigate allocation of resources to feared stimuli over time. If fear is an automatic and impenetrable process, a feared stimulus should immediately demand resources and stay unaffected of other resource demands. This leads us on to another line of research which uses the reversed conditions to investigate attention to fear in relation to available attentional resources. In other words, putting demands on attentional resources with, for example, a difficult task will enable an investigation of whether attention resources are necessary in fear processing.
2.2.3. Attention to threat during load

The work by Lavie and colleagues (see Lavie, 2005, for a review) has shown that an increased load on the perceptual system decreases or eliminates distractor interference. That is, a higher task demand in a visuo-spatial task leaves little resources for processing of task-irrelevant stimuli. The load that Lavie is referring to lies in either an increased number of different items in visual space that need to be perceived, or that the perceptual identification of items is more attention demanding.

Some researchers have used this paradigm to investigate if a high task demand also can interfere with processing of threatening distractor stimuli. If threat captures attention bottom-up and elicits a response automatically, fear processing would not be dependent on attentional resources, and thus, fear processing would not be affected by the load. For example Pessoa and colleagues have investigated the effect of task demand on fear (see e.g. Pessoa, 2005; Pessoa, Kastner, & Ungerleider, 2003, for a review). In one study, facial stimuli were presented at centre with bars in the upper left and right corner of the screen (Pessoa, McKenna, Guiterres, & Ungerleider, 2002). The facial stimuli were pictures of women and men expressing three different emotions (happy, fearful, and neutral). In an attended task participants were to decide if the face was female or male, and in an unattended task they would decide if bars had the same orientation or not. In the task where participants attended the faces, a stronger activation in relevant brain areas (e.g. amygdala, fusiform gyrus) was found to both the two emotional facial expressions compared to the neutral. However, attending to the bar-task resulted in no differential responding with regard to both reaction times and brain activity. To follow up, a study by Smith-erthal et al. (2005) used the same methodology with highly negative mutilation pictures and neutral pictures. In this study they varied the difficulty of the bar orientation task. The results showed impaired responses to negative (compared to neutral) stimuli in the easy task, but an increased difficulty level also decreased any differences between the emotional stimuli. Their conclusion was that if attention resources are depleted, distractor interference is eliminated regardless of the emotional nature of the stimuli. A nice set of experiments by Yates, Ashwin, and Fox (2010; and Fox, Yates, & Ashwin, 2012) also demonstrated that a high versus low perceptual load eliminated any differences in reaction times between a conditioned angry face (CS+), another angry face (CS-), and a neutral face (also happy face in Fox et al., 2012, Experiment 2). Fox et al. furthermore showed that there were no differences between individuals high or low in trait-anxiety, with regard to distractor salience during high load. Taken together these studies demonstrate that selective attention to threat stimuli is dependent on attention resources.
However, there are also studies showing that attention to negative stimuli is independent of load. An fMRI study by Vuilleumier, Armony, Driver, and Dolan (2001) showed, for example, no differentiation in responses in the amygdala between attended and unattended fearful faces. Pessoa (2005) argues that studies that have not been able to remove emotional interference effects probably did not use tasks that were depleting attentional resources.

In both Study I and III, allocation of resources to FR and feared stimuli has been provoked by showing spider or snake fearful participants pictures of spiders and snakes (among others). A common focus in both of those studies has however been to manipulate resources to threat, both by external, or contextual (Study I), and internal, or dispositional (Study III) factors. To clarify one aspect of those studies, the manipulations used have not been in accordance with the theory by (Lavie, 2005). She is making a clear distinction between perceptual load and central (cognitive) load. As described in the beginning of this paragraph, the perceptual system is loaded by an increased number of items in the visual field, causing a reduced distractor effect. However, loading the central system could cause an enhanced effect of distractors (Lavie, 2005). This could also occur if tasks consist of the same stimuli (as in the stroop test) or if they are presented close together (i.e. in focus of attention). For example, in the study by Smith-Erthal et al. (2005), they were using the exact same stimuli, merely changing the angle of the two bars to enhance the difficulty to separate them. The bars were moreover presented close to the picture stimulus (9° to the right and left of the picture) which was presented in the centre. That is, they did not manipulate the focus of spatial attention and it is highly unlikely that individuals were unaware of the picture content. Thus, the results from that study indicate that also a large central load can abolish effects of emotional distractors, even if the distractor was presented in the focus of attention.

2.2.4. Brief summary

The emotion-attention research is a very complex area with a massive amount of research from results supplied by a wide variety of methods, analysis, and conclusions, of which a very restricted sample has been attended to. More importantly, it can also be said that threat stimuli always seem to interact with attention in one way or the other. They seem to grab attention, consume resources, and interfere with processing of other stimuli.

Concerning FR and feared animal stimuli, results from visual search studies have demonstrated a more rapid detection of those, at least compared to vegetative stimuli, both in a general sample and in individuals with specific fears. However,
the only-animal search sets exhibit some ambiguities that ought to be further investigated. Concerning the investigation of resource allocation, there is not much research to be found with FR and feared animal stimuli. It has been shown that threat stimuli demands resources and interferes with task performance. This is also something that has been demonstrated in plenty of other experimental paradigms. However, putting demands on both the perceptual and central resources seem to have a gating function, even for emotion laden distractor stimuli, to enter awareness. This is an expanding field but it is still relatively unexplored with several developing paradigms and a lot of potentials.

