Cortical Correlates of the Processing of Feared and Fear-Relevant Stimuli

Evidence from Event-Related Potential Studies Comparing Phobic and Non-Phobic Subjects

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The same thrill, the same awe and mystery, comes again and again when we look at any question deeply enough. With more knowledge comes a deeper, more wonderful mystery, luring one on to penetrate deeper still. Never concerned that the answer may prove disappointing, with pleasure and confidence we turn over each new stone to find unimagined strangeness leading on to more wonderful questions and mysteries – certainly a grand adventure!

Richard Feynman (1908–1988), Nobel Prize in Physics 1965
Excerpt from a public address "About The Value of Science" given at the 1955 autumn meeting of the National Academy of Sciences
Published in Feynman (1988)

Success is nothing more than going from failure to failure with undiminished enthusiasm.

Winston Churchill

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Contents

List of Abbreviations

ACC	Anterior Cingulate Cortex
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BDI	Beck Depression Inventory
CBT	Cognitive Behavioral Therapy
CG	Control Group
DLPFC	Dorsolateral Prefrontal Cortex
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders, Version IV
ECG	Electrocardiogram
EEG	Electroencephalography
EMG	Electromyogram
EOG	Electrooculogram
EPSP	Excitatory Postsynaptic Potentials
ERP	Event-Related Potential

fMRI	functional Magnetic Resonance Imaging
GAD	Generalized Anxiety Disorder
HEOG	Horizontal Electrooculogram
HR	Heart Rate
ISI	Interstimulus Interval
LPP	Late Positive Potential
rCBF	regional Cerebral Blood Flow
RT	Reaction Times
SD	Standard Deviation
SCID	Structured Clinical Interview for DSM-IV
So	Social Phobics
Spi	Spider Phobics
SPQ	Spider Questionnaire
SPAI	Social Phobia and Anxiety Inventory
STAI	State Trait Anxiety Inventory
Tukey HSD	Tukey Honestly Significant Difference
VEOG	Vertical Electrooculogram

Zusammenfassung

Kolassa, I.T. (2004). Kortikale Korrelate der Verarbeitung gefürchteter und furcht-relevanter Reize. Befunde ereigniskorrelierter Potenziale bei Phobikern und Nicht-Phobikern. *Dissertation. Fakultät für Sozial- und Verhaltenswissenschaften. Friedrich-Schiller-Universität, Jena.*

Diese Arbeit untersucht die elektrokortikalen Korrelate der Verarbeitung gefürchteter und furcht-relevanter Reize bei Spinnenphobikern und nicht-spinnenängstlichen Personen. Drei Studien wurden durchgeführt, an denen jeweils drei Gruppen von Versuchspersonen teilnahmen: Spinnenphobiker, Sozialphobiker und Kontrollpersonen.

Experiment I befasste sich mit den elektrokortikalen Korrelaten der Verarbeitung furcht-relevanter Reize im bildlichen emotionalen Stroop-Paradigma mit manuellem Antwortmodus. Die Analyse der Reaktionszeiten zeigte keine emotionale Stroop-Interferenz bei Spinnenphobikern, die die Farbe von Spinnen identifizierten. Stattdessen identifizierten Spinnenphobiker Spinnen generell schneller als Vögel oder Blumen, was konsistent mit einem Aufmerksamkeitsbias für gefürchtete Reize ist. Jedoch identifizierten Spinnenphobiker auch Blumen und Vögel signifikant schneller als Sozialphobiker und tendenziell schneller als Kontrollpersonen. Dies weist auf einen zusätzlichen Hypervigilanz-Effekt bei Spinnenphobikern hin, welcher zu tendenziell schnelleren Antworten bei Spinnenphobikern führte. Parietale spät-positive Komponenten (LPPs) waren spezifisch bei Spinnenphobikern erhöht, wenn sie ihr phobisches Objekt sahen. Diese erhöhten LPPs wurden auf den stärker erregenden und unangenehmeren Charakter der Spinnenbilder für diese Gruppe zurückgeführt. Eine späte frontale Positivierung wurde zudem bei Spinnenphobikern bei der Farbidentifikation von Spinnen identifiziert. Diese Positivierung trat nach der Antwort der Versuchspersonen auf und könnte als Korrelat einer erhöhten attentiven Verweildauer von Spinnenphobikern auf dem gefürchteten Objekt interpretiert werden. Alternativ ist es möglich, dass die Spinnenphobiker sich

nicht nur auf die Farbe des Objekts konzentrierten, sondern das Bild auch emotional verarbeiteten, was zu der erhöhten Positivierung in diesem Latenzbereich führte. Abschließend lässt sich sagen, dass die Ergebnisse früherer verbaler emotionaler Stroop-Paradigmen nicht mit Bildreizen repliziert werden konnten, zumindest nicht beim Gebrauch eines manuellen anstelle eines verbalen Antwortmodus. Somit sollte die Frage diskutiert werden, wie stark der Einfluss verbaler Verarbeitungsspezifitäten auf den emotionalen Stroop-Effekt ist. Dennoch gab es einige Hinweise für einen Aufmerksamkeitsbias bei Spinnenphobikern für ihr gefürchtetes Objekt, aber dieser Bias drückte sich in einer schnelleren Detektion bedrohlicher Reize und nicht in einem emotionalen Interferenzeffekt aus.

Experiment II untersuchte die neuronalen Korrelate der Verarbeitung schematischer furcht-relevanter Reize im bildlichen emotionalen Stroop-Paradigma. Die schematischen Spinnen- und Blumenbilder bestanden aus identischen grundlegenden visuellen Elementen und stellten somit ideale Kontrollreize füreinander dar. Wiederum wurde keine emotionale Stroop-Interferenz bei Spinnenphobikern gefunden. Stattdessen reagierten alle Versuchspersonen signifikant schneller auf Spinnen als auf Blumen. Die Ergebnisse legen nahe, dass schematische Spinnen furcht-relevante Merkmale beinhalten, für die spezifische Merkmalsdetektoren beim Menschen sensitiv sind, egal ob diese Personen phobisch sind oder nicht. Bei der Objektidentifizierung reagierten Spinnenphobiker generell schneller als Kontrollpersonen und Sozialphobiker, aber sie waren besonders schnell bei der Identifikation von Spinnen. Somit ließen sich Hinweise für eine generelle Hypervigilanz sowie für einen Aufmerksamkeitsbias für gefürchtete Reize bei Spinnenphobikern finden. Alle Versuchspersonen zeigten größere LPPs bei Spinnen als bei Blumen, jedoch wurde kein zusätzlicher spezifischer Effekt für Spinnenphobiker gefunden. Die erhöhten Amplituden bei Spinnen sind konsistent mit den unangenehmeren und erregenderen Einschätzungen der Spinnen, die in einer Pilotstudie bei allen Versuchspersonen gefunden wurden. Allerdings bleibt zu erklären, warum Spinnenphobiker nicht noch höhere Amplituden für ihr gefürchtetes Objekt zeigten, wie es in Experiment I gefunden wurde. Vermutlich sind schematische Spinnen weniger furchterregend als die realistischeren Spinnenbilder, die in Experiment I verwendet wurden.

Experiment III stellte eine erste Annäherung an eine Antwort auf die Frage dar, welche Merkmale eine Spinne furcht-relevant machen. Um diese Frage zu untersuchen, wurden 3 Bilderserien à 7 Bildern konstruiert, die beginnend mit dem Bild einer schematischen Blume (Ankerbild) sich langsam in eine Spinne verwandelten, indem sich die Umrisse der Blütenblätter der Blume langsam öffneten und dadurch zu Spinnenbeinen wur-

den. Die Versuchspersonen mussten entscheiden, ob sie in den einzelnen Reizen eher eine “Spinne”, eine “Blume” oder “Weder/Noch” erkannten. Mit dem ersten Öffnen der Blütenblätter der Blume wurden die Bilder von Spinnenphobikern als signifikant unangenehmer und erregender eingeschätzt als von Kontrollpersonen und Sozialphobikern. Der Unterschied zwischen den Gruppen nahm zu, je spinnenähnlicher die Bilder wurden. Entsprechend kategorisierten Spinnenphobiker die ambiguen Bilder signifikant häufiger als Spinne als Kontrollpersonen und Sozialphobiker, und ihre Reaktionszeiten nahmen rasch ab, je spinnenähnlicher die Bilder wurden. Im Gegensatz dazu waren die Reaktionszeiten der nicht-spinnenängstlichen Gruppen abhängig von der Eindeutigkeit des Reizes, d.h. je eindeutiger der Reiz, desto schneller die Antwort. Die Ergebnisse dieser Studie liefern Hinweise für die Annahme, dass Spinnenphobiker eine stärkere Reizgeneralisation oder aber einen interpretativen Bias aufweisen: sogar in ambiguen Reizen sahen Spinnenphobiker eher eine Spinne. Überraschenderweise fanden sich jedoch keine elektrokortikalen Entsprechungen für die Befunde auf der Verhaltensebene. Die ereigniskorrelierten Potenziale (EKPs) spiegelten einen starken Einfluss der Eindeutigkeit der Reize (bzw. der Äquivokation) wider: die LPPs waren umso größer, je eindeutiger die Reize. Des Weiteren beeinflusste die Ambiguität der Reize die Rückkehr der EKPs zur Baseline: ambigue Bilder führten zu längeren Positivierungen. Abschließend lässt sich sagen, dass es keinen Schwellenwert in der Blume/Spinne-Serie gab, ab dem die Reize als Spinne wahrgenommen wurden. Stattdessen veränderten sich die Klassifikationen eher kontinuierlich, wobei die Spinnenphobiker früher in der Blume/Spinne-Serie begannen, eine Spinne in einer Stimuluskonfiguration zu sehen.

Stichwörter: Ambiguität, Angst, Aufmerksamkeit, Aufmerksamkeitsanomalie, Aufmerksamkeitsbias, bildlicher Stroop, EEG, Eindeutigkeit, EKP, ereigniskorrelierte Potenziale, emotionale Interferenz, emotionaler Stroop, Erregung, Furcht, furcht-relevant, neuronale Korrelate, Reizgeneralisation, schematische Reize, Spinnenphobie

Abstract

Kolassa, I.T. (2004). Cortical Correlates of the processing of feared and fear-relevant stimuli. Evidence from event-related potential studies comparing phobics and non-phobics. *Dissertation. Faculty of Social and Behavioral Sciences. Friedrich Schiller University, Jena.*

This thesis examines the electrocortical correlates of the processing of feared and fear-relevant stimuli in spider phobics and non-phobic subjects. Three different experiments were designed, in each of which three groups of subjects participated: spider phobics, social phobics, and controls.

Experiment I examined the electrocortical correlates of the processing of fear-relevant stimuli using a pictorial emotional Stroop paradigm with a manual response mode. Reaction times showed no emotional Stroop interference in spider phobic subjects when identifying the color of spiders. Instead, spider phobics identified spiders generally faster than birds or flowers, which is consistent with an attentional bias for feared stimuli. However, spider phobics were also significantly faster than social phobics and tended to be faster than controls in identifying flowers and birds. This hints at an additional hypervigilance in spider phobics, which leads to a trend towards generally faster responses in spider phobics. Parietal late positive components (LPPs) were specifically enhanced in spider phobics when viewing their feared object. These enhanced LPPs were interpreted as being due to the highly arousing and unpleasant character of spider pictures for this group. In addition, a late frontal positivity was observed in spider phobics but not in the control groups when subjects identified the color of spiders. This positivity occurred after the subjects responded and may be interpreted as reflecting an enhanced attentional dwell-time on the feared object in spider phobics. Alternatively, it is possible that spider phobics did not only concentrate on the color of the stimuli but also processed the picture emotionally, leading to the enhanced positivity in this

latency range. In conclusion, the results of linguistic emotional Stroop paradigms in anxiety patients were not replicable with pictorial stimuli, at least when using a manual response mode instead of a verbal one. Thus, the question of how strongly verbal processing specificities influence emotional Stroop effects will need to be addressed in future studies. Still, there was evidence for an attentional bias in spider phobics for their phobic object, but this bias was expressed as a more ready detection of threat rather than as an emotional interference effect.

Experiment II examined the neuronal correlates of the processing of schematic fear-relevant stimuli in a pictorial emotional Stroop paradigm. Schematic pictures of spiders and flowers comprised identical basic visual elements, making them ideal control stimuli for each other. Again, no emotional Stroop interference in spider phobics was found. Instead, all subjects identified spiders significantly faster than flowers. This suggests that schematic spiders exhibit fear-relevant features to which feature detectors are specifically tuned in all humans, whether phobic or not. In the object identification task, spider phobics were generally faster than controls and social phobics, but they were particularly fast in the identification of spiders. Thus, there was again evidence for a general hypervigilance and an attentional bias for the feared object in spider phobics. All subjects showed larger LPPs in response to spiders compared to flowers, but no additional spider phobia-specific effects were found. This effect was consistent with the higher valence and arousal ratings for spiders in all subjects, but it remains to be explained why spider phobics did not show even larger amplitudes for their feared object, as was found in Experiment I. Presumably, schematic spiders were not as frightening as the more realistic spider pictures used in Experiment I.

Experiment III was a first approach to explore the question as to which properties make a spider fear-relevant. 3 flower/spider series with 7 pictures each were designed which, starting from the picture of a schematic flower, gradually turned into a spider by shifting the outlines of the petals, turning them into spider's legs. The subjects had to decide whether each stimulus was more similar to a "spider", a "flower" or "neither/nor". With the first opening of the outlines of the petals of the flower anchor, spider phobics rated the pictures as significantly more unpleasant and arousing than controls and social phobics. This difference increased the more pictures became similar to spiders. Accordingly, spider phobics rated ambiguous pictures significantly more often to be similar to a spider than controls and social phobics, and their reaction times decreased the more pictures became spider-like. In contrast, in the groups who did not fear spiders reaction times depended on the ambiguity of the picture, i.e. the

more unequivocal, the faster the response. In conclusion, this study found further support for the conjecture that spider phobics show a stronger stimulus generalization or an interpretive bias: even with ambiguous stimuli, spider phobics were more likely to see a spider. Surprisingly, no electrophysiological correspondence to the behavioral effects were found. ERPs reflected a major influence of equivocation: LPPs were larger, the more unequivocal the picture. Furthermore, ambiguity influenced the return of ERPs to baseline: more ambiguous pictures led to prolonged positivities. Finally, no threshold in the flower/spider series was found beyond which stimuli were perceived as spiders. Instead, the classifications changed in a rather continuous manner, with spider phobics starting earlier in the flower/spider series to see a spider in a stimulus configuration.

Keywords: ambiguity, anxiety, arousal, attention, attentional bias, emotional Stroop, emotional interference, equivocation, ERP, event-related potentials, fear, fear-relevant, neuronal correlates, pictorial Stroop, schematic stimuli, spider phobia, stimulus generalization

1. Introduction

1.1. Fear and Phobias, Anxiety and Anxiety Disorders

Anxiety and fear are closely related, but anxiety is distinguished from fear. First, fear relates to a specific feared object, while anxiety is thought of as objectless, more general and longer-lasting. Second, while fear is a reaction to real danger, anxiety is often viewed as a reaction to an anticipated or imagined threat. Third, fear is elicited in situations that can still be coped with. Anxiety results when coping attempts fail, i.e. when the situation is perceived as uncontrollable (Öhman, 2000a, 2000b).

Admittedly, it is easier to distinguish between fear and anxiety in theory than in practice. Tables 1.1 and 1.2 illustrate the difference between fear and anxiety listing their common and distinctive features according to Rachman (1998). Öhman (2000a, 2000b) proposes similar distinctions between fear and anxiety which will be elaborated in more detail in the following sections.

Fear It has been proposed that we might be biologically "prepared" to easily learn to fear potentially dangerous stimuli, e.g. spiders/snakes, angry faces, closed spaces (Öhman, 1986; Seligman, 1971). Fear therefore is a perfectly normal and desirable reaction to secure survival in the face of real (actual or anticipated) danger and has been reinforced by evolution.

Fear has several components: the subjective feelings, the peripheral physiological responses, and the overt behavior. The detection of a potential threat results in freezing or immobility and enhanced attentiveness toward the environment and the potential threat stimulus. This is accompanied by a vagally mediated deceleration of the heart

rate. When an imminent threat is encountered, the sympathetic nervous system becomes activated, which leads to heart rate acceleration, an increase in blood pressure, and circulating catecholamines from the adrenal medulla. Active fight or flight follows.

Several fears can be distinguished, depending on the eliciting situation: fear of physical stimuli, fear of animals, and social fears.

Fears of *physical stimuli* can be elicited by simple intense stimuli of any sensory modality (e.g. extreme noise or heat leading to tissue damage or inducing pain), but also by complex events (such as lightning and thunder) or evolutionarily relevant situations (such as heights, small enclosures, wide-open spaces, and light or darkness for nocturnal or diurnal species, respectively).

Fears of animals: From an evolutionary perspective, it makes sense that potential prey species fear their predators, but there is also widespread fear of other potentially poisonous animals, such as snakes, spiders, or insects. These fears may be better represented as fear of and disgust for contamination rather than as fear of the animal itself (Öhman, 2000b).

Social fears are attributed by evolutionary psychology to the dominance structure in social groups, with fear being part of the submissiveness shown by the dominated group members when confronting a dominant conspecific. In humans (and other primates) it denotes a fear of being negatively evaluated, of "losing face" in front of the group (Öhman, 2000b).

Moderating factors of fear are *closeness* of the feared object (the closer the feared stimulus, the stronger the fear response), *movement* of the stimulus (approaching objects elicit more fear than stationary objects or objects moving away), and *predictability* and/or *controllability* of the feared stimulus. When the situation is too uncontrollable for active attempts to cope (e.g. escape or avoidance), fear is replaced by anxiety, and when the organism eventually gives up and becomes helpless, anxiety is replaced by depression (Öhman, 2000a, 2000b).

Pathological Fears: Phobias When fears become excessive and interfere with normal adaptive functioning, they turn into *phobias*. For instance, excessive fear of spiders is called *spider phobia*, and excessive fear of social situations that involve evaluation by others is called *social phobia*.

Individuals with phobias of small animals respond to phobia-relevant stimuli with both fear and disgust. Heightened sensitivity to general disgust elicitors has been hypothe-

- Anticipation of danger or discomfort
- Tense apprehensiveness
- Elevated arousal
- Negative affect
- Uneasiness
- Future-orientation
- Accompanying bodily sensations

Table 1.1.: Similarities between fear and anxiety according to Rachman (1998)

Fear	**Anxiety**
Specific focus of threat	Source of threat is elusive
Understandable connection between fear and threat	Uncertain connection between anxiety and threat
Usually episodic	Prolonged
Circumscribed tension	Pervasive uneasiness
Identifiable threat	Can be objectless
Provoked by threat cues	Uncertain onset
Declines with removal of threat	Persistent
Offset is detectable	Uncertain offset
Circumscribed area of threat	Without clear borders
Imminent threat	Threat seldom imminent
Quality of an emergency	Heightened vigilance
Bodily sensations of an emergency	Bodily sensations of vigilance
Rational quality	Puzzling quality

Table 1.2.: Differences between fear and anxiety according to Rachman (1998)

sized as a potential diathesis factor in the etiology of these phobias (de Jong & Merckelbach, 1998; Sawchuck, Lohr, Westendorf, Meunier, & Tolin, 2002). The disease-avoidance model of small animal phobias articulated the idea that fear-relevant, but non-predatory, animals may be avoided for protection from infection and contamination rather than from being attacked and physically harmed (Matchett & Davey, 1991; for further elaboration see Sawchuck, Lohr, Tolin, Lee, & Kleinknecht, 2000).

Anxiety As explained above, anxiety is not an immediate reaction to a specific eliciting stimulus but is more general, longer lasting, and even anticipatory. Furthermore, the threat is often only imagined. Finally, the situation is perceived as uncertain and uncontrollable, and is therefore accompanied by unpleasant feelings of foreboding.

As for fear, several types of anxiety can be distinguished: situational vs. free-floating anxiety, somatic overreactivity vs. cognitive anxiety, and trait vs. state anxiety. With the exception of the distinction between trait vs. state anxiety, the concepts are not relevant in the context of this thesis and will not be elaborated here (cf. Öhman, 2000a). *Trait anxiety* is a habitually elevated anxiety. The affected persons never feel completely free of apprehension and worry. *State anxiety* on the other hand is a momentarily enhanced anxiety at a certain point in time (e.g. during a panic attack).

Anxiety Disorders It is important to distinguish normal anxiety in everyday life from clinical anxiety, which is more intense, recurrent, and persistent. In addition, the intensity of clinical anxiety is clearly above what is reasonable given the objective danger. Therefore, it tends to paralyze individuals, leaving them unable to cope with their situation. Examples of clinically relevant anxiety disorders are Panic Disorder, Generalized Anxiety Disorder, Posttraumatic Stress Disorder, and Obsessive-Compulsive Disorder.

Anxiety Disorders According to DSM-IV

DSM-IV (American Psychiatric Association, 1994) does not follow the above distinction between fear and anxiety exactly. It classifies all these disorders (phobias and anxiety disorders in the sense described above) as *anxiety disorders*. However, among the anxiety disorders, it differentiates between *phobias* (e.g. Agoraphobia, Social Phobia, and Specific Phobia) and *anxiety states* (e.g. Generalized Anxiety Disorder and Panic Disorder with or without Agoraphobia). Thus, the distinctions are similar in that they

take into account the situational specificity of phobias and the long-lasting emotional character of anxiety.

The preconditions for a diagnosis of an anxiety disorder according to DSM-IV are:

- The person must experience intense fear/anxiety of specific objects or situations that is in no relation to the extent of the actual threat, i.e. the fear/anxiety is exaggerated and situationally not appropriate or unreasonable.
- The feared object or situations are avoided or endured with great discomfort.
- The condition interferes significantly with the person's normal routine, occupation, or social relationships.

Of the different anxiety disorders distinguished by DSM-IV, the specific anxiety disorders (and here in particular spider phobia) as well as social phobia are of particular importance in this thesis.

Definition of Terminology

Corresponding to the terminology introduced above, phobias are more closely related to fear than to anxiety, i.e. spider and social phobia are *excessive cue-specific fears*.

However, social phobia is conceptually also related to *anxiety disorders*, as this term has been used in this context. Actually, in the literature the terms "Social Anxiety Disorder" and "Social Phobia" are often used interchangeably and lack a clear distinction. One could also speak of social anxiety disorder if one considers that whether a situational anxiety is called fear or anxiety depends on the controllability of the situation (Öhman, 2000a, 2000b). If social phobics cannot avoid a feared situation (e.g. an oral presentation), they often fail to master it. This again leads to feelings of helplessness. As detailed above, Öhman predicts that this helplessness (uncontrollability of the situation) leads to depression. In fact, social phobia is highly comorbid with depression (Merikangas et al., 1996; Schneier, Johnson, Hornig, Liebowitz, & Weissman, 1992; Stein et al., 2001).

Finally, in this thesis the term **fear-relevant stimulus** refers to any stimulus capable of eliciting a fear response in healthy controls. Examples of fear-relevant stimuli are angry faces, snakes or spiders. **Feared stimuli** are stimuli that evoke a phobic response in individuals with specific phobia. Thus, spiders are feared stimuli for spider phobics, but not for snake phobics.

1.1.1. Psychopathology of Spider Phobia

Characteristically, spider phobics display a persistent fear of spiders, an immediate anxiety response upon exposure, and avoidance of spiders and situations in which spiders can potentially be encountered. For DSM-IV criteria of Specific Phobia, see Appendix A.

The physiological correlates of the fear response are characterized by a distinct sympathetic excitation pattern: heart rate acceleration (Fredrikson, 1981; Hamm, Cuthbert, Globish, & Vaitl, 1997; Sartory, Eves, & Foa, 1987), electrodermal response (Geer, 1966; Öhman & Soares, 1994), an increase in blood pressure (Globisch, Hamm, Esteves, & Öhman, 1999) and muscle tonus as well as vasoconstriction of peripheral blood vessels (Prigatano & Johnson, 1974).

Novel stimuli normally elicit an *orienting response*, i.e. an initial heart rate deceleration (bradycardia) (Pavlov, 1927; Sokolov, 1966). The heart rate decelerates even more as the stimuli become more arousing or aversive (Lang, Bradley, & Cuthbert, 1997), resembling the "fear bradycardia" widely observed in animals (Campbell, Wood, & McBride, 1997). With a further increment in threat, the response changes from orienting to defense, and the heart rate increases (Graham, 1979; Sokolov, 1963a, 1963b). While in normal subjects unpleasant pictures rarely prompt a defense reaction, phobics clearly show accelerated heart rates when viewing pictures of their phobic object, i.e. they typically show a *defense reflex* which is characterized by a temporary cardiac deceleration followed by an acceleration (e.g. Hamm et al., 1997).

For example, Hare and Blevings (1975) found that spider phobics showed a pronounced heart rate acceleration and increases in skin conductance in response to a phobic object, while controls showed a normal orienting response. Similarly, Fredrikson (1981) reported enhanced heart rates and skin conductance in phobics in response to a phobic object, and this fear reaction did not habituate over trials. Furthermore, Globisch et al. (1999) showed that, except for the blood pressure change, even very brief presentations (150 ms) of spider/snake pictures led to the characteristic autonomic response pattern in phobic subjects.

Epidemiology Fredrikson, Annas, Fischer, and Wik (1996) found that animal phobias (snakes or spiders) had a point prevalence of 12.1% in women and 3.3% in men, and specific spider phobia was present in 5.6% of women and 1.2% of men. Animal fears were more intense in younger than in older individuals, which is consistent with the

results of Agras, Chapin, and Oliveau (1972), who found that the prevalence of animal phobia slowly declines with age. The onset of animal phobias is typically in childhood (Marks & Gelder, 1966, Öst, 1987). A gender difference in animal phobia has been well documented: about 90% of all spider and snake phobics are women (Wittchen & Perkonnig, 1996).

1.1.2. Psychopathology of Social Phobia

Social phobia is characterized by extreme fear of social interaction and performance situations. The main symptom, which is also the main fear, is the expectation of negative evaluation by others. For DSM-IV criteria of Social Phobia, see Appendix A.

People with social phobia fear that they will do or say something embarrassing while others are watching, be negatively evaluated, or have their excessive anxiety symptoms noticed. Anxiety symptoms are physiological (e.g. shaking, blushing, sweating) or behavioral (stuttering, poor eye contact, mumbling, nail biting, trembling voice) (Albano, 1995; Beidel & Turner, 1998). Because of these persistent fears, *social interaction* and *performance situations* are either avoided or endured with intense discomfort, which significantly interferes with occupational and private life. Typical feared interaction situations are approaching or leading conversations with strangers, members of the other sex, or persons of authority, as well as conversations on the phone, or "hanging out" with peers. Performance situations are situations in which one acts under observation or appraisal, e.g. speaking, eating, drinking or writing in public, (oral) examinations, or giving talks.

Social phobia is classified as either *generalized*, if the anxiety occurs in most social situations, or *specific*, if the anxiety occurs only in specific situations, e.g. public speaking or eating in public. Newer theories propose a continuous transition from normal or subclinical shyness to clinical social phobia. According to this view subclinical, specific, and generalized social phobia form a quantitative continuum with avoidant personality disorder at the extreme end (Stangier & Fydrich, 2002).

Social phobia often follows a chronic course and is associated with poor school and work performance, school dropout, unemployment, alcohol abuse, and impaired social relations (Davidson, Hughes, George, & Blazer, 1993; Liebowitz, Gorman, Fyer, & Klein, 1985; Mullaney & Trippet, 1979; Turner, Beidel, & Larkin, 1986; Wittchen & Beloch, 1996). People with social phobia are less often married and more likely to be single (Müller, 2002).

Epidemiology In a study by Wittchen, Stein, and Kessler (1999), prevalence rates of social fears and social phobia in adolescents and young adults between 14 to 24 years of age were examined. Lifetime prevalence of social phobia was 9.5% in females and 4.9% in males, with about one-third being classified as generalized social phobics. Twelve-month prevalence was only slightly lower, indicating considerable persistence. Persons with generalized social phobia reported an earlier age of onset, higher symptom persistence, more comorbidity, more severe impairments, and higher treatment rates than persons with non-generalized social phobia. In the United States, the National Comorbidity Survey (Magee, Eaton, Wittchen, McGonagle, & Kessler, 1996) found 12-month and lifetime prevalence rates of social anxiety disorder of 7.9% and 13.3%, respectively. Heimberg, Stin, Hiripi, and Kessler (2000) reported lifetime prevalence rates between 5% and 15% in the US. The mean age of onset is between 10 and 17 years (Lieb & Müller, 2002). Rates of social phobia are consistently found to be higher among women than men (risk factor 1.5 to 2 times higher), higher in younger than in older age cohorts, and inversely associated with socioeconomic status (Magee et al., 1996). Presumably, the lower socioeconomic status is a consequence of the disorder, but the causal relation is not yet clear.

Comorbidity There is consistent evidence that social phobics have a higher risk than non-social phobics of major depression and dysthymia, other anxiety disorders (especially simple phobia, agoraphobia and panic disorder), substance abuse (alcohol, drugs and nicotine), and eating disorders (Merikangas et al., 1996; cf. Lieb & Müller, 2002; Rapaport, Paniccia, & Judd, 1995). These disorders seem to occur mostly secondarily to social phobia, but this conclusion should be drawn with caution. Due to the retrospective assessments used in most studies no final conclusions concerning the temporal relation can be drawn. However, in a prospective, longitudinal epidemiological study of adolescents and young adults aged 14-24 years, Stein et al. (2001) found that social anxiety disorder during adolescence or young adulthood is an important predictor of subsequent depressive disorders.

1.1.3. Why Should One Study Specific Phobia of Animals?

Specific phobias are the most prevalent of all anxiety disorders, and a significant proportion of sufferers are severely disabled by them. Yet, specific phobias tend to be less disruptive and disabling, are associated with less comorbidity, and can be treated faster and easier than other anxiety disorders.

Because highly effective treatments of animal phobia exist (Öst, 1989; Öst, Salkovskis, & Hellström, 1991; Thorpe & Salkovskis, 1997b), it is sometimes forgotten that this progress is a result of intensive research over decades. Animal phobias have played a particular role in the evolution of the psychological theories of anxiety and its effective treatment. Behavior therapy, for example, developed for the most part from early research on animal phobias (Jones, 1924; Wolpe, 1958). The extension of this early work has been particularly important in the development of cognitive-behavioral treatments (Hawton, Salkovskis, Kirk, & Clark, 1989). Research about animal phobias will definitely continue to make a major contribution to the understanding of the nature of fear and the psychopathology of phobias and anxiety disorders, in particular in the light of the progress made in recent years in the field of electrocortical brain research and neuroimaging.

The advantage of studying the processing of fear-relevant stimuli in spider phobia seems obvious: first, spider phobia is a well defined anxiety disorder in which the phobic object – the spider – is quite clear and therefore easy to depict, e.g. in the form of pictures or videos. On the other hand, it is comparatively difficult to confront, e.g. a person with social phobia with a feared, social phobia-specific stimulus in a laboratory situation. Second, because of the high prevalence rates and the even higher prevalence of subclinical spider fears, it is relatively easy to recruit spider phobics. Finally, while social phobia, for example, is often highly comorbid with depression or avoidant personality disorder (Merikangas et al., 1996; Schneier et al., 1992; Stein et al., 2001), it is relatively easy to find spider phobics without any comorbid disorder.

One might wonder why social phobics were also included in the studies if the primary phobia under investigation was spider phobia. This was done for two reasons: first, social phobics represented a clinical control group in addition to the healthy control group. While the spider phobics should experience a higher level of arousal when exposed to spider stimuli, this was comparable to a higher arousal in the social phobics due to the experimental situation itself. Second, several studies on social phobia were conducted in our laboratory, which are not discussed in this thesis. In those studies, the processing of facial expressions in social phobics was investigated with similar paradigms as the ones described in this thesis. Spider phobics then served as clinical control group for the social phobics. Therefore, spider phobics and social phobics served as clinical control groups for each other.

1.2. Evolution and Phobias

1.2.1. The Unequal Distribution of Fears

It is a consistent finding that specific fears and phobias are unequally distributed. In the general population, some fears (e.g. of spiders and snakes) are far more prevalent than others (e.g. of cars, airplanes, electricity), although the danger from the latter is actually higher. However, the fear-relevant stimuli with high phobia prevalence have in common that they threatened prehistoric man during the course of evolution: they are "ancestral" stimuli.

Two different evolutionary theories account for this phenomenon: the first assumes that phobias of ancestral stimuli are *innate fears* that require no learning (e.g. conditioning). This non-associative approach emphasizes, for example, the spontaneous developmental fears of children (e.g. the visual cliff phenomenon). The second approach holds that humans are *prepared to easily learn* to fear ancestral stimuli.

Both approaches will be described in the following sections. For an extensive review of evolutionary models of phobia and their criticism see Merckelbach and de Jong (1997).

1.2.2. Innate Fears: The Non-Associative Account

Animal fears, among other specific fears, are highly prevalent among younger children (Öst, 1987). Mild fears which are common among young children (MacFarlane, Allen, & Honzik, 1954) often seem to appear and disappear spontaneously with a predictable course (Marks, 1987). In most children, these fears represent transitory phenomena. It is plausible to argue that in a subgroup of these children, specific fears do not wane with the passage of time, but instead become chronic phobias that persist into adulthood (Merckelbach, de Jong, Muris, & van den Hout, 1996).

Importantly, this non-associative account assumes that developmental fears *do not rely on aversive learning experiences* but are **innate fears**. Specific phobias seen in adult patients echo these early, innate fears (Menzies & Clarke, 1995). But why are we not all spider phobics in this case? Menzies and Clarke (1993, 1995) emphasize the role of habituation: poor habituators may remain fearful of innate fear cues. Eventually, their developmental fears might become chronic and take the form of a specific phobia. This theoretical account would explain why patients with specific phobias often cannot remember aversive experiences with the feared object, but frequently report that they

have always been afraid (Menzies & Clarke, 1993, 1994, 1995). However, for a critical comment on this theory, see Mineka and Öhman (2002a).

1.2.3. Preparedness Theory

In 1971, Seligman introduced his **preparedness hypothesis**, according to which the unequal distribution of fears is caused by an *evolutionary predisposition which facilitates the acquisition of fears by Pavlovian conditioning*. This preparedness hypothesis would explain why highly aversive experiences that do not relate to our biological inheritance (e.g. car accidents) only rarely produce phobias (Rachman, 1977).

Seligman's theory leads to four important predictions: first, phobias concern mostly *phylogenetically relevant stimuli*, i.e. stimuli that were dangerous to pretechnological men. Second, fear of these stimuli is *easily acquired*. Third, since phobic fears have biological significance they are *non-cognitive*, and finally, they are *relatively resistant to extinction*.

The first prediction is difficult to prove. However, retrospective studies of phobic subjects indicate that a majority of phobias involves stimuli that can be interpreted as dangerous to pretechnological man (Silva, 1988; Silva, Rachman, & Seligman, 1977; Zafiropoulou & McPherson, 1986).

The second prediction has been tested using the illusory correlation paradigm introduced by Tomarken, Mineka, and Cook (1989). In this experiment, subjects are shown slides of phylogenetically relevant stimuli (e.g. spiders or snakes) and phylogenetically irrelevant stimuli (e.g. flowers or mushrooms). Each presentation is followed either by an aversive outcome (an electric shock) or one of two neutral outcomes (a neutral tone or nothing at all). All cue-outcome combinations occur equally often. After the experiment, subjects are asked to estimate the association between phylogenetically relevant cues and aversive outcomes which they generally overestimate (de Jong & Merckelbach, 1991; de Jong, Merckelbach, & Arntz, 1995; Kennedy, Rapee, & Mazurski, 1997; Tomarken et al., 1989).

Furthermore, evidence for the easier acquisition of fears of ancestral stimuli comes from studies examining the acquisition of fears in rhesus monkeys. Mineka and colleagues (Mineka, 1987; Cook & Mineka, 1993; Mineka & Cook, 1993) designed two different videotapes. One displayed a wild-reared monkey (a "model") showing fear towards a phylogenetically relevant stimulus (i.e. a snake). The other displayed a model showing identical fear towards a phylogenetically irrelevant stimulus (i.e. a flower). They then

showed these videotapes to laboratory-reared monkeys ("observers") with no prior fear of snakes and found that observers acquired an extremely persistent fear of snakes after they had observed models reacting fearfully to snakes. On the other hand, observers that had seen models exhibiting identical fears of flowers failed to acquire a fear of flowers.

Concerning the third and fourth prediction, Öhman and associates found that conditioned skin conductance responses to phylogenetically relevant cues are harder to extinguish than those to phylogenetically irrelevant cues (Öhman, 1986; Öhman, Dimberg, & Öst, 1985; Öhman, Fredrikson, & Hugdahl, 1978). Furthermore, extinction of conditioned responses to phylogenetically irrelevant cues was speeded up by cognitive instructions that no more shocks will be applied and by removal of shock electrodes. This was not the case for phylogenetically relevant cues (see review of Öhman & Hugdahl, 1979).

In addition, Öhman and Soares (1993, 1994) showed that phylogenetically relevant stimuli that are presented subliminally (i.e. outside conscious awareness) can elicit a fear response in form of a skin conductance response. In one experiment (Öhman & Soares, 1993), non-phobic subjects reacted with a skin conductance response to backwardly masked pictures of snakes or spiders when these pictures were previously paired with an aversive shock. In contrast, phylogenetically irrelevant stimuli that had been paired previously with an aversive shock and which were presented subliminally failed to elicit a conditioned response. In a second study (Öhman & Soares, 1994), spider-fearful, snake-fearful, and control subjects were shown pictures of spiders, snakes, flowers, or mushrooms for 30 ms. Stimuli were masked backwardly at stimulus offset. The authors claim that under these conditions, subjects are not able to identify the slides better than by guessing. Nonetheless, spider fearful and snake-fearful subjects showed skin conductance responses to their specific feared object whereas controls showed no physiological reaction to the fear-relevant slides. These findings have been interpreted as evidence for a rough, preattentive processing of phylogenetically relevant stimuli which is sufficient to elicit a fear response.

Merckelbach and de Jong (1997) criticize some assumptions of the preparedness theory. First, they argue that there is evidence that humans do easily develop fears of objects that have only recently in the history of our species started to pose a threat. For example, a substantial proportion of car accident survivors develops a phobia related to driving a car (Kuch, Cox, Evans, & Shulman, 1994). Second, they argue that researchers have idiosyncratic views of what constitutes a phylogenetically relevant

stimulus. While, for example, Regan and Howard (1995) considered slides of dogs and cats as phylogenetically relevant, Dawson, Schell, and Banis (1986) used these pictures as neutral filler stimuli. Delprato (1980) also claims that it is doubtful whether mushrooms, used for example by Öhman and coworkers, are actually phylogenetically irrelevant stimuli: "considering the fact that approximately 100 species of poisonous mushrooms have been identified in USA alone..., it is reasonable to suspect that mushrooms have posed a greater threat to the survival of the human species than have spiders and snakes combined" (p. 89).

In conclusion, there are arguments supporting an innate origin of fears as well as arguments favoring a preparedness to easily learn to fear certain ancestral stimuli. The discussion remains unsolved. Decisive evidence might come from future studies investigating the processing of fear-relevant stimuli in toddlers.

1.3. Cognitive Biases in Anxiety Disorders

The areas of empirical study of biases in anxiety disorders can be broadly categorized as biases affecting the three general stages of information processing (1) *attention and the encoding of information*; (2) *elaboration and interpretation*; and (3) *storage and retrieval from memory* (Cameron, 1997; Mathews & MacLeod, 1987). Each of these biases, the *attentional bias*, the *interpretive bias* and the *memory bias*, will be briefly described in turn.

Cognitive biases have been assumed to play an important role in the causation and maintenance of anxiety disorders as well as of depression. However, the biases described in the literature do not apply equally to all anxiety disorders, as will become obvious in the following overview. There is evidence that anxiety disorders differ as to how threatening information is processed. Since the focus of this thesis is on the attentional bias in animal phobia, the other biases will be described only briefly to give an impression of the complexity of research in this field. For more detailed overviews of cognitive biases in anxiety disorders see, e.g. Mathews and Mackintosh (1998), MacLeod and Mathews (1991b), McNally (1996), Merckelbach et al. (1996) and Williams, Mark, Watts, MacLeod, and Mathews (1997).

Attentional Bias Phobics are characterized by an attentional bias towards fear-relevant, threatening stimuli. Their attention is involuntarily drawn to feared stimuli, and these stimuli are processed with high selectivity and priority.

Unlike *voluntary* attention which is 'top-down' or 'goal-directed' in the sense that attention is deliberately directed to outside events by inner intentions, *involuntary* attention is elicited relatively automatically by 'bottom-up' or 'stimulus-driven' processes, for example, by abrupt visual onsets or by stimuli that differ substantially in one or more visual attributes from their backgrounds (e.g. color, orientation, or motion). Involuntary attention is therefore characterized by the absence of an explicit intention to attend (Eimer, Nattkemper, Schröger, & Prinz, 1996; Egeth & Yantis, 1997).

Two forms of involuntary attention can be distinguished: aspecific and specific involuntary attention (Prinz, 1983). *Aspecific* involuntary attention is elicited by stimuli that contain sudden changes of physical attributes (level shifts) or rule deviations as, e.g. deviations from a sequence of regular events. On the other hand, *specific* involuntary attention is elicited by particular stimulus features that lead to a passive selection. This selection occurs when stimulus features correspond with certain latent dispositions as, e.g. general emotional mood, desires, or unconscious motives of the observer (Eimer et al., 1996). Since in the latter case the distinction between an explicit intention and a latent disposition is unclear, there is a smooth boundary between specific involuntary and specific voluntary attention.

On this background the attentional bias observed in phobics can be characterized as an example of specific involuntary attention when processing fear-relevant stimuli. This bias has been observed in animal phobics, social phobics, patients with high trait anxiety, patients with generalized anxiety disorder, and persons with posttraumatic stress disorder (Williams et al., 1997). To investigate the attentional bias in phobia several paradigms have been developed, which will be described in detail in section 1.3.1.