Investigating spider and snake fear might to some people seem very specific, but it should be noted that research on animal fearful individuals is a method to access the emotion of fear. Understanding the mechanisms of fear and anxiety is important work. Not only has it been showed that specific phobias (of which animal phobias is the dominant category) indicate a lifetime prevalence of over 10%, the lifetime prevalence for having a clinical anxiety disorder has been estimated to 25%, and over 30% for women (Kessler et al., 1994, in Barlow, 2002). Worth noting is the most likely large number of hidden statistics, for example, as seen in Agras et al. (1969), which performed diagnostic interviews on 325 individuals, of which 7.7% were diagnosed with a specific phobia, but more than 50% had an intense fear for a specific object.
3. AIM

Attention as a process, between a stimulus and an aware percept, includes many elements - from sensory and perceptual processes, orienting and selection mechanisms, to conceptual and central processes - not necessary as divided entities or in that order. What fear does with attention is that it, at some point, takes attention in possession and once a foothold grasp is established, fear seems to take over the organism; it boosts the physiological system, it motivates behavioural escape patterns, and changes the individual’s perception of the world. This activity demands and consumes resources. Questions that arise from the idea of studying this process include: When and where does this point occur? Is it a fixed point somewhere along the information processing chain or is it impressionable to other influences? Is a fear response at any given point independent from and impenetrable to top down influences?

The main idea of the present research is that fear processing is dependent on all other concurrent processing demands, irrespective of their nature. That is, the expression of fear is dependent on the resources available; meaning, all other processing of internal or external events, will affect the outcome of a fear reaction. The three studies that have been conducted have all aimed to manipulate some aspect of the fear response. Even though the main aim of Study I was to investigate attentional resources allocated to feared stimuli, it was also conducted to investigate whether or not a higher cognitive demand could alter responses to a feared stimulus. Study II was conducted to investigate contextual influences on the selective attention to a feared stimulus. Study III aimed to investigate if an internal cognitive demand was sufficient to alter allocation of attentional resources to feared stimuli.
4. THE EMPIRICAL STUDIES

Three experimental studies have been conducted. The presentation of the studies here is in chronological order, but they will be discussed in the ‘general discussion’, more in accordance with the introduction (i.e. Study II, Study I, and Study III).

4.1. General methods

In this section, I will summarize the general methods used in all three studies. Since we are in the midst of a technological/digital revolution there is however differences regarding the apparatus used, for example screens and computers, and their performance, such as screen resolution, capacity, sampling rates, updated versions of software, and so on. A more detailed explanation of the methods for each study can be found under the ‘method’ section of each respective manuscript.

4.1.1. Participants and assessment of fear levels

Groups of spider fearful, spider or snake fearful, non-fearful controls, and general samples selected irrelevant of any fears they may have, have been participating in the experiments over the three studies. The assessment of fear levels has been conducted with a Swedish version of the SPQ and SNAQ by Klorman et al. (1974). No attempts were made to perform diagnostics for specific phobias. However, some individuals most likely had scores that were in the range of what could be considered a phobia (c.f. Muris & Merckelbach, 1996; Öst, 1989).

4.1.2. Measurements and apparatus

Behavioural measures. In all studies performance measures were collected in terms of reaction times (RT) and accuracy (ACC). ACC has been measured in proportion of correct responses, and RTs in seconds (s) or milliseconds (ms) depending on the software that was used to collect data. Some software manufacturers claim to have millisecond precision, such as the Experimental Run Time System (ERTS; from BeriSoft Cooperation) and E-prime 2.0 (from Psychological Software Tools inc.). The experiments for Study I and III were programmed in ERTS and E-prime respectively. However, Study II was programmed in Authorware 6.0 (from Macromedia ©) which has a timing of one hundredth of a second making it more appropriate to use seconds as the unit of the measure. The main tools used for presentation and collection of data have been 17 inch computer screens and standard computer keyboards for collecting responses.

Psychophysiology. Heart rate (HR) was used as dependent measure in both Study I and III. The ECG signal was recorded with Biopac MP 150, and digitalized
in AcqKnowledge 3.5 (from Biopac Systems inc). Individual signals have been visually inspected and artefacts have been removed. HR was measured by cardiac cycles (in ms) and the peaks of the R-waves were used to calculate the rate (in beats per minute [bpm]) of each interbeat interval (IBI). This method gives an accurate measure of the immediate intrinsic variability (c.f. Graham, 1978; Jennings, Berg, Hutcheson, Obrist, Forges, & Turpin, 1981). Event related HR has been calculated as a change score from baseline based on 3 (Study I) or 2 (Study III) IBIs before stimulus onset. Change scores for the consecutive five IBIs after stimulus onset has been calculated for each presentation.

Subjective measures. SPQ and SNAQ (Klorman et al., 1974) have been used to assess individuals’ fear levels of spiders and snakes respectively, and state anxiety (STAI-S; Spielberger et al., 1983) was also collected in Study III. SPQ and SNAQ have 31 and 30 items respectively with dichotomous answers, and STAI-S has 20 items with a four point likert-scale. Scores for each questionnaire have been summed for each individual. For Study II and III participants have completed a web based version of the questionnaire, created in a system developed at Mid Sweden University (Mod Survey 3.2.6; Palmius, 2012). Depending on the purpose of the measure, participants completed the questionnaires before coming to the laboratory, before starting the experiment, or after completing the experiment.