Interpretive Bias One example of a judgemental bias is the **covariation bias**, which describes the tendency of phobics to overestimate the occurrence of fear-relevant stimuli with aversive consequences (an illusionary correlation). This effect has been studied by the paradigm introduced by Tomarken et al. (1989), as described in section 1.2.3.

In a study with spider phobics, de Jong, Merckelbach, Arntz, and Nijman (1992) found that covariation bias was reduced after behavior therapy. Spider phobics saw three different types of slides: feared slides (spiders), fear-relevant slides (weapons), and neutral slides (flowers). Slides were randomly paired with either a shock, a tone, or nothing at all. As found previously, untreated phobics strongly overestimated the

covariation between spider slides and shock whereas treated phobics did not show a covariation bias. Furthermore, untreated subjects were more confident about their contingency estimates than treated subjects.

Another example for an interpretive bias is the **negative interpretation bias**, which has been found in particular in social phobics. Several studies showed that individuals with social phobia are more likely to misinterpret (ambiguous) social situations as more threatening and to draw more negative inferences from the available social stimuli than controls (Amir, Foa, & Coles, 1998a, 1998b; Stopa & Clark, 2000). For an extensive review of information processing in social phobia, see Heinrichs and Hofmann (2001).

Memory Bias People with anxiety disorders are plagued by disturbing unwanted thoughts. PTSD patients suffer from involuntary retrieval of traumatic memories in the form of intrusive thoughts, nightmares, and flashbacks. Panic patients experience thoughts about impending insanity or heart attacks during a panic attack. Patients with generalized anxiety disorder envision a multitude of possible threats. Thus, at least in some anxiety disorders it seems that information about threats is easily accessible. Therefore, pathological anxiety seems to be associated with a memory bias for threatening information.

Explicit and implicit memory biases have been investigated in anxiety disorders. However, explicit memory biases for threat have not been found consistently in all anxiety disorders. In a recent review, Coles and Heimberg (2002) concluded that explicit memory biases are confirmed in patients with panic disorder (Becker, Rinck, & Margraf, 1994; Cloitre, Shear, Cancienne, & Zeitlin, 1994), and to some extent also for patients with obsessive-compulsive disorder and posttraumatic stress disorder. For example, Vietnam veterans show enhanced recall of negative emotional words related to their traumatic experience (Vrana, Roodman, & Beckham, 1995). However, no explicit bias was found in social phobia or generalized anxiety disorder (Mogg, Mathews, & Weinman, 1987). In contrast, some degree of support for implicit memory biases was demonstrated for each of the above mentioned anxiety disorders (for review see Coles & Heimberg, 2002).

For specific phobias, for instance spider phobia, the results are even more contradictory. Whereas Watts and Coyle (1992) did not find a memory bias in terms of an enhanced recall of spider-related materials in spider phobics, others found lowered or even enhanced memory for spider-related material in spider phobics (see Cameron, 1997 for an overview).

In conclusion, the different biases can be found in varying degrees in the different anxiety disorders. In animal phobias, attentional and interpretive (covariation) biases are well-documented, while the existence of memory biases in phobic patients is still questionable.

1.3.1. Attentional Bias in Phobia: Unconscious Preattentive Mechanisms in the Activation of Phobic Fear

Researchers have devised different paradigms to study the attentional bias in phobia: these are *detection*, *interference*, and *facilitation* paradigms.

Detection Paradigms An example of a detection paradigm is the *visual search paradigm*. Öhman, Flykt, and Esteves (2001) exposed normal, randomly sampled subjects to matrices of pictures of fear-relevant stimuli (snakes and spiders) and neutral objects (flowers and mushrooms). In half of all cases, all stimuli in the matrix were of the same category, in the other half one stimulus was of a deviant category. Subjects were faster to find a fear-relevant stimulus (spider or snake) among flowers and mushrooms than vice versa. Furthermore, a larger matrix size prolonged the search for fear-irrelevant stimuli more than for fear-relevant stimuli.

In the same series of experiments, Öhman et al. (2001) investigated whether this effect was enhanced in spider- and snake-fearful subjects compared to non-fearful controls. This time, phobic and control subjects were selected by means of spider and snake phobia questionnaires (Klorman, Weerts, Hastings, Melamed, & Lang, 1974). Again, subjects were overall faster in identifying snakes and spiders against backgrounds of flowers and mushrooms than vice versa. Whereas it took longer to identify fear-irrelevant targets if more distractors were present, identifying fear-relevant targets was independent of matrix size. Also, subjects determined the absence of a deviant target among fear-relevant stimuli more quickly than among fear-irrelevant stimuli. This effect was more evident with the small than with the large matrix. Similar to controls, fearful participants were faster to identify fear-relevant targets they did not fear (e.g. a spider for a snake-fearful participant) than fear-irrelevant targets. However, the effect of fear-relevance was enhanced in fearful participants confronted with feared stimuli: they identified their feared stimulus (e.g. a snake for a snake-fearful participant) even faster.

Öhman et al. (2001) argued that these results fit the clinical observation that phobic individuals tend to scan their environment for feared stimuli. Spider phobics, for

example, often examine the room for spiders or spider webs.

Similar results have been found for other fear-relevant stimuli, namely angry faces. Öhman, Lundqvist, and Esteves (2001) found that schematic angry faces were detected faster than happy or sad faces among neutral or emotional distractor faces. In addition, Gilboa-Schectman, Foa, and Amir (1999) observed that social phobics were faster than controls in detecting threatening angry faces in a visual search paradigm.

In conclusion, results indicate that fear-relevant stimuli are picked up faster than fear-irrelevant stimuli by healthy controls. This effect is even stronger in phobics. In addition, there is evidence that the faster detection of fear-relevant stimuli does not diminish with increasing number of fear-irrelevant background stimuli. As Öhman (1997, p. 367) notes, "these results indicate that fear-relevant stimuli were picked up independent of their position in the perceptual field in a process reminiscent of a 'pop-out' effect of preattentive origin."

Facilitation Paradigms The *attentional probe* or *dot-probe paradigm* are examples of facilitation paradigms. Interference tasks assume that the presence of a threat cue disrupts performance for a primary task because the threat cue captures attention. Facilitation paradigms, on the other hand, are based on the assumption that attention shifts to the position of a threat cue, which leads to facilitated processing of following stimuli presented in the same location.

In the dot-probe paradigm, a threatening word and a neutral word are simultaneously presented on the screen and followed after 500 ms by a target dot in one of the stimulus locations. Anxious individuals are faster to detect the target when it appears in the threatening word's location, presumably because their attention has been drawn to the threatening word. MacLeod, Mathews, and Tata (1986) showed that GAD patients are faster to respond to dots replacing threat words and slower to respond to dots replacing neutral words. These results were replicated by Mogg, Mathews, and Eysenck (1992). Furthermore, Asmundson and Stein (1994) reported similar results with generalized social phobics who responded faster to probes following social threat words than to probes following neutral and physical threat words.

Pictorial versions of the dot-probe task (Mogg et al., 2000) and masked versions of the dot-probe task have been developed (Mogg, Bradley, & Williams, 1995). For example, the latter study found evidence for a preconscious attentional bias in anxious subjects: their spatial attention shifted to the location of supraliminally as well as subliminally presented negative words.

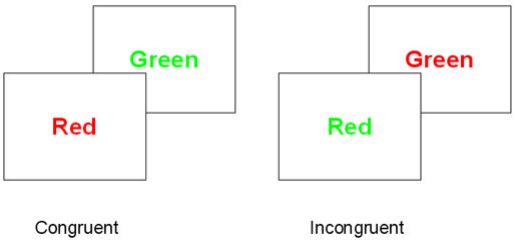


Figure 1.1.: Classical Stroop Paradigm

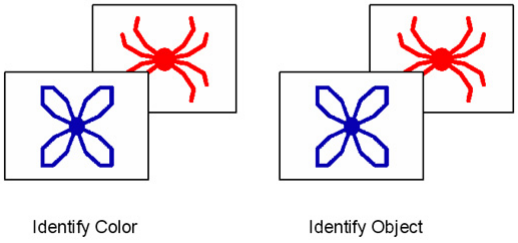


Figure 1.2.: Emotional Stroop Paradigm

However, this attentional bias could not be demonstrated consistently in all anxiety disorders. Wenzel and Holt (1999), for example, applied the dot-probe paradigm to individuals with specific phobias (spider and blood/injury phobia). Attentional deployment towards spider-related, blood-related, positive, negative, and neutral words was examined. Results showed that individuals with specific phobias did not demonstrate an attentional bias towards phobia-related stimuli relevant to their particular fears. Wenzel and Holt concluded that semantic-based information processing paradigms may not be sufficiently potent to demonstrate biased performance towards threatening stimuli in individuals with mild specific phobias who are otherwise healthy.

Interference Paradigms One of the most common paradigms besides the dot-probe paradigm used to study anxiety and attention is the *emotional Stroop paradigm* (MacLeod, 1991; Wells & Matthews, 1994; Williams, Mathews, & MacLeod, 1996) which was derived from the classical Stroop paradigm (Stroop, 1935). Both will be explained in detail in the following sections.

1.3.2. Emotional Stroop Interference as a Measure of Attentional Bias

The Stroop effect is one of the most robust phenomena studied in psychology, and the Stroop color-word interference task is also one of the most widely used experimental tasks in cognitive psychology. For a comprehensive review of half a century of research on the Stroop effect, see MacLeod (1991).

In 1935, Stroop reported that it took subjects longer to *name the color* of the ink that color words were written in and that subjects made more errors if ink and color were incongruent (e.g. the word “red” written in green ink, the correct answer being “green”,

see Figure 1.1) than if they had to name the color of colored squares. When naming the color of incongruent color words, cognitive interference occurs, i.e. the processing of one stimulus feature interferes with the simultaneous processing of a second stimulus attribute. The so-called *inverse Stroop effect* means that it also takes subjects longer to *read a color word* if it is written in an incongruent color. However, this color word reading interference is generally smaller than the color naming interference (Warren & Marsh, 1979). On the other hand, *facilitation* can be observed, i.e. color naming latencies are shorter if color and word are congruent, e.g. "green" written in green. The magnitude of Stroop facilitation is generally much smaller than that of Stroop interference (MacLeod, 1991).

There are two general classes of explanations of the Stroop interference phenomenon: the first class focuses on the *stimulus encoding* stage of processing, the second on *response competition*. The first account assumes that the irrelevant dimension interferes with stimulus encoding for incongruent stimuli and speeds perceptual processing for congruent stimuli (Hock & Egeth, 1970).

The second and more traditional explanation, first suggested by Stroop (1935), assumes simultaneous processing of color and word information, resulting in two competing naming responses. If both responses are incompatible, reaction time is slowed; if they are the same, response selection is facilitated (Cohen, Dunbar, & McClelland, 1990; Sugg & McDonald, 1994; Virzi & Egeth, 1985; Warren & Marsh, 1979). This account is proposed in two rather similar versions: the *relative speed of processing* theory assumes that color and verbal information are processed in parallel but at different speeds (a "horse race"). The *automaticity* view emphasizes that word processing is more automated than color processing and thus requires less attention – reading a word is seen as obligatory, while naming its color is not (see MacLeod, 1991).

The emotional Stroop paradigm (see Figure 1.2) is a modified version of the original Stroop task and has become a popular measure of attentional biases. In this paradigm, the color of words or pictures which vary in personal emotional significance has to be identified either verbally or manually, e.g. by pressing a corresponding button. In earlier studies, the colored words were presented on cards and response times were measured with stopwatches. There was one card for each word set under investigation (i.e. at least one "phobia-related" and one "neutral" set). With the advances in computer technology, studies began to use computers for stimulus presentation and recording of voice onset time. The computerized design had several advantages: first, stimuli could be presented in a mixed randomized design and not only in a blocked de-

sign. Second, computerized registration of voice onset time was more reliable and less susceptible to experimental artifacts, in particular Rosenthal effects (i.e. experimenter expectancy effects; Rosenthal, 1966).

The phenomenon that threatening stimulus attributes impair the processing of non-threatening stimulus characteristics has been called *emotional interference*. The difference in color-naming times between anxiety-related and neutral stimuli – the *emotional Stroop effect* – provides a measure of the attentional bias. Anxiety patients show selectively longer color naming latencies for anxiety-relevant words. For an overview, see Williams et al. (1997).

Selective attentional biases have been observed in a variety of anxiety disorders, e.g. in patients with generalized anxiety disorder (GAD) for GAD-related, speech-related, and positive words and in social phobics for speech-related words (Becker, Rinck, Margraf, & Roth, 2001). Mathews and MacLeod (1985) found that patients who worried mostly about physical harm were particularly slow in color naming physical threat words, whereas patients worrying about social threat were especially slow in naming social threat words. Similar results were reported by Hope, Rapee, Heimberg, and Dombeck (1990) with panic patients who were slowed by physical threat cues, but not by social threat words, whereas the opposite held for social phobics. Finally, several studies found emotional interference in PTSD patients when naming the color of trauma-related words (e.g. McNally, Kaspi, Reiman, & Zeitlin, 1990; McNally, English, & Lipke, 1993). Emotional Stroop interference in animal phobics will be described in Section 1.3.3.

Mechanisms Underlying Emotional Stroop Interference Several explanations for the origin of the emotional interference effect have been proposed (see Williams et al., 1996, 1997 for an extensive overview). One of the best-established theories assumes the existence of a processing channel with limited capacity (MacLeod & Mathews, 1991a). The phobic stimulus category automatically takes up processing resources in this channel and thus impedes rapid identification of the stimulus attribute which has to be primarily identified. For example, in spider phobia, attention is automatically directed to threatening stimulus material (word content or picture of a spider), and this interferes with the main task (i.e. color naming) (Merckelbach et al., 1996). Thus, the interference effect is generally presumed to reflect some form of attentional bias towards threatening material (Cameron, 1997).

More recently, it has been proposed that anxiety delays the disengagement of attention

from a threat rather than facilitating attentional shifts *towards* threatening stimuli (Derryberry & Reed, 2002; Fox, Russo, & Dutton, 2002). Thus, the cause of emotional interference in the Stroop paradigm can also be explained by a difficulty in shifting attention from the irrelevant threat dimension to the relevant color dimension. This explanation also accounts for the results in the dot-probe paradigm. Reaction times are slower if a target stimulus appears in a neutral-cued spatial location than in a threat-cued location. One explanation is that anxiety patients have difficulty in shifting their attention away from the threat-cued location to the neutral-cued location (Derryberry & Reed, 2002). Similar suggestions come from a study by Yiend and Mathews (2001) with high-trait anxious subjects.

Effects of Treatment on Attentional Bias Several studies using the emotional Stroop paradigm have shown that attentional biases in anxiety patients commonly disappear following treatment, as in social phobia (Mattia, Heimberg, & Hope, 1993), obsessive-compulsive disorder (Foa & McNally, 1986), and generalized anxiety disorder (Mathews, Mogg, Kentish, & Eysenck, 1995; Mogg, Bradley, Millar, & White, 1995). Similarly, the attentional bias in spider phobia can be reduced by desensitization or cognitive behavior therapy (e.g. Lavy & van den Hout, 1993; Watts, McKenna, Sharrock, & Trezise, 1986). Yet, so far results of studies remain inconclusive (Thorpe & Salkovskis, 1997b).

For example, Watts et al. (1986) showed that desensitization treatment reduced the amount of interference in a linguistic card Stroop paradigm in treated spider phobics compared to an untreated group. However, according to Thorpe and Salkovskis (1997b) this study had several problems in statistics and study design. Similarly, Lavy and van den Hout (1993) found a reduction of attentional bias for pictorial and linguistic spider-related stimuli after an in vivo exposure treatment according to Öst (1989). However, the untreated controls were not spider phobics, making any interpretation of the study difficult. Finally, Thorpe and Salkovskis (1997b) tested spider phobics before and after a one-session cognitive behavioral therapy for spider phobia. Treatment was highly effective in reducing spider fear and in accordance with this, emotional Stroop interference observed before treatment was significantly reduced after treatment. However, in the untreated group a comparable reduction in Stroop interference was observed. The authors concluded that the emotional Stroop task is an ambiguous measure of fear-related cognitive processes.

Thus, there is some evidence that the attentional bias in anxiety patients disappears

or at least decreases with treatment. However, in particular the reported studies with spider phobics can be criticized in various ways so that final conclusions can not yet be drawn.

1.3.3. Emotional Stroop Interference in Animal Phobics

A number of studies have investigated emotional Stroop interference in animal phobics. The general study design is to present a colored neutral or phobic word or object. The subjects' task is to identify the color of the stimulus. In general, an emotional interference effect is observed when animal phobics have to identify the color of a feared animal. However, results are far from consistent and difficult to integrate, as detailed below.

Several parameters of the experimental design have to be considered if one tries to integrate the varying results of different emotional Stroop paradigms. Were linguistic or pictorial stimuli used? Were stimuli "integrated" (e.g. colored spider pictures) or "non-integrated" (e.g. spider pictures superimposed on colored circles)? Were they presented on cards or by computer? Was a vocal or a manual response mode used? The following paragraphs give an overview on the factors influencing the outcome of an emotional Stroop interference design.

Linguistic vs. Pictorial Stroop Paradigm Earlier studies using the emotional Stroop paradigm mostly relied on *verbal* stimuli (e.g. Watts et al., 1986; Martin, Horder, & Jones, 1992). One of the first studies showing emotional Stroop interference in spider phobics was a study by Watts et al. (1986). Using a linguistic emotional Card-Stroop paradigm, they found significant emotional interference in spider-avoidant subjects when color naming spider words, i.e. spider phobics showed longer reaction times for color naming spider words compared to neutral and emotional words. These results were replicated by Martin et al. (1992), who compared spider-avoidant and control children of different age groups (6–7; 9–10; 12–13 years of age) in a linguistic Card-Stroop paradigm. Interference effects in color naming spider-related words were found in spider-phobic children as young as 6–7 years. There was no significant difference in the overall magnitude of this interference effect for the different age ranges.

In recent years, several studies have been conducted using *pictorial* stimuli (e.g. Constantine, McNally, & Hornig, 2001; Kindt & Brosschot, 1997, 1999; Kindt, van den Hout, de Jong, & Hoekzema, 2000; Lavy & van den Hout, 1993; Martin & Jones,

1995; Merckelbach, Kenemans, Dijkstra, & Schouten, 1993). Obviously the advantage of using pictures of spiders instead of words is a higher ecological validity (see e.g. Lavy & van den Hout, 1993) – after all, spider phobics fear primarily spiders and not spider-related words. One might therefore argue that pictures will offer a better representation of real life stimuli and will lead to larger emotional interference effects. However, to our knowledge, no study found larger interference for spider pictures than for spider words, if any interference for spider pictures was found at all. The existing literature is summarized below.

Lavy and van den Hout (1993) were among the first to report results of a *pictorial* emotional Stroop paradigm. In their study, in addition to colored words, spider and neutral pictures (chairs) were presented on colored circles. To prevent the selective allocation of attention to a specific spatial area of the circle, spiders were placed at different positions on the circles. The subjects' task was to name the color of the circles as quickly as possible. The results indicated that subjects were generally slower in naming the color of linguistic stimuli than of pictorial stimuli. The hypothesized attentional bias was found for pictorial and linguistic spider-related stimuli. However, results did not show greater emotional interference for pictorial spiders but the opposite, i.e. greater emotional interference for linguistic than for pictorial stimuli. On the other hand, Kindt and Brosschot (1997) found similar interference for spider pictures and spider-related words. Finally, Constantine et al. (2001) could not even find unequivocal evidence for emotional Stroop interference in response to snake pictures in a study with snake-fearful subjects.

Several studies have investigated the processing of phobia-related verbal and pictorial stimuli in children. Their results complicate things even more. While Martin and Jones (1995) found emotional interference for spider pictures in spider-phobic children (4–5; 6–7; 8–9 years of age), Kindt and Brosschot (1999) and Kindt et al. (2000) could not corroborate these results. Kindt et al. (2000), for example, found no attentional bias for spider pictures in spider phobic children aged 8–11. However, for spider *words* such a bias was a normal characteristic of children aged 8. In non-fearful children, this bias decreased from age 8 to age 11, while it was maintained with age in the fearful children. Kindt and van den Hout (2001) argue that all young children give priority to threatening information and that selective attention to threatening stimuli is first and foremost a normal phenomenon. However, as age increases, selective attention in normal children decreases while it is maintained in spider phobic children. Kindt and van den Hout suggest that not learning to inhibit the selective attention to fear-

relevant stimuli, which is a normal characteristic of young children, leads to phobias in adulthood. Yet, their arguments still do not explain first, why interference effects in emotional Stroop paradigms were found in normal children only for linguistic stimuli and not for pictorial stimuli, and second, why results of pictorial emotional Stroop paradigms sometimes found evidence for emotional interference effects in spider phobic children (Martin & Jones, 1995) and sometimes could not find such evidence (Kindt & Brosschot, 1999; Kindt et al., 2000).

In summary, the results of the present studies are rather inconclusive. In spider phobics emotional Stroop interference has been well-documented in linguistic emotional Stroop paradigms. However, regarding pictorial emotional Stroop paradigms, if one result is clear, it is that spider pictures do not result in larger interference effects than spider-related words.