4.1.3. Ethical aspects

Study I was conducted after consulting the local ethical committee at Mid Sweden University. Study II was not considered in need of ethical approval. A standard visual search with animal and plant pictures has been conducted in a computer room with 10 cubicles with computers. All participants in Study II have been psychology students conducting an experiment as part of a course requirement. Participation has however been voluntary and in all studies it has been emphasized that subjects are free to cancel at any time during the experiment. From all 306 individuals conducting the visual searches, only one has aborted due to an exaggerated fear of snakes; a woman who, subsequently has received treatment for that fear (see picture1, left). Study III has been conducted with approval of the regional

1 Frida and the snake Korven after exposure. With permission from Frida Ivansson. Photo: Anna Bjärt. 

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ethical committee. All data collected have been averaged over conditions and presented only at group level. For Study I and II personal data was not collected. Fearful participants in study III were offered participation in an ongoing treatment study, wherefore contact data has been saved.

4.2. A brief summary of the studies

This section will mainly cover details of importance to get an overview of the studies, and the most relevant analyses and results will be emphasized. Further details can be found in the respective manuscripts.

4.2.1. Study I

The time course of resource allocation in spider-fearful participants during fear reactions, Anders Flykt and Anna Bjärtå, 2008.

Aim. The aim of this study was twofold with the main objective being to investigate the time course of attentional resources allocated feared, fear-relevant (FR) but non-feared, and fear-irrelevant (FIR) animals respectively. The secondary objective was to investigate the effect of task demand on the fear response.

Method. Eighteen right-handed spider fearful women conducted two secondary task experiments with two different task demands. Pictures (640 x 480 pixels) of spiders, snakes, wolves, beetles, turtles and rabbits, served as backgrounds to a simple detection task and a more complex discrimination task (see Figure 1), over two counterbalanced blocks.

![Image](image1.png)
![Image](image2.png)

Figure 1. Examples of displays for the different tasks. In the detection task (a) participants were to respond on detection of the triangle. In the discrimination task (b) participants were to discriminate between an arrow pointing to the left or to the right.
Spiders were considered the feared animal, snakes and wolves were considered FR animal, turtles and rabbits were considered FIR animal, and beetles provided a perceptual control to spiders. The animals were from the animal categories arthropods, reptiles, and mammals. The detection probe was 21 Xs forming a triangle and in the discrimination task the ‘triangle’ was pointing to the left or right. Probes were presented superimposed on the pictures at eight different time positions (SOA; stimulus onset asynchrony) with steps of 100 ms, starting at 100 ms after stimulus onset and ending at 800 ms. In the detection task participants were asked to press the ‘L’-key of the computer keyboard, with their right index finger, as fast as possible on detection of the triangle. In the discrimination task they were told to discriminate between arrows, and press the ‘L’-key with their right hand for arrows pointing to the right, and the ‘F’-key with their left hand if the arrow was pointing left. Speed and accuracy was emphasized.

Performance was measured with RT and ACC, and HR was used as a measure of the physiological response. The analysis was conducted with a 2 x 6 x 8 within-subjects Analysis of Variance (ANOVA) for RT and ACC, with task (detection, discrimination), animal (spider, beetle, snake, turtle, wolf, rabbit), and SOA (100-800 with steps of 100 ms). For the HR analysis, SOA was exchanged with the change scores of the five consecutive IBI5 following picture onset (IBI1-IBI5). Relevant contrasts were conducted in accordance with the investigation.

Results and conclusions. The results showed a larger impairment and a faster acceleration of HR to tasks in the presence of spider pictures, indicating a larger allocation of resources to the feared animal. As shown by Figure 2, participants had generally longer RTs and a lower ACC in the discrimination task, and only the latter in the detection task, showing that the discrimination task also imposed a higher task demand. In addition, it was shown that the longer participants looked at the spider the larger the impairment in the detection task. In the discrimination task, all SOAs but 100 and 500 exhibited a significant impairment (see Figure 2, middle panel).

During the discrimination task, a smaller difference in HR between pictures of spiders and other animals was shown, in comparison to the detection task (see Figure 2, right panel). This is indicating that a higher task demand could decrease the physiological response to pictures of spiders. Regarding FR but non-feared and FIR animal there were no obvious differences of interest for the specific investigation. As shown by the ACC (see Figure 2, middle panel), there was a decline over time in the detection time.
Figure 2. Mean reaction times (ms), accuracy (proportion of correct responses), and heart rate change scores from baseline (beats per minute), in the left, middle, and right panels respectively, from the discrimination task (upper row) and detection task (lower row). ²

Thus, the main findings from these results are that a feared animal demands attentional resources and interferes with processing of task. As task demands increased, performance decreased and even worsened when a spider picture was present. This goes well in line with Lavie’s (2005) suggestion that central load can enhance the effect of distractors. However, the increased task demand also decreased the physiological responses to spiders, indicating that an enhanced cognitive load also can interfere with the fear response.

² With permission from Taylor & Francis
4.2.2. Study II

The effect of using different distractor sets in visual search with spiders and snakes on spider-sensitive and non-fearful participants.