Integrated vs. Non-Integrated Stimuli *Integrated* stimuli combine the interfering characteristics (color and emotional picture/word) in one stimulus. For example, colored words and colored pictures are integrated stimuli. On the other hand, in *non-integrated* stimuli these interfering characteristics are presented in separate spatial locations. For example, spider pictures or spider-related words superimposed on colored circles are non-integrated stimuli. It is possible that it has a significant influence on the results of an emotional Stroop paradigm whether integrated or non-integrated stimuli are used. So far, no study using an emotional Stroop design directly compared integrated and non-integrated *pictorial* stimuli. However, a few studies compared integrated and non-integrated *verbal* stimuli.

Kindt and Brosschot (1997), for example, compared spider phobic and control participants in a Stroop paradigm with integrated and non-integrated verbal stimuli, on the one hand, and non-integrated pictorial stimuli, on the other hand. They found a similar bias for pictures and words in the spider phobic group, and to a smaller degree also in the control group. Integrated word stimuli generally led to more interference than non-integrated stimuli. However, this effect was not specific to spider phobics, but also applied to controls.

Furthermore, in a study with spider phobic and control children, Kindt and Brosschot (1999) found that integrated spider-related words led to more interference in both groups, while non-integrated words led to an attentional bias in spider phobic children only.

To our knowledge, only two emotional Stroop studies so far used integrated pictures of spiders. These are the Card-Stroop experiment by Martin and Jones (1995) and the computerized Stroop experiment by Constantine et al. (2001). While the former found evidence for emotional Stroop interference in children and adults, the latter could not find such an interference effect. The other studies described above used non-integrated pictures, e.g. spiders and chairs placed on colored circles.

In conclusion, there seems to be some evidence that integrated verbal stimuli lead to more interference than non-integrated stimuli. However, in the two studies cited above this effect was not specific for spider phobics. For integrated and non-integrated pictures, there are no direct comparisons available.

Card vs. Computer Format While earlier studies mostly relied on the classical card format of the Stroop task, in recent years the computer format has become more common. In the *card version* of the Stroop task, several words or pictures (up to 40) of one stimulus category (either phobic or neutral) are presented on one card, and the overall time it takes subjects to name the color of all stimuli on one card is measured. This type of design is therefore also called a *blocked design*. A common criticism of card Stroop paradigms is that interference effects might sum up across stimuli. Spider phobics might become more and more distracted as they continue color naming one spider after the other and might start ruminating about spiders. In addition, it has been noted by Kindt, Bierman, and Brosschot (1997) that if stimuli of the same emotional valence are presented on one card, this might enhance the emotional impact of the individual stimuli. In contrast to the card version, the *computer version* of the Stroop task also allows the *mixed, single trial* presentation of stimuli, i.e. the randomized presentation of phobic and neutral stimuli. Furthermore, while in earlier studies stopwatches were used to measure response times in the card Stroop designs, accurate timing of stimulus presentation and response times became possible with computerized designs.

It has been suggested that these two presentation types are not equivalent. For example, Kindt et al. (1997) directly compared a computerized Card-Stroop (presenting multiple stimuli on the screen) and a single-trial computerized Stroop task in a study with spider-fearful and control children. They found a bias for spider words in spider-fearful but also in control children regardless of the format used. However, they found no correlation between the spider interference score in the card and the single-trial computer format, which suggests that both may measure different mechanisms. In-

deed, McNally, Amir, and Lipke (1996) demonstrated in Vietnam combat veterans using trauma-related words that the card format led to stronger interference than the single-trial format.

Vocal vs. Manual Response Mode The magnitude of Stroop facilitation and interference on reaction times is generally larger when vocal instead of manual responses are used (MacLeod, 1991; Redding & Gerjets, 1977). Even though reliable Stroop interference effects have also been demonstrated with manual responses (Keele, 1972; Logan, Zbrodoff, & Williamson, 1984; Roe, Wilsoncroft, & Griffiths, 1980; Schmit & Davis, 1974; Virzi & Egeth, 1985) so far – to our knowledge – all *emotional* Stroop studies with animal phobics used vocal and not manual response modes. However, using vocal responses is problematic when event-related potentials are recorded simultaneously, since facial muscle movements accompanying speech production could introduce significant artifacts.

1.3.4. Inconsistencies in Studies Investigating the Attentional Bias in Animal Phobics

Not all studies found evidence for an attentional bias in phobics. Constantine et al. (2001), for example, investigated the attentional bias in snake phobics with a pictorial emotional Stroop paradigm. They designed integrated stimuli by placing a color filter over the pictures, tinting them blue, green, red, and yellow. Snake-fearful and control subjects had to name the color of threatening pictures (snakes), positive pictures (rabbits), and neutral pictures (cows) presented in a computerized single-trial design. Results showed that snake-fearful and non-fearful subjects had longer response latencies for emotional stimuli (rabbits as well as snakes) relative to neutral stimuli (cows). A subgroup analysis ($n = 5!$) of the most intensely snake-fearful individuals exhibited additional interference for snake pictures beyond that evoked by rabbit pictures. Obviously, this result has to be interpreted with caution given the small number of subjects. However, results support the emotionality hypothesis according to which subjects selectively process *any* personally emotional cue, regardless of its valence (e.g. Martin, Williams, & Clark, 1991).

Furthermore, some studies using other paradigms than the emotional Stroop or the visual dot-probe also could not find consistent evidence for an attentional bias in animal phobics. Merckelbach et al. (1993), for example, designed a task in which slides of

spiders or flowers were presented together with horizontal and vertical bars. One half of the slides, e.g. the upper, displayed a spider or a flower, the other half, e.g. the lower, displayed a horizontal or vertical bar. Subjects were instructed to identify the bars (vertical or horizontal) as fast as possible and to ignore accompanying pictures (spider or flower). No evidence for an attentional bias for fear-relevant pictorial stimuli in spider-fearful subjects was found. Instead, a general increase of reaction times in spider phobics was reported that increased over the trials. The authors argued that fear-relevant pictures might have induced a state of anxious arousal that interfered with reaction time performance on both fear-relevant and neutral trials. In this study, it is problematic that the spider-fearful group had a mean SPQ score of only 15 (SD = 2.8). The authors argue that this corresponds to the 75th percentile in Norway. Still, results may have been different if the authors had recruited subjects in the 90th percentile.

Finally, Lavy, van den Hout, and Arntz (1993) used a pictorial flanker task to study the attentional bias in spider phobics. Slides with three pictures were constructed so that one picture was in the middle position and two flanked it. Pictures could be phobic (spiders) or neutral (sheep and ducks). Thus the following slide constructions were possible: NNN, PNP, NPN, PPP (N = neutral, P = phobic). Spider phobics were not slower in responding to PNP-slides compared to NNN-slides, i.e. no attentional bias in favor of the phobic flankers was found. However, phobics showed a facilitated response to the NPN-slides, i.e. when the spider was presented in the center of the slide. After two sessions of in vivo exposure treatment the facilitated response was significantly removed. The response to PNP-slides did not change significantly as a result of treatment.

Because of the inconsistent results, various authors have questioned the adequacy of the emotional Stroop paradigm as an index of attentional bias in phobics (Merckelbach et al., 1993; Thorpe & Salkovskis, 1997a, 1997b). However, it seems that a systematic study of influencing parameters, i.e. verbal vs. linguistic Stroop, integrated vs. non-integrated stimuli, vocal vs. manual reactions etc. as well as age of participants (children vs. adults) would be necessary before final conclusions can be drawn.

1.3.5. Models Accounting for the Attentional Bias in Phobias

Several models have been proposed to account for the attentional bias in phobias. They can be divided into *cognitive* and *neuroscientific* theories.

Cognitive models explain the attentional bias by *acquired* dysfunctional cognitive mechanisms – *dysfunctional schemata* – which lead to the selective processing of threat-related, schema-congruent stimuli (Beck, Emery, & Greenberg, 1985). Cognitive models do not assume that the attentional bias is simply a by-product of an emotional disorder. Instead, they ascribe to it a vital role in the causation and maintenance of anxiety disorders, but also in other emotional disorders such as depression. Beck's cognitive theories have been very influential, leading to effective treatments in anxiety and depression, namely cognitive behavioral therapy.

Neuroscientific theories assume that specialized neural systems for the processing of fear-relevant stimuli evolved during evolution since rapid detection of fear-relevant cues was critical for survival. In an evolutionary sense, fleeing a situation that turns out to be harmless (i.e. a false positive) is less costly than failing to flee a dangerous situation (i.e. a false negative). Whereas the latter situation may result in death the former only leads to wasted energy (LeDoux, 1990). Mineka (1992) has termed this cautiousness of evolution "evolutionary conservatism". It is assumed that these specialized neural systems are developed particularly strongly in phobics.

One influential evolutionary model is the information processing theory of Öhman (1993, 1997), see also Mineka and Öhman (2002b), Öhman and Wiens (2002). This model is given its neuroscientific counterpart in the two-way processing model of LeDoux (1996). Both theories agree in the following points:

- It takes time until we consciously perceive a stimulus, and it takes even longer to think about what we see, decide what to do, and act.
- Consciously thinking over the situation before defensive actions are initiated would take too long in dangerous situations like the attack of a predator.
- Thus, it is likely that we have been equipped throughout evolution with parallel processing sensory systems that continuously scan the environment for potential dangers.
- As soon as a potential threat is located on a preattentive level, the defense system is activated.
- Conscious, higher level processing mechanisms can adjust responses by evaluating the situation in interaction with memory and context information.

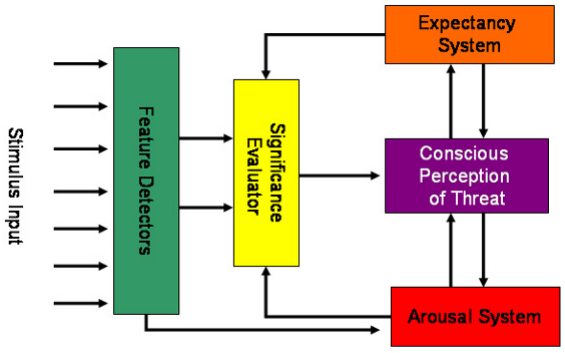


Figure 1.3.: Öhman's model according to Öhman, 1993

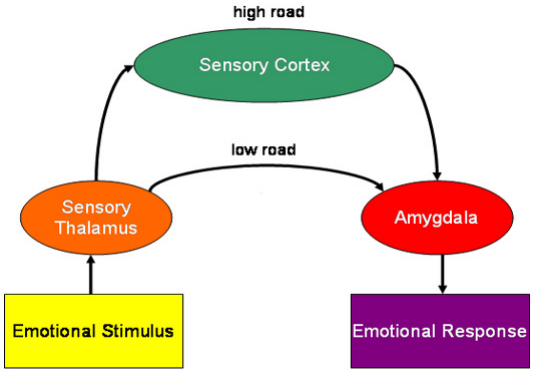


Figure 1.4.: LeDoux's model according to LeDoux, 1996

In addition, both theories agree that the amygdala plays a central role in the fear system (Öhman, 1993; LeDoux, 1996).

Öhman's Model – an Evolutionary Perspective

Öhman's model (1993) is based on the preparedness theory by Seligman (1971) described in Section 1.2.3. Since the early detection and avoidance of dangerous stimuli and situations was undoubtedly an evolutionary advantage to early primates, Öhman postulates that evolution favored the development of several systems in the brain which detect potential threats. These systems should be tuned to specific features of recurrent threats to which hominids were exposed during evolution. This screening occurs at a preattentive level. As soon as a specific threat feature has been detected, an orienting response occurs and a defense reaction is prepared. Thus, we are tuned to process fear-relevant stimuli with high priority, and this processing bias is biologically prepared. It follows from this argument that stimulus configurations which are reliably associated with phobias should be particularly effective in activating fear.

Öhman distinguishes several modules within the processing system: the *feature detectors*, the *significance evaluator*, the *expectancy system*, and the *arousal system* (see Figure 1.3):

1. *Feature detectors* screen the incoming information for specific threat cues (e.g. high intensity or biologically prepared stimulus characteristics). This primary processing occurs preattentively, and stimuli are processed in parallel. As soon as crucial threat characteristics have been detected, defensive mechanisms are triggered, e.g. autonomic arousal increases. In addition, biologically relevant

stimuli are selected for preferential treatment by the significance evaluation system (Öhman, 1993).

2. The *significance evaluator* assesses stimuli still preattentively for relevance, analyzing stimuli for their full meaning. This processing is still not accessible to consciousness. While the feature detectors operate by filtering stimuli for biologically important features, the significance evaluator works "top-down" or schema-driven. It is set by the expectancy system to look for particular categories of input (Öhman, 1993).

3. The evaluation of stimuli regarding their threat value is influenced by the *expectancy system*, which stores a network of earlier learning experiences and emotional memories. By biasing the significance evaluator to respond to information matching currently activated memory nodes, the expectancy system can influence stimulus processing already on a preattentive level. In addition, the expectancy system provides the context for interpreting new stimuli to the conscious perception system. In this dual role, the expectancy system can thus prime early detection and processing of incoming stimuli related to expected dangers, giving rise to attentional bias effects (Mathews & Mackintosh, 1998; Öhman, 1993).

4. After significance evaluation has marked a potential threat, the information is passed to the *conscious perception system*. Then, attention is quickly oriented towards the threatening stimulus: an orienting response has been triggered. The conscious perception system has two functions: first, it appraises the meaning of the incoming information, evaluating it in interaction with emotional memories stored in the expectancy system and the current arousal level. If such an appraisal signals danger, further autonomic arousal occurs, which sets the significance evaluator into a more sensitive mode, increasing its output (Mathews & Mackintosh, 1998). Second, the conscious perception system selects an action to cope with the perceived threat (Öhman, 1993).

Öhman (1979) ascribes to the *orienting reaction* a key role in the transfer of information from unconscious to conscious processing levels, i.e. from preattentive to attentive processing stages. He describes it as the "gateway to consciousness" or the "call for processing resources" which always occurs when the preattentive levels need support (Öhman, 1979; Öhman, Esteves, Flykt, & Soares, 1993). The orienting response either occurs because the stimulus is novel and thus no matching representation in memory can be found or because it implies consequences that cannot be dealt with at

preattentive levels (see also Öhman, 1997). This transfer of control from preattentive to attentive levels is accompanied by an increase in arousal which in turn leads to a sensitization of the evaluator system (a kind of a heightened state of alert).

In a more recent elaboration of his model (Öhman, 1992, 1997; Öhman & Wiens, 2002), Öhman argues that orienting reflexes can be elicited from evolutionarily threatening stimuli after only preattentive processing by a direct route from the significance evaluator to the arousal system. Öhman and Soares (1993) coupled nonmasked presentations of fear-relevant or neutral stimuli with electric shocks in a study with nonfearful subjects. In the subsequent extinction phase, in which the stimuli were masked and could only be processed preattentively, only those subjects conditioned to fear-relevant stimuli retained a significant conditioned skin conductance response, while those conditioned to neutral stimuli did not. Other studies have replicated this pattern of results (Soares & Öhman, 1993a, 1993b).

Öhman's model permits the various anxiety disorders to be viewed as resulting from different emphases within the same information-processing structures. Phobias, for example, are assumed to result from the automatic activation of the arousal system by specific features located by the feature detectors (Öhman, 1993). For instance, Öhman and Soares (1994) reported that fear-relevant and neutral stimuli did not elicit a preattentive orienting response in phobics and controls in a backward masking paradigm. In contrast, snake and spider phobics did show an orienting response to their feared objects. Thus, this study offers evidence for a preattentively triggered orienting response to feared stimuli in phobics.

Öhman's model offers a detailed framework for understanding the processing of fear-relevant stimuli. However, there are still some open questions. How exactly do phobics differ from healthy people in their processing of feared stimuli? Are their feature detectors more sensitive for specific features of feared stimuli? Is their arousal system more strongly activated preattentively by feared stimuli? Or are their significance evaluators biased towards a more ready detection of threat, possibly tuned by memories stored in the expectancy system? Finally, the question remains unsolved whether phobics' processing anomalies are innate or learned, and if learned, by what mechanisms. Öhman considers it possible that biologically prepared learning (conditioning) may be decisive for phobias (Öhman, 1993; Öhman et al., 1985). Future studies will have to address these questions.

LeDoux's Model – the Neuropsychological Counterpart

LeDoux (1996) also assumes that the brains of primates possess a complex, innate fear system. Its task is to screen the environment, to reliably detect potential treats, and to initiate appropriate responses. In this way, the probability to survive dangerous situations is maximized. According to LeDoux, the limbic system, with the amygdala as a central structure, might be a possible neuronal correlate of the preattentive surveillance and assessment system.

LeDoux distinguishes two parallel processing routes that work with different speed and precision: a direct, fast subcortical route and a slower cortical route (Figure 1.4). The *subcortical route* runs from the sensory nuclei of the thalamus directly to the lateral nucleus of the amygdala. It allows a first rough processing of incoming stimuli and thus the detection of potential threats as well as the initiation of appropriate defense reactions. The *cortical route* runs from the thalamus over the cortex to the amygdala and includes higher cognitive structures which allow a precise, but relatively slow, stimulus analysis. This processing is influenced by memory and context information. The higher cortical route is able to modulate and correct the processing of the lower route (e.g. by activating or inhibiting the amygdala) and allows the voluntary control and selection of behavior responses.

Recently, some evidence for the existence of the two processing routes postulated by LeDoux was published by Junghöfer, Bradley, Elbert, and Lang (2001). They investigated primary and secondary visual areas in the early processing of affective pictures taken from the IAPS (International Affective Picture System; Lang, Bradley, & Cuthbert, 1999). In a so-called *Rapid Serial Visual Presentation (RSVP)* paradigm they exposed subjects to a series of high- and low-arousing pictures presented in rapid sequence. Presentation time was 200 ms in one and 333 ms in another experiment. In both experiments, stimuli were presented without an interstimulus interval. This fast succession of pictures was suggested to lead to a "conceptual masking" of pictures: each stimulus is immediately replaced by a semantically new stimulus. As was shown previously (Intraub, 1999; Potter, 1976; Potter & Levy, 1969), when stimuli are presented in this fast succession, subjects can identify the picture content, but their recognition memory of the stimuli is little better than chance. As Intraub (1999) notes, "the subjective experience is ... one of grasping and losing large amounts of information within moments" (p. 66). Junghöfer et al. (2001) were able to show that even at this early conceptual processing level there are distinct differences in the neuronal processing of high- and low-arousing stimuli. High-arousing stimuli led to a stronger occipital

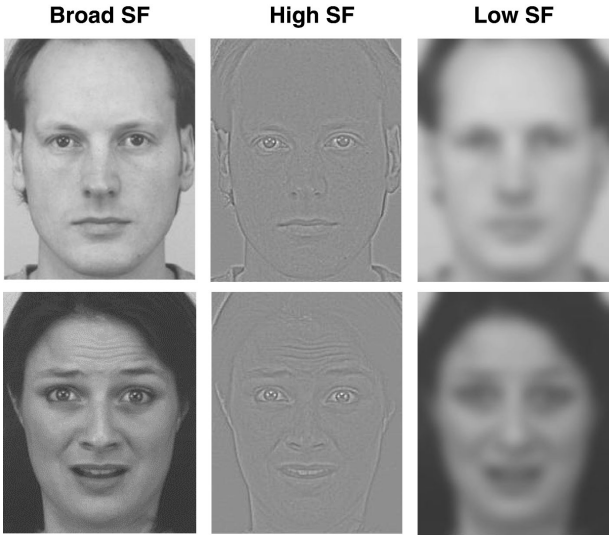


Figure 1.5.: Example pictures used in the study by Vuilleumier et al. (2003)

negativity than low-arousing stimuli. This negativity started about 150 ms after stimulus onset and reached its maximum about 260 ms post-stimulus. The discrimination between emotionally high- and low-arousing stimuli in a time range in which information processing is still preconscious could provide some evidence for the existence of a fast processing route from the thalamus over the amygdala to the visual cortex, as postulated by LeDoux (1996).

Further support for the two routes postulated by LeDoux comes from a fMRI study by Vuilleumier, Armony, Driver, and Dolan (2003). They were able to show that high and low spatial frequency information in visual images are processed by distinct neural channels. Subjects were shown pictures of faces that contained either broad spatial frequency information (i.e. normal images) or just the high or low spatial frequency elements. Example pictures are depicted in Figure 1.5. The task of the subjects was to identify the gender of the faces. Results showed that activation of the fusiform face area was greater with broad and high spatial frequency stimuli than with low-frequency faces, regardless of emotional expression. In contrast, amygdala activation in response to fearful facial expression was greater for normal or low-frequency faces than for high-frequency faces. Thus, their results showed a dissociation between activation of the amygdala and the extrastriate visual cortex depending on spatial frequency ranges. Whereas the fusiform cortex was activated more by fine-grained high spatial frequency information, the amygdala was activated more by coarse low spatial frequency cues.

According to Vuilleumier et al. (2003), these results support the existence of a subcortical pathway processing coarse low spatial frequency information and a second cortical

route processing high spatial frequency information. The *subcortical pathway* starts with the magnocellular cells on the retina, and goes via the pulvinar to the amygdala (Schiller, Malpeli, & Schein, 1979; Leventhal, Rodieck, & Dreher, 1985; Berson, 1988). It might provide fast but coarse processing of low spatial frequencies and might therefore convey global configurational information. It allows a fast screening for danger signals and fear-related information independent of the attentional focus, i.e. also in the visual periphery (Livingstone & Hubel, 1988). Moreover, the subcortical route is also crucial for processing stimuli in motion (Merigan & Maunsell, 1993) and might even underlie the visual abilities of newborn infants who can detect coarse facial and emotional cues in the absence of a mature cortical visual system (Johnson & Vecera, 1993). Presumably this pathway also plays a role in blindsight (Vuilleumier et al., 2003; Sahraie, Weiskrantz, Trevethan, Cruce, & Murray, 2002). For example, Morris, DeGelder, Weiskrantz, and Dolan (2001) found evidence that a blindsight subject (GY) discriminated emotional facial expressions in his blind field. In contrast, the *cortical pathway* starts with the parvocellular cells on the retina from where it projects chiefly to the ventral stream (Livingstone & Hubel, 1988; Merigan & Maunsell, 1993). It allows high resolution and detailed processing of high-frequency visual information, but processing is slower than in the subcortical pathway (Vuilleumier et al., 2003).

Finally, support for LeDoux's theory that emotional stimuli can capture attention even preattentively via the subcortical route comes from a study by Vuilleumier and Schwartz (2001). They found that patients with unilateral neglect and visual extinction, who usually remain unaware of contralesional stimuli, more frequently detected emotional stimuli (schematic spiders) than neutral pictures (schematic flowers) on the contralesional side. This suggests that while mechanisms of spatial attention are impaired in neglect patients due to parietal lesions, intact visual pathways to the ventral temporal lobe and the amygdala might still mediate distinct mechanisms of emotional attention.

1.4. The Neuronal Basis of the (Emotional) Stroop Interference

Since little is known about the neuronal underpinnings of the emotional Stroop interference, research on the classical color-word Stroop task provides a useful heuristic for a first approach to this topic. Yet, it should be noted that it cannot be assumed

that the same mechanisms are at work in emotional Stroop interference as in standard Stroop interference (see Wells & Matthews, 1994).

1.4.1. Brain Regions Involved in Color-Word Stroop

Despite nearly 70 years of research, the nature of Stroop interference is still not completely understood. A number of functional imaging and event-related potential studies have attempted to identify the neuronal basis of Stroop interference. First, results of functional imaging studies (fMRI and PET) will be described in the following sections, and afterwards the focus will be placed on event-related potential (ERP) studies.

Functional Imaging Studies It is well established that attentional selection enhances activity within brain regions specialized for processing the stimulus or stimulus attribute to which attention is directed (e.g. Corbetta, Miezin, Dobmeyer, Shulman, & Petersen, 1991). However, surprisingly, several PET studies found no increase in activation of color perception regions, i.e. V4, when subjects named the color of incongruent color-word stimuli (e.g. Bench et al., 1993; George et al., 1994; Pardo, Pardo, Janer, & Raichle, 1990; Taylor, Kornblum, Lauber, Minoshima, & Koeppe, 1997).

In general, functional imaging studies suggest that multiple, broadly distributed brain regions contribute to Stroop performance. Among other regions, the dorsolateral prefrontal cortex (DLPFC), the anterior cingulate cortex (ACC), and the parietal cortex have been repeatedly found to be activated in incongruent color-word conditions of the Stroop task compared to neutral word conditions (fMRI studies: Banich et al., 2000; Leung, Skudlarski, Gatenby, Peterson, & Gore, 2000; MacDonald III, Cohen, Stenger, & Carter, 2000; Milham et al., 2001; Peterson et al., 1999; PET studies: Bench et al., 1993; Carter, Mintun, & Cohen, 1995; Pardo et al., 1990).

The ACC is involved in a wide range of cognitive tasks (Botvinick, Braver, Barch, Carter, & Cohen, 2001), e.g. tasks which are difficult or performed under high-load conditions, such as divided attention or dual tasks (Corbetta et al., 1991; D'Esposito et al., 1995); tasks in which a large number of errors of commission are made, such as the Go/No-go and Eriksen task (Botvinick, Nystrom, Fissel, Carter, & Cohen, 1999; Casey et al., 1997; Kiehl, Liddle, & Hopfinger, 2000); tasks which require the selection of responses in an undetermined context, such as stem completion or voluntary/random movements (Buckner et al., 1995; Frith, Friston, Liddle, & Frackowiak, 1991; Jueptner, Frith, Brooks, Frackowiak, & Passingham, 1997); and tasks which involve response

inhibition and response competition, such as the Stroop task (Barch et al., 2001; Carter et al., 1995, 2000; Pardo et al., 1990). Although the specific function of the ACC remains unclear, its role in cognitive and selective attentional tasks is well-established, and most interference research has concentrated on this structure.

It has been proposed that the ACC detects conflicts between incompatible potential responses (Botvinick et al., 2001; Carter et al., 1998; MacDonald III et al., 2000). MacDonald III et al. (2000), for example, investigated the role of the ACC and the DLPFC with a task-switching version of the Stroop paradigm. Before each trial, subjects were given the instruction either to read the word (which is considered a more automatic response) or to name the color (which requires greater control). After a delay, the stimulus was presented. The ACC was more active in response to incongruent compared to congruent color-naming trials, which is consistent with a role in conflict monitoring. Also, the subjects with the largest Stroop interference effect also tended to have more ACC activation. Consistent with other studies that found DLPFC activity in tasks that require maintenance and manipulation of information in working memory, they found larger activity in DLPFC during task preparation for color-naming compared to word-reading trials. Thus, the DLPFC may be involved in representing and maintaining the attentional demands of a task.

The anterior cingulate cortex can be divided into two major subdivisions which are functionally and cytoarchitecturally distinct (Devinsky, Morrell, & Vogt, 1995; Vogt, Finch, & Olson, 1992; cf. also Bush et al., 1998; Bush, Luu, & Posner, 2000). These are the dorsal cognitive division (ACcd) and the rostral-ventral affective division (ACad). The *cognitive subdivision* is activated by cognitively demanding tasks that involve stimulus-response selection in the face of competing streams of information, e.g. Color Stroop and Stroop-like tasks (e.g. Bush et al., 1998). On the other hand, the *affective subdivision* is activated by affect-related tasks, e.g. in the emotional counting Stroop (Whalen et al., 1998), in which the number of words (neutral or negative) that appear on a screen has to be counted and reported by pressing a button.

The cognitive subdivision of the ACC is part of a distributed attentional network with reciprocal interconnections with the lateral prefrontal cortex, the parietal cortex, and premotor and supplementary motor areas. Various functions have been ascribed to it, among them executive functions by influencing sensory or response selection, competition monitoring, error detection, and complex motor control (cf. Bush et al., 2000). In contrast, the affective subdivision is involved in assessing the salience of emotional and motivational information and the regulation of emotional responses. It is connected

with the amygdala, periaqueductal gray, nucleus accumbens, hypothalamus, anterior insula, hippocampus, and orbitofrontal cortex and projects to autonomic, visceromotor, and endocrine systems (cf. Bush et al., 2000).

To summarize the results, it may be said that incongruent color words do not lead to a larger activation of color perception areas (V4). Areas which were consistently found to be more activated in incongruent as compared to congruent color words are the ACC, the DLPFC, and parietal areas. The ACC plays a key role in research on Stroop interference due to its role in conflict monitoring. It can be divided into a cognitive subdivision (ACcd), involved in stimulus response competition tasks like the classical Stroop task, and an affective subdivision (ACad), which is activated by affect-related tasks like the emotional counting Stroop task. The ACC should therefore also be investigated in studies of emotional Stroop interference.

Event-Related Potential Studies An ongoing debate is whether interference occurs early, during *stimulus processing*, or late, in the form of *response competition*. Duncan-Johnson and Kopell (1981) examined P300 latency in a Stroop task and found no evidence of a delay in P300 latency for incongruent as compared to congruent stimuli. They concluded that Stroop interference must primarily arise from response competition at the output stage rather than stimulus evaluation processes. Grapperon, Vidal, and Leni (1998) and Ilan and Polich (1999) replicated these results. Finding no relationship between reaction time and P300 latency, they also concluded that Stroop interference occurs after the stimulus has been evaluated. In accordance with this assumption, Grapperon et al. (1998) found a premotor negativity for incongruent stimuli which was only present in the color naming and not in the word reading condition. This premotor negativity occurred 400–205 ms before the subjects responded.

Rebai, Bernard, and Lannou (1997) recorded ERPs while subjects performed a modified Stroop task. Subjects were shown congruent or incongruent color words and had to either mentally name the color or mentally read the word (covert Stroop design). For the mental color naming condition, Rebai et al. (1997) reported an enhanced N400 at midline frontal and central sites for discordant words. The N400 is accepted as an indicator of semantic-context mismatch (Kutas & Hillyard, 1980). They proposed that the response the subject has to make when color-naming discordant stimuli is incongruent with the stimulus context and therefore a N400 is elicited. For the word reading condition, this enhanced N400 was not found. However, ERPs were significantly more positive in the P300 time window [250 ms; 350 ms] for discordant than for concordant

color words. This effect was most pronounced on central and parietal sites. They interpreted this enhanced P300 wave when reading discordant color words as some kind of surprise or enhanced attention effect.

West and Alain (1999) also investigated ERPs in a manual Stroop task. ERPs were analyzed with all electrodes referenced to an average reference. Results showed a robust Stroop effect in both the response latency and response accuracy data, i.e. not only did subjects show significantly longer reaction times for incongruent as compared to congruent, neutral, and word identification trials, but they also committed significantly more errors in incongruent trials. Several modulations of ERPs for incongruent as compared to other trials were observed. First, incongruent trials led to an attenuated bilateral positivity peaking at 500 ms over the lateral fronto-polar region, which was attributed to conflict detection. Second, for incongruent trials a negative fronto-central and positive fronto-polar slow wave was observed, beginning at about 500 ms and persisting over the remainder of the trial. This effect was interpreted to represent conflict resolution processes in the ACC. Third, a decreased left parietal positivity (peak $\sim$ 522 ms post-stimulus) and a greater left temporo-parietal positivity (peak $\sim$ 650 ms post-stimulus) was found for incongruent relative to congruent trials. West and Alain argued that on incongruent trials, conflict detection (phasic fronto-polar positivity) and resolution processes (fronto-central slow wave) may be activated to modulate processing of information in the perceptual color pathway (left temporo-parietal modulation). The Stroop effect was explained by the time required to activate the color pathway to a level sufficient to guide a response.

Liotti, Woldorff, Perez, and Mayberg (2000) examined the influence of verbal (covert and overt) vs. manual response modalities on reaction times and ERPs. They observed a very robust Stroop color-word interference effect in both the vocal version and the manual version of the task. Of course, for the covert vocal condition no reaction times were available. Again, ERPs were referenced to an average reference. For incongruent trials, they found a medial-dorsal negativity between 350–500 ms post-stimulus. The effect had a distinct scalp topography for the verbal (covert and overt) and manual versions of the task, with an anterior-medial focus for overt or covert speech and a broader medial-dorsal distribution for the manual task. Dipole analysis suggested two independent generators of this activity in the ACC, more dorsal in the verbal task and more posterior in the manual task. The authors presumed that the activity in the ACC in incongruent trials was related to the need of suppressing or overriding the processing of the incongruent word meaning, i.e. they interpreted it as evidence of

conflict processing and resolution in the ACC. Although the observed interference effect was in the time range of the N400 as in the Rebai et al. (1997) study (covert design) and also had a similar scalp distribution, the authors argued that a N400 interpretation appeared unlikely for several reasons, one being the different scalp distribution of the interference effect for vocal and manual responses. A second finding of the study was a prolonged positivity between 500–800 ms post-stimulus over the left superior temporo-parietal scalp for incongruent relative to congruent trials. This effect was evident in all three versions of the task and presumably reflects additional activation of word meaning regions (possibly Wernicke's region) in incongruent trials.

Atkinson, Drysdale, and Fulham (2003) examined various ERP components in a manual classical Stroop (identify color) and reverse Stroop (identify word) task. They found Stroop interference for incongruent and facilitation for congruent stimuli. In addition, they found a reverse Stroop interference for reading incongruent color words. However, they failed to replicate the midline frontal and central negative modulation 300–500 ms post-stimulus and later found by other studies reported above (Liotti et al., 2000; Rebai et al., 1997; West & Alain, 1999) and purported by some to be an N400 for the incongruent condition. Furthermore, for the P300 at midline central and parietal sites, Atkinson et al. found a greater amplitude for congruent and incongruent than neutral trials but no difference between congruent and incongruent trials. P300 latency data also showed no difference between the three conditions. The authors concluded that the lack of difference between congruent and incongruent conditions implies that both are processed much the same until motor output stage. Thus, interference must be a consequence of response competition at the output stage. Furthermore, they found significant amplitude and latency differences for the parietal P300 component between the color identification and word identification task, supporting the notion that P300 latency reflects stimulus evaluation time (Duncan-Johnson & Kopell, 1980; Ilan & Polich, 1999) and that evaluating a stimulus for a word response takes longer than evaluating the same stimulus for a color response.

In conclusion, so far no component modulation has been reported to be consistently related to the Stroop effect. Task and stimulus variations might play an important role in the different results and need to be investigated systematically. The results reported by Duncan-Johnson and Kopell (1981), Grapperon et al. (1998), Ilan and Polich (1999), and Atkinson et al. (2003) indicate that Stroop interference is not reflected in a delay of P300 latency, which is generally assumed to reflect stimulus evaluation time (Duncan-Johnson, 1981; Czigler & Szenthe, 1988). This points to *response competition* rather

than *stimulus processing* as the source of interference. In addition, P3 amplitude has been found only in one study (Rebai et al., 1997) as being larger for discordant than for concordant color word stimuli. Thus, P3 amplitude also does not seem to be an electrophysiological correlate of the classical Stroop interference. Furthermore, late frontal and temporo-parietal components occurring near or at response latency have been thus far the most promising ERP indices of Stroop interference. Finally, there is some evidence that the left hemisphere generally shows more interference-related effects than the right hemisphere, which is consistent with the dominant role of the left hemisphere in verbal processing (MacLeod, 1991).

1.4.2. What Do We Know About Emotional Stroop Interference?

Only few studies have investigated the neuronal correlates of emotional Stroop interference (Compton et al., 2003; George et al., 1994; George et al., 1997; Isenberg et al., 1999; Whalen et al., 1998).

A PET study by Isenberg et al. (1999) found enhanced amygdala activity for color naming threatening as compared to neutral words. In an fMRI study, Whalen et al. (1998) investigated the role of the ACC in an emotional counting Stroop paradigm. In this paradigm, the number of words (neutral or negative) that appear on a screen has to be counted and reported by pressing a button. Although Whalen et al. did not find a reaction time increase for negative as compared to neutral words, they found the ventral affective division (ACad) of the ACC to be more activated for negative vs. neutral words during initial presentation blocks. In contrast, George et al. (1997) did not find any ACC activation in an emotional Stroop task.

More recently, Compton et al. (2003) compared the classical color-word Stroop with an emotional word Stroop task. Subjects had to identify the color of a word as fast as possible by pressing a button while ignoring word content. The authors suggested that both tasks may draw upon overlapping brain regions when they share common processing components. The dorsolateral prefrontal cortex (DLPFC), for example, was engaged regardless of whether the task involved emotional or non-emotional distractors, i.e. negative words or incongruent color words. This region seems to be important for maintaining an attentional set in the presence of a salient distractor. Similarly, the left lateral orbitofrontal cortex was significantly activated in response to negative emotional words as compared to neutral words, and there was also a small (but non-significant)

area of activation for incongruent color words vs. neutral words. The authors suggested that this area is involved in the inhibition of salient responses.

Color-naming *negative emotional words* led to increased bilateral occipito-temporal activity and decreased right amygdala activity. On the other hand, color-naming *color-incongruent words* led to increased activity in the left superior parietal lobe as well as decreased activity in the parahippocampal gyrus.

These results extend prior reports of increased activity in visual-processing areas when subjects view emotional pictures (Lane, Chua, & Dolan, 1999; Lane et al., 1997; Lang, Bradley, & Cuthbert, 1998). The greater involvement of right occipito-temporal regions, especially in response to high-arousal vs. low-arousal negative words, is consistent with the notion that the right hemisphere has an emotional surveillance function that is especially sensitive to signals of threat (Bear, 1983; Nitschke, Heller, & Miller, 2000).

However, there are some limitations to the interpretation of the results of Compton et al. (2003). The emotional Stroop task did not produce the same degree of interference as the color-word Stroop task, limiting the comparability of the tasks. In fact, Compton et al. did not find any significant behavioral difference between negative and neutral words unless they analyzed only the first 16 trials of each word type. In this analysis high-arousal negative words did lead to significantly slower reaction times than matched neutral words.

In conclusion, a small number of PET and fMRI studies (but no EEG studies) have investigated the neuronal correlates of emotional Stroop interference. The results of these studies are rather inconsistent regarding the regions which were found to be more activated on negative/threatening compared to neutral trials. Some studies found the ACC to be more strongly activated for threatening compared to neutral stimuli (Whalen et al., 1998), but other studies could not replicate these results (George et al., 1997). Some studies did not even find emotional Stroop interference in reaction times but still reported differences in activated brain regions (Compton et al., 2003). In addition, all studies investigating the neuronal underpinnings of emotional Stroop interference so far examined only healthy subjects but no clinical samples. Thus, these studies still shed no light on how anxiety patients differ from healthy controls in emotional Stroop paradigms and, most importantly, which brain regions underlie the emotional Stroop interference observed in these patients.

1.5. The Processing of Emotional and Fear-Relevant Stimuli

Fear-relevant stimuli are a special case of emotional stimuli. Thus, this section will summarize what is known about the processing of emotional stimuli and will then deal with the processing of fear-relevant ones. A brief overview of functional imaging and event-related potential studies in this field will be given.

1.5.1. Results of Functional Imaging Studies

In general, fMRI studies found more extensive activity in the visual cortex when subjects viewed emotional compared to neutral pictures, with larger differences in the right compared to the left hemisphere (e.g. Dolan et al., 1996; Lang et al., 1998). This suggests that the visual cortex is differentially activated as a function of emotional arousal, and that the larger positive electric potentials found for arousing as compared to neutral pictures (see section 1.5.2) may be at least partially generated by differential activity in the visual cortex.

Studies with Animal Phobics Several PET studies have investigated the processing of fear-relevant stimuli in phobic patients (Fredrikson et al., 1993; Fredrikson, Fischer, & Wik, 1997; Fredrikson, Wik, Annas, Ericson, & Stone-Elander, 1995; Johanson et al., 1998; Rauch et al., 1995; Wik et al., 1993; Wik, Fredrikson, & Fischer, 1997).

Fredrikson et al. (1993) were among the first to report elevated rCBF in the visual associative cortex of snake phobics who viewed phobic as compared to neutral and aversive stimuli. Furthermore, they found cortical and thalamic rCBF to be correlated, suggesting that the thalamus is a relay station for phobic stimulus processing and affect. The results were replicated with spider phobics (Fredrikson et al., 1995). The latter study also found reduced relative rCBF in the hippocampus, the prefrontal, orbitofrontal, temporopolar, and posterior cingulate cortices.

Johanson et al. (1998) examined activity in frontal areas while spider phobic subjects watched videos of living spiders or control videos (nature scenery). Subjects who showed severe panic during spider exposure had marked rCBF decreases in the frontal cortex, particularly in the right hemisphere. Those subjects who were frightened but did not panic during spider exposure showed a consistent right frontal rCBF increase

during spider exposure. The authors suggest that these differences in frontal activity are related to the experience and cognitive control of phobic anxiety.

A recent fMRI study by Paquette et al. (2003) investigated the influence of cognitive-behavioral therapy (CBT) on brain activation patterns in spider phobics. Before treatment, spider phobics showed significant activations of the right dorsolateral prefrontal cortex, the parahippocampal gyrus, and the visual associative cortex when viewing spiders as compared to butterflies. After CBT, the activation in the dorsolateral prefrontal cortex and the parahippocampal gyrus disappeared. However, additional activations of the superior parietal lobule and the right inferior frontal gyrus were observed. The authors interpreted these activities as indicating a higher state of visual vigilance. However, this study has severe limitations: the control group was scanned only once, and the study lacked a spider phobic control group receiving no CBT, i.e. a waiting control group.

To summarize, the elevated rCBF in the visual cortex of phobics in response to their feared object (Fredrikson et al., 1993, 1995) is in line with studies reporting more extensive activation of the visual cortex when viewing highly emotional (arousing) stimuli (e.g. Dolan et al., 1996; Lang et al., 1998). The activity of frontal areas in phobics might depend on the cognitive control of anxiety when viewing a feared object (Johanson et al., 1998). So far, no study has convincingly demonstrated how brain activations in response to feared objects change after cognitive-behavioral treatment of phobia.