Aim. The aim of Study II was to investigate category effects on the search-asymmetry between FR and FIR stimuli. A search set with different categories FR animal and FIR vegetative stimuli, was compared to a search set with same categories FR animal and FIR animal stimuli. A general sample, spider sensitive (SS) and non fearful (NF) individuals conducted the different versions of the experiment.

Method. Two experiments were conducted with two visual search tasks in each experiment. One task was testing FR spider and snakes together with FIR flowers and mushrooms, and the other used FIR rabbits and turtles. Experiment 1 was performed on a general sample (25 + 25 participants in each group conducting the different versions). For Experiment 2, data was extracted, from a large collection of data from visual searches (256 individuals), based on participant’s scores on the SPQ and SNAQ (Klorman et al., 1974). Data from the 22 right-handed women with the highest scores on SPQ and low scores on SNAQ, and 22 right-handed controls with the lowest scores regarding both questionnaires, was collected. Considering the scores of the SS individuals (see manuscript) it is most likely that they had a strong fear, but since we did not ask them specifically they were referred to as spider sensitive.

Figure 3. Three samples demonstrating three target search arrays with a spider target (FR animal) on a.) different category (vegetative) FIR distractors, b.) same category FR distractors, and c.) same category FIR distractors (FIR animal).
Nine coloured pictures (200 x 200 pixels) from each stimulus category were used. Contrast and mean optical density of the colours red, green, and blue was made equivalent for all pictures to rule out as many perceptual confounds as possible. The FIR animal pictures were also chosen so that they would be more homogenous to the FR animals with regard to the natural background of the animal; that is, no animals were under water or in the sky (as fish and birds are).

The task was a replication from previous odd-one-out search tasks (sometimes also called same-different, see Figure 3 for some samples) with 3 x 3 matrices (e.g. Flykt, 2005, 2006; Lipp, 2006; Lipp et al., 2004; Öhman et al., 2001; Soares et al., 2009). The participant’s task was to decide whether all stimuli were from the same category or if there was one discrepant stimulus in the search array. The ‘F’ and ‘L’-keys were used for non-target and target displays respectively. Speed and accuracy was stressed, and RT and ACC were collected for the analysis. A 2 x 2 x 2 mixed ANOVA with between group factor, experimental condition (flower/mushroom, rabbit/turtle), and within group factors, background (FR, FIR), and target (FR/FIR), was conducted in the first experiment. For the second experiment, adding individual’s fear level to the analysis, a 2 x 2 x 3 ANOVA was conducted with experimental condition (as above), fearfulness (SS, NF) as another between group factor, and target (spider, snake, FIR). The last factor was analysed with only FIR backgrounds. Relevant analyses of asymmetries were conducted in both experiments.

Results and conclusions, The results from Experiment 1 replicated the results from above mentioned studies with regard to a search-asymmetry between FR targets and FIR targets, with shorter RTs to FR targets on FIR distractors than the opposite condition. This effect was however found only among mushroom and flower distractors, and not when using rabbits and turtles (see Figure 4a, the two middle bars of each experimental condition).

A category effect was furthermore evident in the flower/mushroom condition but not in the rabbit/turtle condition, as shown by the longer RTs over conditions with same category targets as distractors in the flow/mush conditions. Of all possible asymmetry comparisons in Experiment 2, only the spider-FIR comparison was significant for SS individuals in the flower mushroom condition, with faster RTs to spider on FIR distractors, compared to the opposite condition. It was furthermore shown that SS individuals had the fastest RTs to their feared target, but again, only in the flow/mush condition of the experiment. It should be noticed that the FIR animal distractors did not impair the search, in the sense that RTs became much longer. They rather equalized the RTs within the experimental
condition. This indicates that participants tune in on the categories used in the search set, suggesting top-down influences during the task.

Figure 4. Mean reaction times for a.) a general sample conducting different versions of the experiment, and b.) spider sensitive and non fearful individuals conducting different versions of the experiment. For Experiment 2 targets were split to spiders, snakes, and FIR targets, all on FIR background.
Taken together, these results show that the constellation of stimuli used in a visual search clearly coincides with reaction times. Stimulus relevance was expressed in terms of shorter reaction times but only when the search set allowed an obvious categorization of the stimuli included in the set. Thus, faster responses to FR and feared stimuli are most likely due to other factors than a bottom-up capture.

4.2.3. Study III

_Consistent cognitive demands influence allocation of attention during fear processing._ Anna Bjärtä, Jens Bernhardsson, Anders Flykt, and Örjan Sundin, 2013.

_Aim._ In Study III, two experiments were performed in order to investigate if attentional resources to FR and feared stimuli could be manipulated by an internal cognitive demand. Experiment 1 included a general sample of participants to investigate if FR stimuli at all demand more processing resources than FIR stimuli. As shown in Bjärtä, Flykt, and Sundin (2013, Study II) the stimuli set used in comparative groups are of utmost importance. That is to say, the FR stimuli might not be fear-relevant in a biological sense, but they could be more fear-relevant or just more relevant, depending on what stimuli they are compared with. Thus, in Experiment 1 of the present study, spiders and snakes are still referred to as FR because they are considered more fear-relevant in relation to flowers and mushrooms. Nevertheless, the aim of both experiments was to maximize any differences in resource allocation between stimulus types and then investigate if a cognitive demand could affect the distribution of resources.