1.5.2. Results of Event-Related Potential Studies

It has been repeatedly shown that the amplitude and scalp topography of the P300 is significantly influenced by the emotional content of stimuli. ERP studies consistently found higher parietal cortical positivity (P3 and later components) in response to emotional stimuli, both pleasant and unpleasant, as compared to neutral ones (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Diedrich, Naumann, Maier, Becker, & Bartussek, 1997; Johnston, Miller, & Burleson, 1986; Keil et al., 2001, 2002; Laurian, Bader, Lanares, & Oros, 1991; Mini, Palomba, Angrilli, & Bravi, 1996; Palomba, Angrilli, & Mini, 1997; Radilovà, 1982; Radilovà, Figar, & Radil, 1983, 1984; Schupp et al., 2000).

Lifshitz (1966) and Begleiter, Gross, and Kissin (1967) were among the first to assess the influence of emotional visual stimuli on ERPs. Later on, Radilovà (1982) observed

that unpleasant visual stimuli led to more positive P3 waves than neutral ones and that erotic slides led to larger P3 amplitudes than non-erotic slides such as flowers, landscapes, etc. (Radilovà et al., 1983, 1984). This supported the conclusion that higher emotionality of visual stimuli in general leads to higher P3 amplitudes. Further support for this assumption comes from studies by Johnston and colleagues (Johnston, Burleson, & Miller, 1987; Johnston et al., 1986). In their 1986 study, subjects watched pleasant (babies, opposite and same sex models), unpleasant (dermatological diseases) and neutral (ordinary people) slides. They found evidence for multiple late positive components: P3 and P4 as well as a slow wave. P3 and P4 were larger for emotional (pleasant and unpleasant) as opposed to neutral stimuli. Similarly, Mini et al. (1996) using pleasant, unpleasant and neutral pictures from the International Affective Picture System (IAPS: Center for the Study of Emotion and Attention, 1995) also found more cortical positivity to emotional than neutral slides within the latency ranges 300–400 ms and 400–500 ms. This pattern of sustained positivity has been interpreted as indicative of deeper processing of the emotional information (Palomba et al., 1997). Specifically, Lang et al. (1997) proposed that it reflects motivational engagement and a commitment of attentional resources to the picture viewing task.

Recently, this greater magnitude of parietal late positive deflection has been attributed more to the arousal of the stimuli, rather than to their emotional valence. This interpretation has already been proposed by Yee and Miller (1987), who reported larger P300 amplitudes to unpleasant slides than to pleasant ones but pointed out that the unpleasant slides could be "viewed as more [affectively] intense" and that the difference may reflect the "emotional intensity" of the stimuli rather than their valence.

In correspondence with this interpretation, Schupp et al. (2000) suggested that the crucial variable influencing late positive components is arousal rather than valence. They used three different categories of pictures from the IAPS: positive, negative and neutral pictures. The valence of the three categories differed significantly. The pleasant and unpleasant pictures did not differ in arousal, but were significantly more arousing than the neutral pictures. High-arousing (pleasant and unpleasant) affective pictures elicited larger LPPs than low-arousing (neutral) pictures. LPPs did not differ between pleasant and unpleasant slides. However, attributing the entire LPP effect to arousal rather than valence would be premature, since Schupp et al. (2000) lacked positive and negative low-arousing pictures, which would have been necessary to draw such a conclusion from their paradigm. A basic problem of the arousal and valence dimensions is that they are not independent but follow a U-shaped relation, i.e. highly positive

and highly negative stimuli are in general also evaluated as more arousing (Lang et al., 1997). Thus, separating the effects of valence and arousal does not seem to be feasible.

Hemispheric Specialization in the Processing of Emotional Stimuli There is considerable evidence for a functional hemispheric specialization in the regulation of affect. For example, Laurian et al. (1991) recorded ERPs while subjects viewed neutral, happy or angry facial expressions. They found the largest difference in P3 amplitudes between emotional and neutral target stimuli over the right centroparietal area. They interpreted their results as supporting the right hemisphere superiority in the processing of emotional stimuli.

However, Kayser et al. (1997) noted that left-hemispheric activity may have been confounded with motor potentials since subjects responded with their right hand. This possibly could have reduced differences in P3 amplitudes between emotional and neutral conditions over the left hemisphere, leading to a right hemisphere advantage. To rule out this possibility, Kayser et al. (1997) recorded ERPs while subjects watched negative (dermatological diseases) or neutral pictures (after cosmetic surgery) in a visual half-field paradigm. This paradigm required no discriminative or motor response. They found effects of emotional content on ERP components N2, early P3, late P3, and slow wave. However, hemispheric asymmetries were restricted to N2 and early P3, with maximal effects over the right parietal region. The N2-P3 amplitude was increased for negative and reduced for neutral stimuli over right-hemispheric recording sites. They interpreted this finding as supporting a hemispheric lateralization of the processing of emotional stimuli.

In conclusion, a right hemispheric superiority is generally reported in response to emotional stimuli, particularly in response to threat (Etcoff, 1989; Kayser et al., 1997; Laurian et al., 1991; Silberman & Weingartner, 1986; Van Strien & Hejit, 1995; Van Strien & Morpurgo, 1992).

Studies with Animal Phobics Few studies so far have investigated ERPs in animal phobics who view their feared objects. Gutberlet and Miltner (1999) showed that the presentation of fear-relevant stimuli (spiders and snakes) led to enhanced P3 amplitudes for the feared object in the corresponding specific phobia group, i.e. spider phobics showed enhanced P3 amplitudes for spiders but not for snakes, and snake phobics for snakes but not for spiders.

A follow-up study with spider phobics replicated these results (Gutberlet & Miltner, 2001). Additionally, in this study the influence of cognitive-behavioral therapy according to Öst (1989, 1996; Öst et al., 1991) on electrophysiological variables and ERPs was investigated. Results showed significant changes in electrodermal activity and heart rates before and after treatment. While before treatment, spider phobics showed a defense reaction in response to spiders, after treatment a normal orienting response was observed. However, the enhanced P3 amplitude in spider phobics in response to spiders was observed before and after treatment. Presumably, despite therapy, spider phobics evaluated spiders still as more arousing than control objects.

It could be objected that in all the paradigms described above an *affective oddball paradigm* was implicitly constructed. If spider phobics view pictures of highly unpleasant and arousing stimuli, i.e. spiders, presented together with neutral and positive stimuli, they could classify the stimuli as "non-phobic" and "phobic" stimuli. "Non-phobic" stimuli would be grouped together as one category, and spiders would stand out – a classical oddball effect, leading to larger P3 amplitudes.

To rule out this argument, Krieschel (2003) created an oddball paradigm in which the probability of stimuli was systematically varied. In two different conditions, subjects saw pictures of spiders and flowers or spiders and birds. Each pair of stimuli was presented at a ratio 1:4 (which corresponds to the classical oddball paradigm: 20% deviant stimuli, 80% standard stimuli). Subjects had to count either the deviant or the standard stimuli. The factors *Task* (counted, not counted), *Probability* (deviant or standard stimuli) and *Condition* (spiders–flowers; spiders–birds) led to 8 different conditions. Results showed that the variation of the P3 amplitude was not completely explained by the factors Probability and Task. The emotional relevance of stimuli also had a significant influence on P3 amplitude, which resulted in specifically higher P3 amplitudes in spider phobics when viewing pictures of spiders.

To summarize, the enhanced P3 amplitudes in animal phobics in response to their feared object (Gutberlet & Miltner, 1999, 2001; Krieschel, 2003) are in accordance with the larger parietal cortical positivities in response to highly emotional (arousing) stimuli (e.g. Schupp et al., 2000). The argument that the enhanced P3 amplitude in phobics for their feared object is merely due to an affective oddball effect could be ruled out (Krieschel, 2003). Finally, it still remains unclear why P3 amplitudes were still enhanced after treatment of phobia, even though peripheral physiological measures normalized. Whether this effect could be due to spider phobics' still elevated arousal ratings of feared stimuli even after therapy has to be investigated in future studies.

1.6. The Late Positive Complex: Multiple P3 Components

Since the P3 and related components are the focus of this thesis, the next sections explain factors influencing these amplitudes.

Probably no electrocortical component has received as much attention from researchers as the P3 component. Since its discovery by Sutton, Zubin, and John (1965), various different P3 components (P3a, P3b, P3 Vertex, P3 No-Go, slow wave, ...) have been described. Today, there is general agreement that there is no one unique P3, but probably multiple P3s which are independent and dissociable. Ruchkin, Sutton, and Mahaffey (1987) wrote:

> "With the accumulation of human brain event-related potential (ERP) data, it has become apparent that there are a number of endogenous late positive components, different in their scalp distribution, latency, duration, and psychological correlates. Components may occur alone or may overlap spatially and temporally. This group of components is sometimes referred to as the late positive complex. The most widely studied member of the late positive complex is the long latency (300–600 ms) parietal P300. Its amplitude can be relatively large with respect to other late positivities, and it is therefore generally the most readily observed. In much of the earlier literature, the P3 and P300 nomenclature is used, but in the more recent literature, it is commonly referred to as P3b (Squires, Squires, & Hillyard, 1975) so as to explicitly distinguish it from other late positivities in the same time region."

As noted above by Ruchkin et al., the P3 component investigated in this thesis is often also referred to as the P3b component. Its maximal amplitude is centro-parietal with a latency between 300–600 ms. The P3b is generally elicited by events that are relevant for the subject for some reason. Tasks eliciting a P3b include, among others, oddball paradigms, signal detection paradigms, comparisons of two stimuli, and discrimination learning (for more information see Roesler, 1982; Trimmel, 1990). The *relevance* and *amount of information* extracted from the eliciting event, rather than its physical properties, are key determinants of P3b (Sutton et al., 1965). However, the P3b can also be elicited by the *absence* of a stimulus, when absence conveys relevant information

to the subject (Sutton, Tueting, Zubin, & John, 1967). In the following sections, to simplify matters, the P3b will be referred to as P3.

Neurochemical Substrates and Neuroanatomical Generators of P3 Recently, the neurochemical substrates of P3 were elucidated (see Frodl-Bauch, Bottlender, & Hegerl, 1999). The neurotransmitter glutamate, which is the most important excitatory neurotransmitter in the brain, appears to play a major role in P3 generation. In fact, P3 is most likely caused by a direct excitatory postsynaptic effect of glutamatergic neurotransmission. Important modulators of excitatory postsynaptic potentials (EPSPs) triggered by glutamate are cholinergic and GABAergic influences. While cholinergic neurotransmission increases P3 amplitude and decreases P3 latency, GABAergic influences reduce P3 amplitude and prolong P3 latency.

The P3 seems to be a composite of activity arising from different generators in the brain (Verleger, 1997). While early studies suggested the importance of medial temporal lobe structures (hippocampus, parahippocampal gyrus, amygdala) for P3 generation (e.g. Halgren et al., 1980; Okada, Kaufman, & Williamsen, 1983; Wood et al., 1984), more recent studies hint at neuronal generators in the parietal and temporo-parietal cortical areas (see Frodl-Bauch et al., 1999 for more information). For several reasons, the limbic system probably has little influence on the generation of the scalp-recorded P3. One reason is, for example, that deep structures such as the hippocampus are unlikely to be direct generators of the large 10–20 μV P3 potentials recorded on the scalp (Lutzenberger, Elbert, & Rockstroh, 1987), and there is further evidence substantiating this assumption (see Frodl-Bauch et al., 1999).

1.6.1. Influences on P3 Amplitude

As a result of studying the P3 in a wide variety of behavioral paradigms, a large number of hypothetical constructs have been suggested to account for the observed variations in P300 amplitude. The most common are *attention*, *probability*, *uncertainty reduction* or *equivocation*, *processing demands*, *task relevance*, *stimulus value*, and *salience*. In a comprehensive review, Johnson (1986) summarized various influences on P3 amplitude and developed a triarchic model of P3 amplitude.

Johnson's (1986) Triarchic Model of P3 Amplitude

According to Johnson, variables that account for the P3 amplitude can be classified into three dimensions: *subjective probability*, *stimulus meaning*, and *information transmission*.

The variables on the subjective probability and stimulus meaning dimensions have independent and additive contributions to overall P3 amplitude. The amplitude contributions of both these dimensions, however, are modulated by a multiplicative relation with the proportion of transmitted stimulus information. The model is summarized by the following equation:

$$\text{P3 Amplitude} = f\left(T \times \left(\frac{1}{P} + M\right)\right)$$

T denotes information *transmission*, i.e. the proportion of stimulus information received by a person. P denotes the *subjective probability* of a stimulus. Finally, M denotes the effect of stimulus *meaning*.

Transmission Information transmission stands for the proportion of stimulus information received by a person relative to the total amount of information the subject could possibly receive about the stimulus. Thus, the transmission variable will assume values between 0 and 1. Information transmission is dependent on two categories of experimental variables: first, on those creating equivocation, e.g. stimulus discriminability, and second, on those affecting the allocation of attention, e.g. ignore or attend instructions. Increased uncertainty in identifying the eliciting event (equivocation – information loss) reduces P3 amplitude (e.g. Fitzgerald & Picton, 1982; Johnson & Donchin, 1978; Ruchkin & Sutton, 1978).

Probability The amplitude of the P3 follows an inverse relation with stimulus probability, i.e. the P3 is larger for low probability events and smaller for high probability events. This inverse relation between P3 amplitude and the probability of an event's occurrence has been well documented (e.g. Duncan-Johnson & Donchin, 1977; Sutton et al., 1965; Tueting, Sutton, & Zubin, 1970). Stimulus probability is influenced by a priori probability and by subjective probability, i.e. the latter takes human judgment into account. Thus, the P3 amplitude is largest if the stimulus occurs unexpectedly and infrequently.

Meaning The meaning dimension consists of three independent variables: *task complexity*, *stimulus complexity*, and *stimulus value*. Johnson argues that probability

is unrelated to the meaning or significance of an event and that the variables on the meaning dimension therefore must be independent of those on the subjective probability dimension.

1. *Task complexity* refers to the demands of a task. Simple counting tasks, for example, are less demanding than reaction time tasks (Johnson, 1986). The more complex a task, the smaller is the decrease in P3 amplitude as a result of habituation (Lew & Polich, 1993). Thus, it seems that the P3 amplitude is directly related to the extent to which a stimulus must be processed.
2. *Stimulus complexity* refers to the perceptual demands of a stimulus. Some stimuli have more relevant features than others and thus require more processing for identification and categorization. Verbaten (1983) found larger P3 amplitudes for visual stimuli with more intricate patterns.
3. *Stimulus value* emphasizes the subjective meaning or significance of a stimulus for a person. Stimulus value can be manipulated, e.g. by monetary rewards. Several studies manipulating monetary rewards found larger P3 amplitudes for high-value stimuli as compared to low-value stimuli (cf. Johnson, 1986). Similarly, feared stimuli have a different stimulus value for phobics as compared to controls.

1.6.2. Influences on P3 Latency

The latency of the P3 is influenced by *task difficulty*. Task difficulty and complexity of stimulus evaluation are related. With more complex stimulus displays, stimulus evaluation and processing time increases, and P3 latency is prolonged (e.g. Czigler & Szenthe, 1988; Duncan-Johnson, 1981).

However, a review by Verleger (1997) suggested that P3 latency might not only depend on stimulus-processing time, but might also be influenced by the timing of response selection. He argues that the areas that contribute to P3 not only integrate perception, but also contribute to response selection. Therefore, it would not be plausible to assume that P3 latency was free from components that refer to response selection. He concludes that the P3 latency is not a sharp diagnostic tool to separate the processing of the stimulus itself from the processes related to the response. In contrast, Coles, Smid, Scheffers, and Otten (1995) argue that P3 latency is independent of the processes associated with response selection and execution. For example, although manipulations

of stimulus-response incompatibility have a large effect on reaction time, they have little if any effect on P3 latency (McCarthy & Donchin, 1981; Magliero, Bashore, Coles, & Donchin, 1984; Ragot, 1984). Furthermore, a study by Smid, Mulder, Mulder, and Brands (1992) found that an increase in response selection difficulty failed to influence P3 latency, while it resulted in an increase in reaction time. On the other hand, when the difficulty of stimulus identification increased, P3 latency increased.

In sum, while there is disagreement about the influence of response-related processes on P3 latency, it is widely accepted that P3 latency provides a measure of the relative timing of evaluation processes (Coles et al., 1995). One could assume that the P3 latency therefore is an ideal measure for the electrophysiological processes underlying Stroop interference. However, as discussed in Section 1.4, Stroop interference in the color-word Stroop task is *not* associated with a delay in P3 latency (Duncan-Johnson & Kopell, 1981). If indeed P3 latency is a marker of stimulus evaluation time, then this result would suggest that the interference occurs somewhere downstream from the system responsible for stimulus evaluation, i.e. in the system responsible for response selection and execution.

1.6.3. Theoretical Interpretations of the P3

Major theoretical interpretations of the P3 amplitude are that it indexes the updating of working memory (*context-updating theory*, Donchin, 1981), that it reflects the *closure of a cognitive epoch* (Verleger, 1986, 1988), or that it represents controlled, effort demanding cognitive processes (*theory of controlled processing*, Roesler, 1982).

The **context-updating theory** assumes that the P3 component is associated with updating or reorganizing working memory contents (Donchin, 1981; Donchin & Coles, 1988). The amplitude of the P3 is proportional to the amount of updating/change in working memory.

The **cognitive closure theory** assumes that the P3 marks the closure of a cognitive epoch and that its amplitude is a measure of the deactivation of the parietal "tertiary zone" (Verleger, 1986, 1988). This refers to Luria's (1973) distinction between primary, secondary and tertiary areas in his hierarchical model of the perception system. Primary areas are modality specific and project to secondary association areas, which again project to tertiary modality-independent areas located in the parietal cortex.

The **theory of controlled processing** (Roesler, 1982) presumes that a P3 is elicited when controlled instead of automatic processes are necessary, i.e. when stimulus evalu-

ation leads to the conclusion that a new, capacity demanding stimulus processing has to be initiated. The amplitude of the P3 reflects the amount of capacity necessary for this process. From this account the hypothesis can be drawn that the amplitude of the P3 would be greater for larger processing efforts.

Whatever the theoretical interpretation of the P3, there is abundant evidence for a modulation of P3 amplitude by the emotional content of stimuli, as reviewed in section 1.5.2. The interpretations of the P3 as reflecting deeper processing of emotional information, motivational engagement, or the commitment of attentional resources, together with the ERP studies with spider phobics described above fit Johnson's (1986) model well, since it also accounts for an influence of stimulus meaning.

In conclusion, the P3 amplitude is a valid indicator of emotional processing of fear-relevant stimuli in both phobics and non-phobics.

1.7. The Aims of This Thesis

The aims of this thesis were to study behavioral measures and electrophysiological correlates of the processing of fear-relevant stimuli in general and specifically of feared stimuli in spider phobics. In particular, reaction times, heart rates, and event-related potentials were investigated. Furthermore, in an exploratory study, the question as to which properties make a spider feared or fear-relevant was addressed.

Experiment I investigated the electrocortical correlates of the attentional bias in spider phobics by means of a pictorial emotional Stroop paradigm. While previous emotional Stroop studies mostly relied on verbal stimuli, in this study pictorial stimuli were used because of their higher ecological validity. In addition, manual instead of verbal responses were recorded to avoid artifacts due to speech-related movements in the simultaneous recording of ERPs.

The aims of this study were first, to replicate the results of previous studies investigating emotional Stroop interference in spider phobics and to identify the electrocortical correlates of the neuronal processes underlying this interference. Second, spider phobics, social phobics, and controls were compared in their processing of feared and fear-relevant stimuli, respectively. The focus of research lay on the amplitude of P3 and related components because of the well-documented influence of emotionally arousing stimuli on components in this latency range.

Experiment II aimed to replicate the results of Experiment I with schematic pictures of spiders and flowers. Schematic stimuli have several advantages as compared to non-schematic stimuli: they are simpler and unequivocal, and they show less variance than non-schematic pictures, e.g. they are not confounded with factors like spider size, species, or hairiness. In addition, it is easier to construct a control condition consisting of the same basic visual elements as the schematic spider pictures. The flower pictures we used in this study contained exactly the same basic visual elements as the spider pictures and were therefore ideal control pictures. All other parameters were the same as in Experiment I.

Experiment III explored the question as to which properties make a spider feared or fear-relevant. In a first approach to this question, the influence of Gestalt properties was investigated by varying the configurational position of the legs of a schematic spider in relation to its body, turning the schematic spider into a flower in seven steps. Spider phobics, social phobics, and controls had to classify each picture into the categories "spider", "flower", or "neither/nor".

One aim of this study was to identify crucial elements which cause a stimulus to be identified as a spider. Furthermore, the question was addressed whether spider phobics differ from control groups in their behavioral and electrocortical responses to ambiguous stimuli, possibly as a result of a stimulus generalization effect or an interpretive bias. Therefore, differences in valence and arousal ratings, reaction times, classification frequencies, and ERPs between spider-fearful and non-fearful subjects when viewing spider-like, ambiguous, and non-spider-like stimuli were investigated.

2. Experiment I – Pictorial Emotional Stroop Paradigm

2.1. Introduction: Aims and Hypotheses

So far, apart from the recent fMRI study by Compton et al. (2003), no study has investigated the neuronal correlates of the emotional Stroop interference in spider phobics. Instead, studies concentrated on color naming latencies.