_Method._ A secondary task experiment, similar to the discrimination task used in Flykt and Bjärtä (2008), was also used in the present study. Natural coloured 600 x 600 pixels pictures served as backgrounds to a discrimination task consisting of a yellow arrow (2 x 2 cm) pointing to the left or to the right, presented superimposed at the centre of the picture. Pictures of spiders, snakes, mushrooms, and flowers were used on the general sample (33 individuals selected irrelevant of any kind of fear). In Experiment 2, spider (16) or snake (3) fearful (FF) individuals conducted the same kind of experiment but with pictures of their feared animal (spiders or snakes), rabbits and turtles. Since the aim was to investigate manipulation of resources to FR and feared stimuli, the task was designed to maximize effects between the threatening stimuli and non-threatening stimuli. This is why the discrimination task was used, and SOAs where varied to reduce automaticity of responses to probes.
To create an incentive to motivate participants to respond quickly and correctly, they received a threat of a punishment for slow and incorrect responses. The punishment was provided by a small burst of white noise. The idea was not to administer the punishment per se, which is why adjustments were made to minimize the risk for participants of actually receiving one. All participants conducted both conditions (no demand, cognitive demand) over two counterbalanced blocks, and they were explicitly told to focus on the task. Speed and accuracy were stressed, and performance measures were RT and ACC. In Experiment 2, HR was also measured to control for fear responses. It should be emphasized that the purpose of the punishment was not to enhance the load, but merely to create an incentive, or internal directive, to answer quickly and correctly. It could however be reasoned, that if a reallocation of resources to the task was shown, HR could be expected to decrease in the punishment condition.

The analysis of Experiment 1 was conducted with a 2 x 2 matrix within subjects ANOVA, with demand (no demand, cognitive demand) and relevance (FIR, FR). In Experiment 2, the relevance variable was exchanged with the 3 levels variable animal (feared [spiders for spider fearful, and snakes for snake fearful], rabbit, turtle). For the HR analysis, the five consecutive IBIs were added (IBII-IBI5), rendering a 2 x 3 x 5 ANOVA.

Results and conclusions. The results showed a ceiling effect in the accuracy with low error rates throughout both experiments and no differences between the demand conditions (1% and 2% for Experiment 1 and 2 respectively). This indicates that the choice probe task was not very difficult. In spite of that, probes presented on both FR (Experiment 1) and feared (Experiment 2) pictures resulted in longer RTs (see Figure 5a and b, bars to the left) in the condition with no demand, demonstrating that both FR and feared stimuli are resource demanding. More importantly, the cognitive demand affected probe RTs in such a way that they were shortened and any differences between FR and feared animals were abolished, showing that resources allocated to threatening stimuli can be altered by an internal cognitive demand. The results from Experiment 2 showed a small impairment in probe ACC and an elevated HR (to pictures of a feared animal compared to FIR animals, see Figure 5), both of which persisted throughout the experiment. This means that an effect of fear remained during the demand even though RT differences were abolished. This finding is an important methodological issue that ought to be considered in future research.

The occurred dissociation between ACC and RT could indicate that impairment in these measures reflect limitations at different stages of information
processing. For example, Pashler (1989) suggested that a postponement of reaction times reflects a limitation at a later central stage (i.e. at response selection) but he has also suggested that an impairment of accuracy is related to a capacity limitation at the perceptual stage.

**Figure 5** Mean reaction times for a.) a general sample and b.) a fearful sample conducting the experiment. Please mind the different time axes. Heart rate (c) is shown with demand conditions merged. Responses were almost identical in both conditions.
This could infer that the internal demand used in the present study operated only at the central stage, indicating that a fear reaction is triggered at an early stage of information processing. What it moreover shows is that the cognitive detriments due to fear can be prevented by an internal cognitive demand.
5. GENERAL DISCUSSION

The results from the present research confirm previous findings of fear-relevant and feared stimuli as prioritized in the selection process, and as demanding more resources once they are attended. The overarching aim was however to investigate whether or not the fear reaction was susceptible to manipulation. The results show that the processing of threatening stimuli can be manipulated, by both external and internal means. For example, Study II showed that the search asymmetry between a fear-relevant or a feared animal, and fear-irrelevant vegetative stimuli, was abolished by exchanging the vegetative stimuli to other animals in a visual search. Study I showed that a higher task demand tended to diminish heart rate responses to a feared animal stimulus in a secondary task. Study III furthermore showed that an internal demand could remove increments in reaction times to fear-relevant and feared stimuli in another secondary task. Thus, by altering aspects in the surrounding or in the individuals, responses to threatening stimuli can be altered. This means that processing of threatening stimuli is influenced by other concurrent events, suggesting that a fear response is not occurring as an isolated and modular process. However, Study III also showed that even though reaction times could be manipulated, a heightened physiological response and an impairment in task accuracy remained, demonstrating a dissociation between the measures.

5.1. Selection

Can a stimulus, fear-relevant or feared, in any true sense be captured by the bottom-up processes? There are two findings from Study II which speak against that possibility, of which the first pertains to stimulus relevance. The fact that individual fear levels affected the reaction times also indicates that internal goals have much to do with the selective attention, if that is what the reaction times of the visual search measure. One important aspect that has to be taken in consideration when doing experiments with choice response tasks is that there are a lot of different mechanisms included in the reaction times. That is to say, reaction times are reflecting not only the early search process but also central processes, such as decision making, response preparation and execution. Some researchers have suggested that differential emotional effects of response latencies are due to other processes, such as decision making (e.g. Derakshan & Koster, 2010) or action preparation (Flykt, 2006). Flykt, Lindeberg, and Derakshan (2012) have furthermore shown that the response force was strongest when fearful individuals responded to a feared target on non-feared distractors.
The second aspect indicating that search is governed by top-down control is the impact of the conceptual categorizations. As shown by the results from Study II, the search for a fear-relevant or feared target seemed to be facilitated when the whole search-set contained non-uniform objects that easily could be separated into different categories (i.e. animals and non-animals), while using a search-set with a uniform category (i.e. only animals) did not allow scope for any differences in stimulus relevance. This requires knowledge of the stimuli at a conceptual level. There is of course the possibility that the fear-irrelevant animal pictures used could have been more perceptually similar to the fear-relevant animals than that of the flowers and mushrooms (c.f. Duncan & Humphreys, 1989), obstructing the figure ground segregation (see e.g. Wolfe, 1992a). The studies by Lipp (2006) and Soares et al. (2009) had both fish and bird stimuli, while one of the precautions when choosing the material for the present study was that no pictures would be underwater pictures or pictures with sky background. The pictures were moreover equalized with regard to colour and contrast. However, the animal distractors did not impair the search, in the way that reaction times became longer, but they were equalized over all conditions. This is an interesting result because search arrays with the same category target as distractor (i.e. FR target on FR background or FIR target on FIR background) appeared to be more difficult to search through in the flower/mushroom experiment than in the rabbit/turtle experiment. This suggests that when it is possible to make a categorisation among stimuli (i.e. into animal and non-animal), the search with different category target and distractors seems to become easier and also give room for any expression of the emotional content, while the search with same category target and distractor becomes more difficult (i.e. rendering longer reaction times). For example, in Experiment 1 of Study II, it was shown that a fear-relevant target on a fear-relevant background was found much faster in the rabbit/turtle experiment than in the flower/mushroom (1.66s and 1.92s respectively, see manuscript of Study II). This result is particularly interesting since these matrices contained the exact same stimulus material (a spider on a background of snakes, and a snake on a background of spiders). This indicates, in line with Folk et al. (1992; Folk & Remington, 1998), that individuals tune in on the whole search-set used, and that the search is dependent on attentional control settings that are induced by the task demand. However, experiments were conducted between groups, and a within-group design could have made a better case of this.

Taken together, the present results indicate that if a categorisation of the search-set is enabled, the search for a feared object, or a more relevant object (e.g. Blanchette, 2006; Brosch & Sharma, 2005; Fox et al., 2007; Lipp, 2006; Lipp et al.,
2004; Tipples et al. 2002), can be facilitated, but if a categorization cannot be made, it seems like stimulus relevance are of less importance and more focus is put to the task. These results could also go in line with the findings of Study I showing that the physiological reaction to a feared animal decreased with an increase in task demand. That is, if a task requires less processing resources, more resources are available for fear expressions. At present, the position taken will be that faster reaction times to threat in visual searches are due to a facilitated selection as a function of concurrent processing at the perceptual level, at the conceptual level, and at the level of relevance. This is leaving a very restricted scope for bottom-up processes. For example, Wolfe and Horowitz (2004) state that there are only a few simple features that can produce a true bottom-up process (i.e. colour, motion, orientation, and size), and that threat is not likely one of these. There are, however, several other potential factors that also could promote faster responses, such as action preparation (Flykt, 2006), and an enhanced perception in the presence of threat, possibly due to activation in the amygdala (e.g. Phelps, Ling, & Carrasco, 2006).

5.2. Interference

The second topic of discussion is about interference in multiple task experiments. As Study I and III show, a task-irrelevant picture of a feared animal interferes with task performance, which is in line with the results of other studies. This is said to be due to the fact that threat engages attention and demands attentional resources leaving little over for processing of other things. Studies from another line of research which investigated effects of task demand on the processing of a task-irrelevant threat, have shown that loading both perceptual and central aspects of attention can abolish the expressions of emotional responses in terms of brain responses (Pessoa et al., 2002), and reaction times (Smith-Erthal et al., 2005; Fox et al., 2010; Yates et al., 2012).

One thing that should be made clear before continuing this discussion is that both Study I and III aimed to provoke a fear response. This is why a secondary task was incorporated, with a time allowance between picture onset and task onset. Picture stimuli were presented at centre of the computer screen with duration until participants responded. That is, no attempt was made to prevent initial processing of the picture, but rather to manipulate processing after perception. Another detail that is important to clarify concerns the demands used in the studies; the enhanced task demand of Study I aimed to increase load by external means, whereas the internal demand of Study III was a cognitive directive that did not aim to put demands on central resources, but rather to direct resources; to help individuals
prioritize resources with an internal demand. In Study III, it was however discussed that if resources could be prioritized to task, that would also have an effect on the physiological response.