This study aimed to elucidate the hitherto neglected electrocortical correlates of the processing of feared and fear-relevant stimuli. To this end, a pictorial emotional Stroop paradigm with integrated stimuli was designed. Pictures instead of words were used because of their higher ecological validity. Öhman's theory (described in section 1.3.5) also predicts that spider pictures, not words, are special fear-relevant cues to which preattentive feature detectors are sensitive. However, previous pictorial Stroop studies with spider phobics found mixed results ranging from no unequivocal interference over less interference to similar interference for spider pictures as compared to words. Furthermore, the computerized studies which found evidence for emotional Stroop interference used non-integrated spider pictures but when integrated pictures were used the results were inconclusive. Therefore, another aim of this study was to further investigate emotional Stroop interference with integrated pictorial stimuli. To avoid artifacts due to speech-related muscle movements in the simultaneous recording of ERPs, manual reaction times instead of verbal responses were recorded, although the latter is more common in emotional Stroop experiments.

Three groups of subjects participated in the study: spider phobics, social phobics, and controls. The social phobics served as a clinical control group for the spider phobic group. Subjects saw colored pictures of spiders, birds, and flowers. Their task was

either to identify the color of the object or to name the object itself. In addition to reaction times, heart rates and ERPs were recorded. The focus of ERP analyses lay on parietal late positive components, since previous studies found that highly pleasant and unpleasant stimuli led to larger P3 amplitudes than neutral stimuli. This effect has been interpreted as an effect of stimulus valence, but more recently as an effect of stimulus arousal. However, it has to be noted that the arousal and valence dimensions are not independent but follow a U-shaped relation, i.e. highly positive and highly negative pictures are in general also evaluated as more arousing (Lang et al., 1997).

In a pilot study, subjects rated a subset of the spider and bird stimuli used in this experiment for valence and arousal, using the Self-Assessment Manikin (SAM; Lang, 1980). Spiders were rated by all subjects as significantly more unpleasant and more arousing than birds. In addition, spider phobics rated spiders as significantly more unpleasant and more arousing than controls and social phobics. See Section 2.2.3 for the analysis. Thus, the stimuli were suitable for eliciting specific responses in subjects.

We expected the following results:

Reaction Times

- We anticipated to find *specific emotional interference* in spider phobics but not in controls and social phobics, expressed as longer reaction times for the color identification of spiders compared to neutral pictures.
- Furthermore, we hypothesized to find a *general facilitation effect* for fear-relevant stimuli. According to Öhman, fear-relevant stimuli are processed with high selectivity and priority, and this should apply not only to spider phobics but to all subjects. Thus, faster reaction times for the identification of spiders should be found in general.
- However, this facilitation effect should be particularly pronounced in spider phobics. Therefore, we expected an additional *specific facilitation effect* in spider phobics when identifying spiders as compared to social phobics and controls.

Heart Rates

- For flowers and birds a normal *orienting response* was expected in all groups, i.e. the heart rate should briefly decelerate and then slowly return to baseline.

- Deceleration increases progressively as unpleasant pictures are judged more arousing. Therefore, social phobics and controls should show higher heart rate decelerations for spiders as compared to flowers or birds.
- However, this pattern does not characterize the response of phobic subjects to pictures of their phobic object. After an initial small deceleration of the heart rate, spider phobics should show heart rate accelerations in response to spiders (*defense reaction*).

Event-related Potentials

- Since spiders are generally more arousing than birds, they should lead to a larger positivity in the P3 latency range compared to neutral objects. Thus, we expected to find in all subjects a *general arousal effect* for spiders on late positive potentials.
- Since spiders are particularly arousing for spider phobics, the arousal effect should be particularly pronounced for them, i.e. they should show even larger amplitudes in the P3 latency range for their phobic object. We thus anticipated a *specific arousal effect* for spiders on late positive potentials in spider phobics.
- Frontal areas, in particular the ACC, play a role in conflict monitoring. The cognitive subdivision of the ACC (ACcd) has been found to be involved in stimulus response competition tasks, such as the Stroop task, while the affective subdivision (ACad) is activated by affect-related tasks such as the emotional counting Stroop task. We therefore expected a *frontal interference component* representing the neuronal correlates of the emotional Stroop interference in spider phobics. However, because of the lack of previous studies in this field of research, this research question was more exploratory.

2.2. Methods

2.2.1. Subjects

Altogether, 57 subjects (mean age 23 yrs, SD 3.4 yrs; age range: 19–32 yrs) participated in the study: 19 spider phobics (9 male, 10 female), 19 social phobics (10 male, 9 female), and 19 normal controls (10 male, 9 female). There was no significant difference

between the groups regarding age (Kruskal-Wallis Test: $\chi^2_{df=2} = 5.43$; $p = 0.07$) or gender (Pearson $\chi^2_{df=2} = 0.14$; $p = 0.93$). However, there was a tendency for social phobics to be older than spider phobics. 54 of the subjects were right-handed and 3 left-handed, as measured by the Edinburgh handedness questionnaire (Oldfield, 1971).

Subjects were recruited by newspaper advertisement and within the university student population. All participants provided informed consent, and the procedures were approved by the ethics committee of the University of Jena. Subjects received 6 Euro per hour for their participation. In addition, spider phobics could participate in a one day spider phobia therapy (Öst, 1989). Social phobics could participate in a 10 session group training of social competences (Hinsch & Pfingsten, 2002).

In a preliminary interview participants were screened with the Structured Clinical Interview for DSM-IV (SCID; Wittchen, Wunderlich, Gruschwitz, & Zaudig, 1997). To be accepted for the study, subjects had to have no current or previous history of other major disorders according to DSM-IV except for a diagnosis of Spider Phobia for the spider phobic group and a diagnosis of Social Phobia for the social phobic group. Furthermore, subjects completed the following tests:

- Spider Questionnaire (SPQ; Klorman et al., 1974)
- Social Phobia and Anxiety Inventory (SPAI; Fydrich, 2002)
- Beck Depression Inventory (BDI; Hautzinger, Bailer, Worall, & Keller, 1995)
- State Trait Anxiety Inventory (STAI, trait version; Laux, Glanzmann, Schaffner, & Spielberger, 1981)

Normal controls were selected if they had less than 45 points on the SPAI and less than 7 points on the SPQ. It has to be noted that the German SPAI score can be transformed into the original SPAI score (Turner et al., 1989) by dividing by 22 and multiplying by 32.

All *spider phobics* fulfilled the diagnostic criteria of Spider Phobia according to DSM-IV. In addition, female spider phobics had to have 20 points or more on the SPQ and male spider phobics 16 points or more. According to Klorman et al. (1974), for women SPQ scores of 21 or more and for men scores of 15 or more correspond to the 95th percentile. Additionally, all spider phobics had to score below 45 points on the SPAI.

Social phobics were accepted if they received a diagnosis of Social Phobia according to DSM-IV and a SPAI value above 60 as well as a SPQ value smaller than 7. Furthermore,

Group	SPQ	SPAI	SPAI (orig.)	BDI	STAI
Spider Phobics: Mean	20.89	30.18	43.90	4.79	33.32
SD	2.87	10.48	15.25	4.67	7.86
Social Phobics: Mean	2.58	87.18	126.81	9.42	50.47
SD	1.95	12.49	18.17	7.09	6.61
Controls: Mean	2.47	23.05	33.53	2.68	30.79
SD	1.78	11.61	16.89	2.71	5.92
Kruskal-Wallis Test: $\chi^2_{df=2}$	37.75	38.63	38.63	12.22	32.81
p-value	0.0005	0.0005	0.0005	0.002	0.0005

Table 2.1.: Mean questionnaire values per group (SD = Standard Deviation); results of Kruskal-Wallis Test (χ^2 and p-values); Note: The German SPAI score can be transformed into the original SPAI score (Turner et al., 1989) by dividing through 22 and multiplying with 32

they were not allowed to have a current diagnosis of major depression or a history of a major depressive episode.

The BDI values were measured in order to find out whether the social phobics had elevated scores on a depression scale. The STAI was administered to investigate whether spider phobics also had enhanced general trait anxiety.

Mean values and standard deviations (SDs) for each test and each group are depicted in Table 2.1. The Kruskal-Wallis test showed that groups differed significantly on SPQ ($p = 0.0005$), SPAI ($p = 0.0005$), BDI ($p = 0.002$), and STAI ($p = 0.0005$) (see Table 2.1 for exact χ^2 values). Subsequent single comparisons with nonparametric Mann-Whitney-U Test (two-tailed) showed that controls and spider phobics differed only significantly in SPQ scores ($U = 0$; $p = 0.0005$). However, controls and social phobics differed significantly in SPAI values ($U = 0$; $p = 0.0005$), BDI values ($U = 65.5$; $p = 0.001$), and STAI values ($U = 6.5$; $p = 0.0005$). Furthermore, social phobics and spider phobics differed significantly on the SPAI ($U = 0$; $p = 0.0005$), SPQ ($U = 0$; $p = 0.0005$), BDI ($U = 104.5$; $p = 0.03$), and STAI ($U = 20.5$; $p = 0.0005$).

It is well known that depression is highly comorbid with social phobia (Merikangas et al., 1996; Schneier et al., 1992; Stein et al., 2001). Although we did not include social phobics with a clinically significant depression into the study, the social phobics we did include scored on average higher on the BDI than controls and spider phobics, thus leading to significant differences between the groups in BDI scores. To select a sample of social phobics with BDI scores comparable to controls would have been problematic since – besides the difficulty in recruiting subjects – one would select a

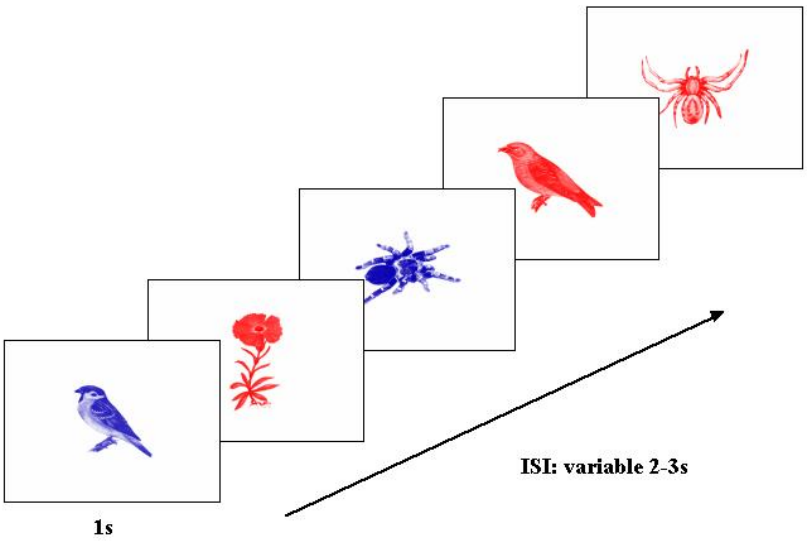


Figure 2.1.: Pictorial emotional Stroop paradigm with integrated stimuli

specific subtype of social phobics, who would probably also show less symptom severity. Given that social phobics only served as an additional clinical control group and were not the group of main interest, these differences in BDI should not compromise the interpretation of the results of this study. Furthermore, social phobics' BDI scores were elevated but not clinically significant (mean BDI score = 9.42; SD = 7.09). Yet, in order to estimate the influence of depression, for all ANOVAs calculated, additional ANCOVAs (Analysis of Covariances) with BDI values as a covariate were calculated. Additionally, for social phobics correlations of dependent variables and BDI scores were calculated. Since no consistent significant influences of depression on results were found and since the relationship of depression to social phobia was not the focus of this thesis, ANCOVA results will not be discussed in the following results section. The results of the ANCOVAs can be found on the CD-ROM accompanying this dissertation.

2.2.2. Paradigm

The experiment consisted of two blocks preceded by a training phase for each task. In each block 90 pictures of spiders, flowers and birds (30 of each) were presented. 45 pictures had been colored red, the others blue (for example pictures see Figure 2.1 and Appendix C.1). In one block subjects had to identify the color of the object (blue, red),

in the other block subjects had to identify the object itself (spider, flower, bird) by pressing the appropriate button on a button box with the index finger of their dominant hand. Each block started with a practice task in which 6 stimuli were shown. Subjects could repeat the practice trials as long as they felt it to be necessary in order to learn to press the button without looking at the button box. Each stimulus was shown for 1 s with a variable interstimulus interval of 2–3 s (2 s plus an exponential distribution with mean 500 ms, truncated at 1 s, as generated by ERTS).

Each stimulus was presented only once. The order of the stimuli was pseudo-randomized with the following conditions: the same color was only allowed up to four times in a row and the same type of object only up to two times in a row. This was done to avoid expectations which color or object would be presented next. The order of the two conditions and the sequence of keys which had to be pressed to classify the stimulus were randomized across subjects.

2.2.3. Subjective Ratings of Valence and Arousal

For a different study, a subgroup of the subjects rated the affective valence and arousal of a subset of the pictures, using the Self-Assessment Manikin (SAM; Bradley & Lang, 1994; Lang, 1980), a pictographic assessment instrument. The SAM is largely culture-free and has been used in various emotion studies. In this study an adapted version of this scale was used. For more details, see Appendix B. Affective valence was rated on a 9-point scale ranging from 0 = *highly unpleasant* to 8 = *highly pleasant*. Physiological arousal was also rated on a 9-point scale ranging from 0 = *not at all arousing* to 8 = *highly arousing*.

54 subjects rated the pictures according to their emotional valence and physiological arousal: 18 spider phobics (9 male, 9 female), 18 social phobics (9 male, 9 female), and 18 controls (9 male, 9 female). Mean age was 23, SD 3.5, age range 19–32 years.

For both valence and arousal ratings a 3×2 ANOVA was calculated with between factor *Group* and repeated measures factor *Object* (spider, bird). Mean valence and arousal ratings and standard deviations for each object are depicted separately for each group in Figure 2.2.

The analysis of **valence ratings** yielded main effects of Group ($F_{(2,51)} = 8.49$; $p = 0.001$) and of Object ($F_{(1,51)} = 159.44$; $p = 0.0005$), and a significant interaction of Group $\times$ Object ($F_{(2,51)} = 19.98$; $p = 0.0005$).

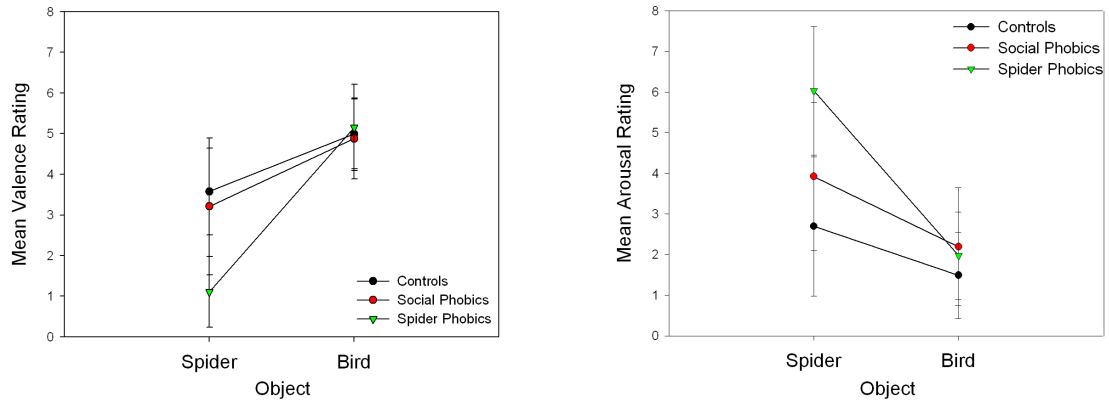


Figure 2.2.: Mean valence (left) and arousal ratings (right) and SDs for spiders and birds for each group

The main effect of Object indicated that all groups rated spiders as significantly more unpleasant than birds. Subsequent t-tests comparing valence ratings of spiders and birds for each group confirmed this finding (all p-values ≤ 0.0005).

To further analyze the interaction Group $\times$ Object, subsequent ANOVAs were calculated for each object. Results showed that valence ratings of birds did not differ significantly between groups, but the differences in valence ratings of spiders between groups were highly significant ($F_{(2,53)} = 20.36$; $p = 0.0005$). Tukey honestly significant difference (HSD) post hoc tests revealed that spider phobics rated spiders as significantly more arousing than controls ($p = 0.0005$) and social phobics ($p = 0.0005$).

Similarly, the analysis of **arousal ratings** showed main effects of Group ($F_{(2,51)} = 10.32$; $p = 0.0005$) and of Object ($F_{(1,51)} = 121.83$; $p = 0.0005$), and a significant interaction of Group $\times$ Object ($F_{(2,51)} = 17.24$; $p = 0.0005$).

The main effect of Object was further analyzed by subsequent t-tests. They revealed that all groups showed significantly higher arousal ratings for spiders than for birds (controls: $p = 0.001$; social phobics and spider phobics: $p = 0.0005$).

The interaction Group $\times$ Object was further analyzed by subsequent oneway ANOVAs calculated separately for spiders and birds. The analysis showed no significant difference between groups in arousal ratings for birds. However, there were highly significant differences in arousal ratings between groups for spiders ($F_{(2,53)} = 17.48$; $p = 0.0005$). Post hoc tests (Tukey HSD) revealed that spider phobics rated pictures of spiders as significantly more arousing than controls ($p = 0.0005$) and social phobics ($p = 0.002$).

In conclusion, all subjects rated spiders as more unpleasant and more arousing than

birds. However, spider phobics rated the spider pictures as significantly more unpleasant and more arousing than controls and social phobics. Thus, the pictures were suitable to elicit the specific reactions in each group.

2.2.4. Assessment of EEG and Other Psychophysiological Variables

After arrival in the lab, the scalp of the subjects was first cleansed with 70% isopropanol, and afterwards the hair was dried with a towel. The position of C_z was defined by bisecting the distance between nasion and inion, as well as the distance between the two preauricular points. Starting with C_z as a reference point the electrode cap (*Easy-Cap*, Falk Minow Services, Herrsching-Breitbrunn, Germany) was put on the subject's head and attached to a band around the chest. Then the hair under the electrode adapters was parted, and the skin was prepared with slightly abrasive preparation cream for EEG (*Every*, GVB-geli MED, Bad Segeberg, Germany). With blunt syringes the electrode gel (*ECI electrode-gel*™, Electro-Cap International Inc., Eaton, Ohio, USA) was injected in the electrode adapters, and 62 Ag/AgCl electrodes with 8 mm diameter were attached to the cap according to an extended version of the international 10-10 system (see Figure 2.3). The ground electrode was placed between F_z and FC_z on the forehead, and the reference electrode was C_z. All electrode impedances were kept below 5 kΩ.

Vertical and horizontal electrooculograms (VEOG and HEOG) were measured for later correction of eye movements and blink artifacts. VEOG was measured bipolarly by channel FP_1 and an Ag/AgCl electrode (E220N, In Vivo Metric, Healdsburg, California, USA) with 4 mm diameter placed beneath the left eye. HEOG was recorded bipolarly by channels F_9 and F_{10}. To facilitate artifact rejection during analysis EEG data, an *electromyogram* (EMG) was measured by 2 baby electrodes (GE Medical Systems, Solingen, Germany) with 5 mm diameter. For EMG recording *Elefix* EEG Paste was used (Nihon, German branch office, Bad Homburg v.d.H.).

The *electrocardiogram* (ECG) was measured by 2 precordial Ag/AgCl electrodes (V3, V4) according to Wilson et al. (1944). A reference electrode (V3R) was placed on the corresponding right side of V3, and a ground electrode was attached to the right waist. For electrode placement compare Figure 2.4. Electrode sites were cleansed with alcohol (70% isopropanol) to reduce impedances and prepared with ECG preparation cream (Arbo®Prep, Tyco Healthcare GmbH, Neustadt, Germany). To control for possible

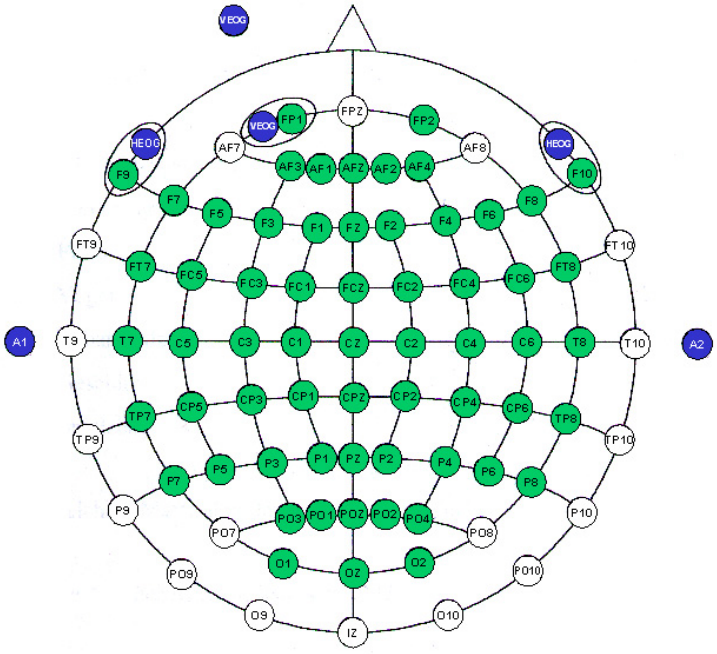


Figure 2.3.: Electrode placement according to the extended international 10-10 system

effects of respiration on heart rate (sinus arrhythmia), respiration was measured by an elastic belt around the chest which contained a piezoelectrical element.