The results from Study I showed that an enhanced task demand could decrease the heart rate response to a feared stimulus, while the internal demand, looked at in Study III, could speed up the prolonged reaction times to feared stimuli although not affecting the differentiation in accuracy or heart rate. As mentioned in the introduction, there are some disagreements as to where processing limitations may occur. One idea, perhaps mirroring the present results, fits within a theory proposed by Pashler (1989). He suggested that limitations can occur at different processing stages and he makes a distinction between the early perceptual attentional process and the later central attentional process. Perceptual limitations are thought to be resource dependent leading to an impaired accuracy, while the central response selection stage has more “bottleneck” like properties, leading to a postponement of reaction times. This could imply that the internal demand, used in Study III, affected processing only at a central stage. The results from Study I moreover imply that perceptual impairments due to fear occurs secondary to central impairments, as shown by an increasing impairment in accuracy over time. This could also indicate that a feared stimulus craves resources from “inside out”, resulting first in central limitations, and the increasing demands will eventually affect even the perceptual processing stage.

Taken together, the present results show that the physiological response could be affected by incoming information, while an internal demand could not affect early processing. This indicates that the fear response can be triggered very early, “on the way in”, but fear is generated from “inside out”, causing increasing impairments. This statement calls for some explaining and an attempt to make some implications will be made below. The model proposed below should however be seen as a tentative suggestion.

5.3. Synthesis

The only emotion that will be considered here is, for obvious reasons, fear, and whether it is applicable to other emotions or if fear is a special case will not be discussed further. A recurring theme throughout history has been a separation between the physiological division and the cognitive division, and in some cases physiology has been equated to emotion and contrasted with cognition. It has been shown that physiological activation to threat stimuli can occur when presented outside (i.e. before) the frames of visual awareness (e.g. Carlsson et al., 2004;
Esteves, Dimberg et al., 1994; Öhman & Soares, 1994), suggesting that fear can be elicited automatically and at an early processing stage. This is also consistent with the results from Study III, indicating that a cognitive demand (i.e. at central processing stage) could not affect the physiological response. However, the present view is taking a learning perspective on fear. Strong contingencies require less resources when processed and the stronger the contingencies are, the less resources are required (see e.g. Navon, 1989). This means that it might not be that threats are ‘seen’ any earlier than other stimuli; just that they are strongly associated to the arousal system, hypothetically amygdala based. Because of this association, a stimulus can trigger the arousal system fast and effortlessly at an early perceptual stage before information reaches visual awareness. This is not to say that it is a bottom-up process. On the contrary, associations are memory based, at the neuronal level. The amygdala has strong reciprocal connections throughout the visual system and it also poteniatizes plasticity in cortex (e.g. McGaugh, 2002, 2012; Phelps & LeDoux, 2005). Thus, in the present view, stimuli can be processed before awareness, but not likely without any processing resources. An interesting suggestion about the definitions of attention and awareness has been made by Lamme (2003). While many are equating focal attention with conscious awareness, Lamme suggests that it is possible for us to have a wide visual consciousness (that share its neural basis with the visual iconic memory), but only things we are attended to (connected to working memory) are explicitly reportable. This could be said to be a neurological ‘late selection theory’, that would make sense of many of the above mentioned results. A preliminary processing of the visual field is made, unconditionally, if we have our eyes open, but certain stimuli, possibly promoted by activation of the amygdala, are singled out, or selected, for central processing. Many studies have, for example, shown that amygdala do facilitate attention to emotional stimuli (see Phelps & LeDoux, 2006, for a review).

On a general level, it can be said that that the physiological activation is a unique and important part of fear. However, the question is if a physiological response alone can be viewed as an emotion? The present view is: absolutely not. A fear response is not as simple as a stimulus-response mechanism, especially not in humans having this large chunk of brain for cognitive processing to get through. A feared stimulus can trigger a physiological response at an early stage, possibly promoting or facilitating selection for central processing, but the consequences of that cannot be removed from the emotion. After a fear reaction is triggered it will make increasing demands on processing resources, starting at the central processing stage, working its way out to the sensory systems. This is an alertness state, making the organism focus on sensory information; sensory hypervigilance during threat has been shown in many studies (e.g. Crombez et al., 2005; Deveu,
Belopolsky, Theeuwes, 2011; Gerdes et al., 2007). It seems like emotional activation actually can make people see better. Phelps et al. (2006) showed that cueing a task with a fearful face (compared to a neutral) could facilitate perception in terms of enhanced contrast sensitivity, and they suggest that this modulation may occur via feedback from the amygdala. Since all this energy, or resources, is devoted to the investigation of threat stimuli, there is little left over to, for example, conduct a task. The more difficult the task will be, the larger the impairment in performance.

The detection task of Study I, showed an increasing impairment in the accuracy to probes presented on the pictures of a feared animal, indicating that it takes some time for the feedback process to affect early perceptual processes. That no differentiation in reaction times was shown merely indicates that it was a very easy task, which only involved detection and response, and no central decision aspects. However, in the discrimination task it was shown that central processing was affected by the threat, as shown by longer reaction times in the presence of the feared animal. This task was also more difficult, as shown by generally longer reaction times. When comparing the tasks on the time spent looking at the feared object it can be inferred that an impairment in accuracy occurs at about 1000 ms after picture onset, while central limitations occurs prior to that. The results from Study III, with longer reaction times to probes presented on fear-relevant animals compared to fear-irrelevant but no difference in accuracy indicates a small interference effect at the central stage. The fearful individuals showed a much larger impairment, stretching all the way “out” to the perceptual stage. In this experiment (Experiment 2 of Study III) heart rate was used to measure fear responses, showing stronger activation to pictures of a feared animal compared to other animals. As for the results of Study II, which is a much more difficult task than any of the tasks used in Study I and III, it could be discussed that an enhanced categorization effect between target and distractor, could facilitate attention to threat, causing both shorter reaction times to a threat target and longer reaction times to search array with threat distractors. However, the analyses used in the revised version of the manuscript do not have much focus on the disengagement aspect.

Concerning manipulation, it was shown in Study I that an external manipulation (i.e. higher task demand) can affect the physiological response, indicating that the fear reaction can be prevented by incoming load. This is also supported by the results from other studies (see e.g. Pessoa, 2005, for a review), and it seems that the earlier in the process the system is loaded, the more it can decrease the fear reaction. That is, manipulation of visual awareness with perceptual load can eliminate differentiations in brain responses, while an internal
manipulation (Study III) showed no differentiation in heart rate. One alternative explanation to ‘elimination’ is that responses are postponed. In a study from Krolak-Salmon, Hénaïf, Vighetto, Bertrand, & Maugière (2004), intracranial event-related potentials in the amygdala, by means of human depth electrodes in epileptic patients doing a pre-surgical evaluation, was measured. In a task where participants were shown male and female faces with different expressions (neutral, fear, happy, disgust), they were told to either attend to the gender or to the facial expression. In the facial expression task, a differential response to fear could be found in the amygdala already after 200 ms, which was not shown in the gender task. However, a differentiation occurred at a later stage (600-800ms), indicating that emotional expressions were processed, but the reaction was postponed. Another interesting finding in this article is that only 100 ms after a differentiation in the amygdala occurs there is a differentiation in the visual regions, supporting the hypothesis that neuro-modulatory feedback from the amygdala, as suggested by Phelps et al. (2006), may create a facilitation of attention. This rapid and amygdala dependent feedback could also explain the results from Study II, causing a facilitation of attention to threat in the easier task, while the more difficult task might have suppressed activity in the amygdala.

This is by no means a complete model building on enough empirical data, rather more similar to an elaboration of ideas that have been gathering for the past years, trying to take some kind of shape. That is, many other studies have helped in its evolution and there are still many critical studies to be conducted. There are also many potentially interesting areas that could/should have been included, such as the area of cognitive emotion regulation and suppression (see e.g. Gross, 1999, for an overview). This area is for example connected to the results of Study III, but the choice was made to focus on resources. The influences of cognitive control settings (i.e. Folk et al. 1992) has not been incorporated in the model, but is thought of as a feedback system from working memory, also creating a facilitation due to, for example, task demands or primes.

5.4. Limitations

Focus will be on Study II and III, given the extent of personal contribution to the studies. In Study II, a within-subjects design could have been conducted, but was not due to the sampling of Experiment 2. Experiment 1 was furthermore performed after the analysis of Experiment 2. We decided to test a general sample, which cannot be “picked” from a database. Nevertheless, plenty of visual search experiments have been performed previous to the ones conducted in this study and the results seem to be very stable. The focus here was on the search
asymmetry, which is an important, however sometimes forgotten, part of the test, which is why only one set size was used. Study III has a rather straightforward design. However, heart rate could have been measured in Experiment 1 of this study. Another thought is that experiments manipulating fear could have had subjective valence rating after every trial that might have strengthen the results.

This leads to another important point, which is more of a general methodological issue than a limitation of the present studies. It has to do with the “trustworthiness” of the reaction times. Study III shows that there are no differences in reaction times during the manipulation, while heart rate show the same heightened response and accuracy remained lower in the presence of a feared animal. Reaction times are often used as a behavioural measure in emotion research and if latencies differ between stimulus types, it is often said to be due to some emotional significance. If they do not differ, it is said to be due to either a lack of emotional significance, or to a lack of processing of emotional stimuli. The results of Study III indicate that there can be a lack of differences in reaction times without necessarily lacking an emotional response. This also has obvious implications for the results and interpretations of Study II. Thus, reaction time data should be complemented with other measurements.

A general limitation for this thesis is that the studies could have been more coherent, with respect to experimental paradigms used and processes investigated. The thesis could have had a larger focus on one specific process. However, the interests of this PhD-student was double, of which one was to further investigate visual search, and the other was a more general interest in resources. On the bright side, there are many follow-up studies to conduct.

5.5. Concluding remarks

This work has shown that a fear reaction certainly has a given place; it facilitates attention and demands processing resources. More importantly, the work has also shown that a fear reaction is influenced by concurrent information processing. It can be affected by occurrences in the individual’s external and internal environment, showing that it by no means is impenetrable to influence. The results from Study III is especially important showing that even when a fear reaction occurred, the cognitive demand could exert control over cognitive detriments created by a feared stimulus. In an evolutionary perspective, a fear system that is easily triggered but has access to cognitive evaluations at all times is far more flexible, and ought to create a better chance for survival than a modular and impenetrable fear system.
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>>> Here’s for you (and Örjan) >>>
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