During the recording session subjects sat in a comfortable chair in a sound-attenuated, electrically shielded room (Industrial Acoustics Company GmbH, Niederkrüchten, Germany). Stimuli were shown on a 20 inch *Sony* monitor (resolution 800×600) placed 1.1 m in front of the subject's eyes. The stimuli were presented by a computer using *ERTS* (Experimental Runtime System, Version 3.18, BeriSoft, Frankfurt, Germany).

EEG was recorded with a 62-channel EEG montage (see Figure 2.3). Two *Synamp* amplifiers (NeuroScan, Inc.) were used for EEG and EOG acquisition. All signals were sampled continuously in AC-mode at a rate of 500 Hz (gain = 1000, filters: high pass = 0.05 Hz, low pass = 70 Hz). Data acquisition was performed by an Intel PC (500 MHz) with NeuroScan software (Acquire 4.1-1, Neurosoft 1999). Furthermore, EMG, ECG, and respiration were recorded using bioamplifiers (16 bit AD interface) operated by *DASYLab 5.0* software (Data Acquisition System Laboratory, Mönchengladbach, Germany). Amplification of EMG was 0.2 mV/V, high-pass filter 5.3 Hz, low-pass filter 150 Hz. Heart beats were amplified by 0.5 mV/V and filtered high-pass at 0.53 Hz and low-pass at 30 Hz. Amplification of respiration data was set to 5 mV/V, and data were high-pass filtered at 10 Hz and low-pass filtered at 1 Hz.

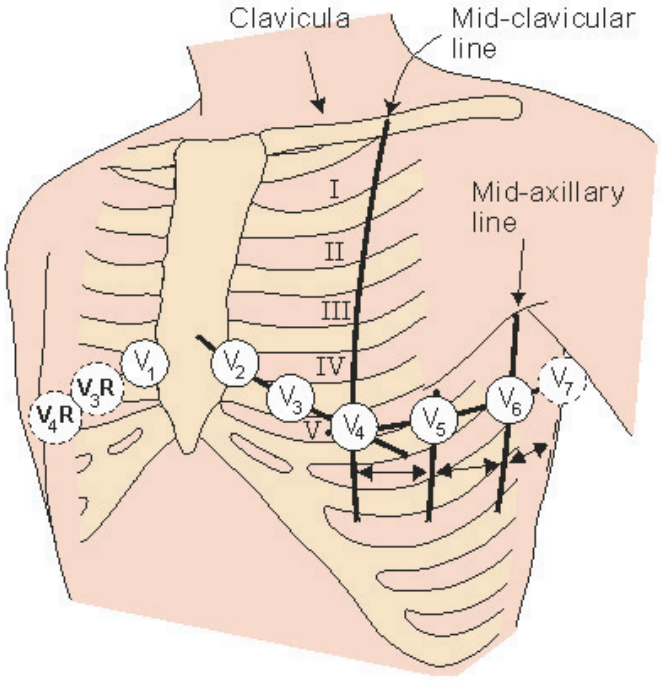


Figure 2.4.: Standard positions of the 12 precordial electrodes (Malmivuo and Plonsey, 1995: "12-Lead ECG System")

2.2.5. Analyses of Dependent Variables

Analysis of Performance and Reaction Times in the Stroop Task

All trials were excluded from further analysis in which no reaction occurred, the answer was wrong, or the reaction time was below 200 ms. Mean reaction times (RTs) were calculated for each subject and for each condition, i.e. *Task* (identify color, identify object) × *Object* (spider, bird, flower). Data analysis was performed with EXCEL 2002 (Microsoft Inc.) and JMP 5.01 (SAS Institute Inc.).

The screening for outliers (data points deviating more than 3 standard deviations from the group mean) and extreme values (highly influential data points) was done with JMP 5.01 and SPSS 11.5 (Statistical Package for the Social Sciences, SPSS Inc.).

Analysis of Heart Rates

Heart rates (HRs) were analyzed in an interval of [−500 ms; 3000 ms] around stimulus onset with Brain Vision Analyzer 1.04 (Brain Products GmbH, München, Germany). By visual inspection of the data it was assured that respiration was not stimulus-locked. In this case, the influence of respiration on heart rate (respiratory sinus arrhythmia)

is balanced by averaging. Heart rates were determined by R-wave detection and subsequent conversion into bpm (beats per minute) in intervals of 500 ms. The interval [−500 ms; 0 ms] served as baseline. HR changes were computed by subtracting the baseline heart rate from the heart rate in each time interval after stimulus presentation. Averaging these heart rates per time interval over stimuli is valid (see Graham, 1978).

One subject (male spider phobic) was excluded from the analysis of heart rate because of electrode failure. Therefore, heart rate data of 56 subjects were further analyzed.

Analysis of Event-Related Potentials

The EEG data was filtered (low pass = 30 Hz, 24 dB/oct; high pass = 0.1 Hz, 24 dB/oct; 50 Hz notch), segmented [−200 ms; 900 ms], corrected for eye blinks (Gratton, Coles, & Donchin, 1983), and screened for artifacts using Brain Vision Analyzer 1.04. The averages for each condition and for each subject were baseline corrected using the [−200 ms; 0 ms] period as a baseline and then rereferenced to the averaged linked earlobes. Data of one subject (male social phobic) was excluded from further analysis because of extreme alpha activity.

A temporal Principal Components Analysis (PCA) was performed on the data set to reduce its dimensionality and disentangle overlapping ERP components. While screening the data it already became apparent that there must be at least two positive components: one between 250 and 400 ms and one between 400 and 600 ms. Thus, the aim of the PCA was to find further evidence for the existence of these two positive components. The input to the temporal PCA consisted of all the averages for each condition and for each of the 21 electrodes F_3, F_z, F_4, FC_3, FC_z, FC_4, C_3, C_z, C_4, CP_3, CP_z, CP_4, P_3, P_z, P_4, PO_3, PO_z, PO_4, O_1, O_z, and O_2 for each subject. Time condense factor was five, i.e. only every fifth data point was included in the analysis to reduce the amount of data and therefore processing time. The PCA was calculated by analyzing covariances among time points for all conditions and subjects. To find a factor solution a VARIMAX rotation was used. First, the factor analysis was performed with eigenvalue 1 as limit, then the number of factors was limited to six as a compromise between taking all relevant factors into account and keeping complexity manageable.

The six factors identified are depicted in Figure 2.5. Factor 1 accounted for 61.5% of total variance, factor 2 for 14.5%, factor 3 for 5.7%, factor 4 for 3.6%, factor 5 for 3.3%, and factor 6 for 1.8%. Of importance are factors 2 and 5 which can be interpreted

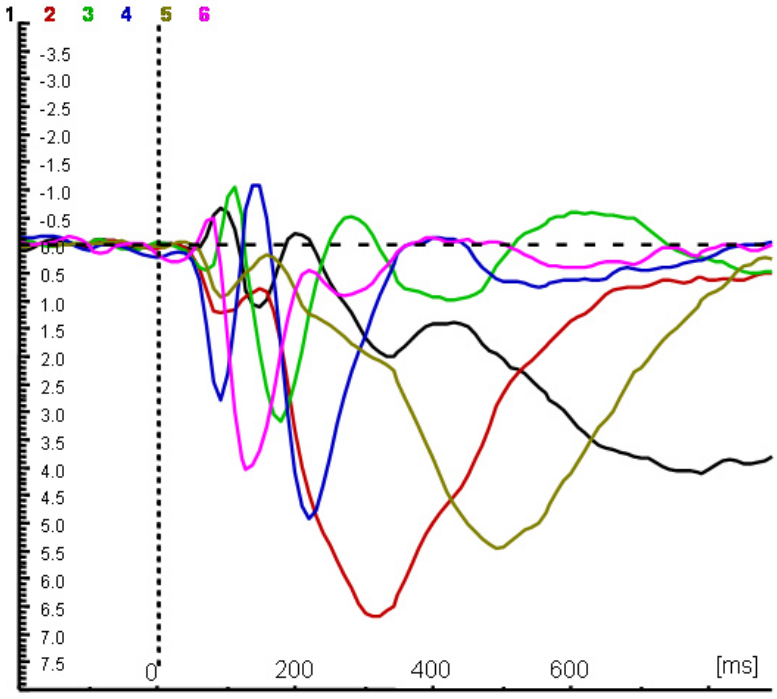


Figure 2.5.: Results of Principal Components Analysis (PCA)

Figure 2.6.: Mean component values over subjects for factors 2 (left) and 5 (right)

as a positive component between 200–400 ms (P3) and a second positive component between 400–600 ms (P4). Spatial distributions of these two factors are depicted in Figure 2.6. The posterior spatial distribution of these two components fits very well with the interpretation as P3 and P4 components. Factor 1 (a slow wave) and factors 3, 4, and 6 are of no relevance for the further analysis of the study and are therefore not further elaborated in this context.

Thus, the PCA confirmed the existence of multiple late positive components: P3 and P4. For further analysis, peaks were detected semiautomatically with P_z as a reference channel. Peak detection was performed for P3 in the time interval [250 ms; 400 ms] and for P4 in the interval [400 ms; 600 ms]. Mean P3 and P4 amplitudes were exported for leads F_3, F_z, F_4, C_3, C_z, C_4, P_3, P_z, P_4, O_1, O_z, and O_2.

In addition to P3 and P4 amplitude, a late frontal component was analyzed. Therefore, mean amplitudes in the time interval of [500 ms; 700 ms] were exported for electrodes F_3, F_z, and F_4.

Further statistical analysis and data screening for extreme values and outliers was performed with JMP 5.01 and SPSS 11.5. As for heart rate and reaction time analyses, data values were classified as outliers and excluded from further analysis when they deviated 3 or more standard deviations from the group mean. Apart from the subject excluded because of severe alpha activity as mentioned above, no further subjects had to be excluded as outliers. Thus, the data of 56 subjects was included in the statistical analysis.

2.3. Results

Preconditions for ANOVAs are: *normal distributions*, *homogeneity of variances*, and specifically for repeated measures designs *sphericity*. With respect to non-normality the F statistic is robust: the effect on type I error rate of even strongly kurtotic or skewed distributions is negligible, even for quite small n (Stevens, 1996, 1999). Concerning the second assumption, homogeneity of variances, the F statistic is robust for unequal variances if group sizes are equal or approximately equal (ratio largest/smallest group ≤ 1.5; Stevens, 1996, 1999). Data screening showed in general no severe violations of the preconditions of normal distributions and homogeneity of variances, and group sizes were approximately equal, which makes the F statistic robust for small inhomogeneities. To correct for violations of sphericity, Greenhouse-Geisser (ε) corrections were used (Greenhouse & Geisser, 1958).

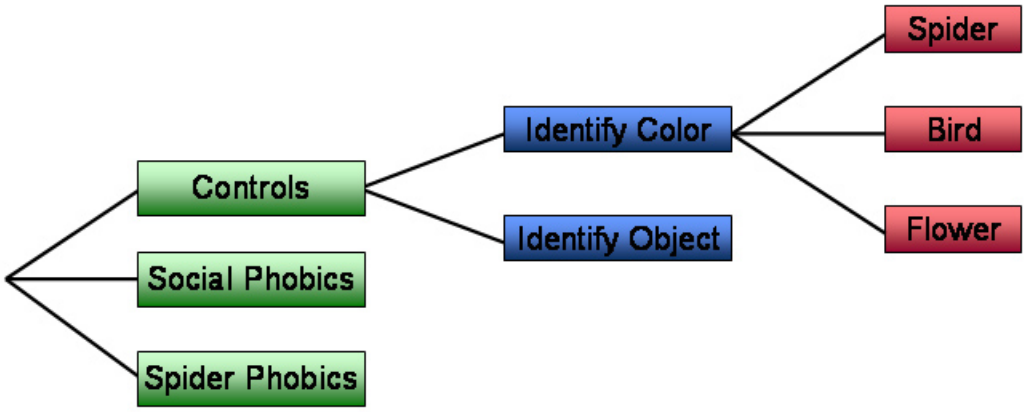


Figure 2.7.: ANOVA design for the analysis of reaction times

2.3.1. Performance and Reaction Times in the Stroop Task

There was neither a significant difference between groups in missing responses (Kruskal-Wallis Test: $\chi^2_{df=2} = 4.81$; $p = 0.09$), nor in wrong responses (Kruskal-Wallis Test: $\chi^2_{df=2} = 4.3$; $p = 0.12$), or in total mistakes (missings & errors; Kruskal-Wallis Test: $\chi^2_{df=2} = 0.52$; $p = 0.77$). Overall, subjects failed to react in 2.26% of all trials, and incorrect responses were observed in 1.66% of all trials.

To examine the influence of task and picture type on reaction times, a $3 \times 2 \times 3$ ANOVA with between factor *Group* and repeated measures factors *Task* (identify color, identify object) and *Object* (spider, flower, bird) was performed. Figure 2.7 depicts the ANOVA design and Figure 2.8 the mean reaction times and standard deviations for each group in the different conditions.

Analysis revealed main effects of Task ($F_{(1,54)} = 103.97$; $p = 0.0005$) and of Object ($F_{(2,108)} = 4.72$; $p = 0.01$; $\varepsilon = 0.94$), as well as significant interactions of Group $\times$ Task ($F_{(2,54)} = 4.09$; $p = 0.02$), Group $\times$ Object ($F_{(4,108)} = 2.98$; $p = 0.025$; $\varepsilon = 0.94$), and Task $\times$ Object ($F_{(2,108)} = 7.4$; $p = 0.001$; $\varepsilon = 0.99$). The two-way interaction Group $\times$ Task $\times$ Object was also significant ($F_{(2,108)} = 2.95$; $p = 0.02$; $\varepsilon = 0.99$).

The main effect of Task is clearly visible in Figure 2.8: reaction times were significantly faster when subjects had to identify the color of a stimulus than when the object itself had to be classified. Subsequent ANOVAs calculated separately for each group showed that this effect was highly significant in all groups (all p-values ≤ 0.0005) despite the significant interaction of Group $\times$ Task. A further analysis of the interaction Group

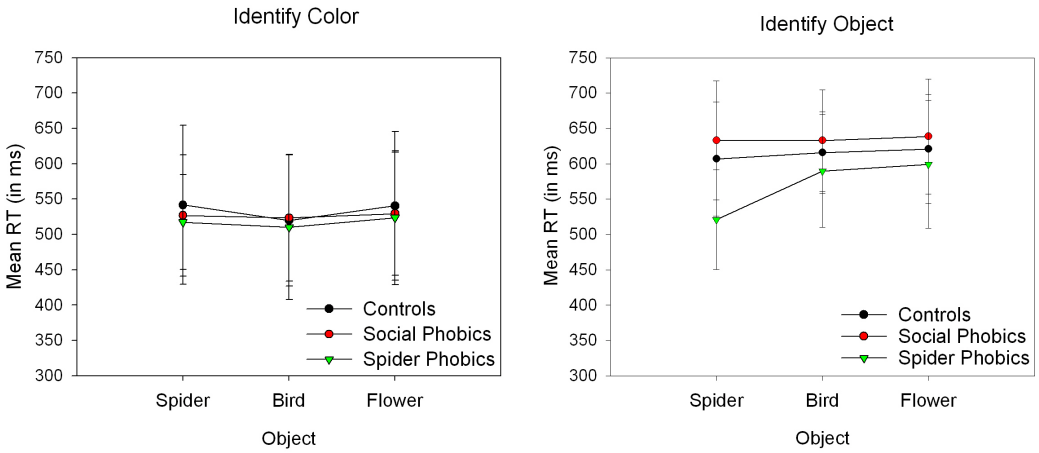


Figure 2.8.: Mean reaction times and SDs for the color (left) and object (right) identification of spiders, flowers and birds for each group

× Task revealed that there were no differences in reaction times between groups in the color identification task, but there were significant group differences in the object identification task ($F_{(2,54)} = 4.85$; $p = 0.01$). Tukey HSD post hoc tests showed that spider phobics responded significantly faster than social phobics in the object identification task ($p = 0.01$), while the comparison 'spider phobics–controls' failed to be significant ($p = 0.1$) but can be interpreted as a tendency.

The significant main effect of Object cannot be interpreted without considering the significant interaction Group × Object. Subsequent ANOVAs were calculated separately for each group and revealed no difference for controls and social phobics in RTs between spiders, birds and flowers. However, for spider phobics there was a main effect of Object ($F_{(2,36)} = 6.78$; $p = 0.01$; $\varepsilon = 0.59$). Simple contrasts showed a significant difference for the comparisons 'spider–bird' ($p = 0.04$) and 'spider–flower' ($p = 0.009$).

However, this effect also has to be interpreted in the light of the significant interactions Task × Object and Group × Task × Object. Again, subsequent ANOVAs calculated separately for each group revealed no significant interaction of Task × Object for controls and social phobics. However, spider phobics showed a significant interaction of Task × Object ($F_{(2,36)} = 11.7$; $p = 0.0005$; $\varepsilon = 0.91$) . While they did not show any significant difference in RT for identifying the color of spiders, birds and flowers, they showed a significant RT difference in the object identification condition ($F_{(2,36)} = 12.26$; $p = 0.0005$; $\varepsilon = 0.77$). Simple contrasts showed that both comparisons 'spider–bird' ($p = 0.001$) and 'spider–flower' ($p = 0.002$) were significant, i.e. they identified spiders

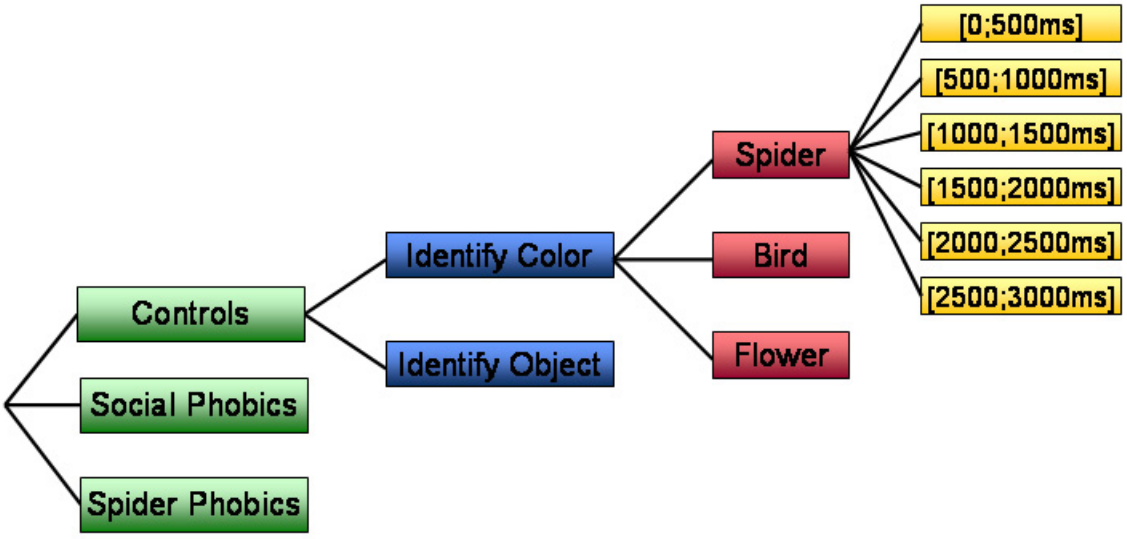


Figure 2.9.: ANOVA design for the analysis of heart rate changes in response to stimulus presentation

significantly faster than birds or flowers.

Finally, groups were directly compared on their RTs in response to spiders. Groups did not differ in their RTs for identifying the color of spiders. However, spider phobics were significantly faster in their identification of spiders than controls ($p = 0.001$) and social phobics ($p = 0.0005$).

2.3.2. Heart Rates

There were no differences in baseline heart rates [−500 ms; 0 ms] between groups (one-way ANOVA: $F_{(2,53)} = 0.23$; $p = 0.8$).

The heart rate data in the time interval [0 ms;3000 ms] was submitted to a $3 \times 2 \times 3 \times 6$ ANOVA with between factor *Group* and repeated measures factors *Task* (identify color, identify object), *Object* (spider, bird, flower), and *Time* (time intervals t_1 =[0 ms; 500 ms], t_2 =[500 ms; 1000 ms], t_3 =[1000 ms; 1500 ms], t_4 =[1500 ms; 2000 ms], t_5 =[2000 ms; 2500 ms], t_6 =[2500 ms; 3000 ms]). The ANOVA design is depicted in Figure 2.9, and Figure 2.10 shows the time course of heart rate changes per group and for each condition in beats per minute (bpm).

Heart rates showed the typical pattern of an orienting response, i.e. a brief deceleration and a slow return to baseline. This was confirmed by the main effect of Time ($F_{(5,265)} = 35.2$; $p = 0.0005$; $\varepsilon = 0.34$), but no further significant effects were found. In particular, the relevant interactions Group × Object × Time ($F_{(20,530)} = 0.73$; $p = 0.8$; $\varepsilon = 0.22$)

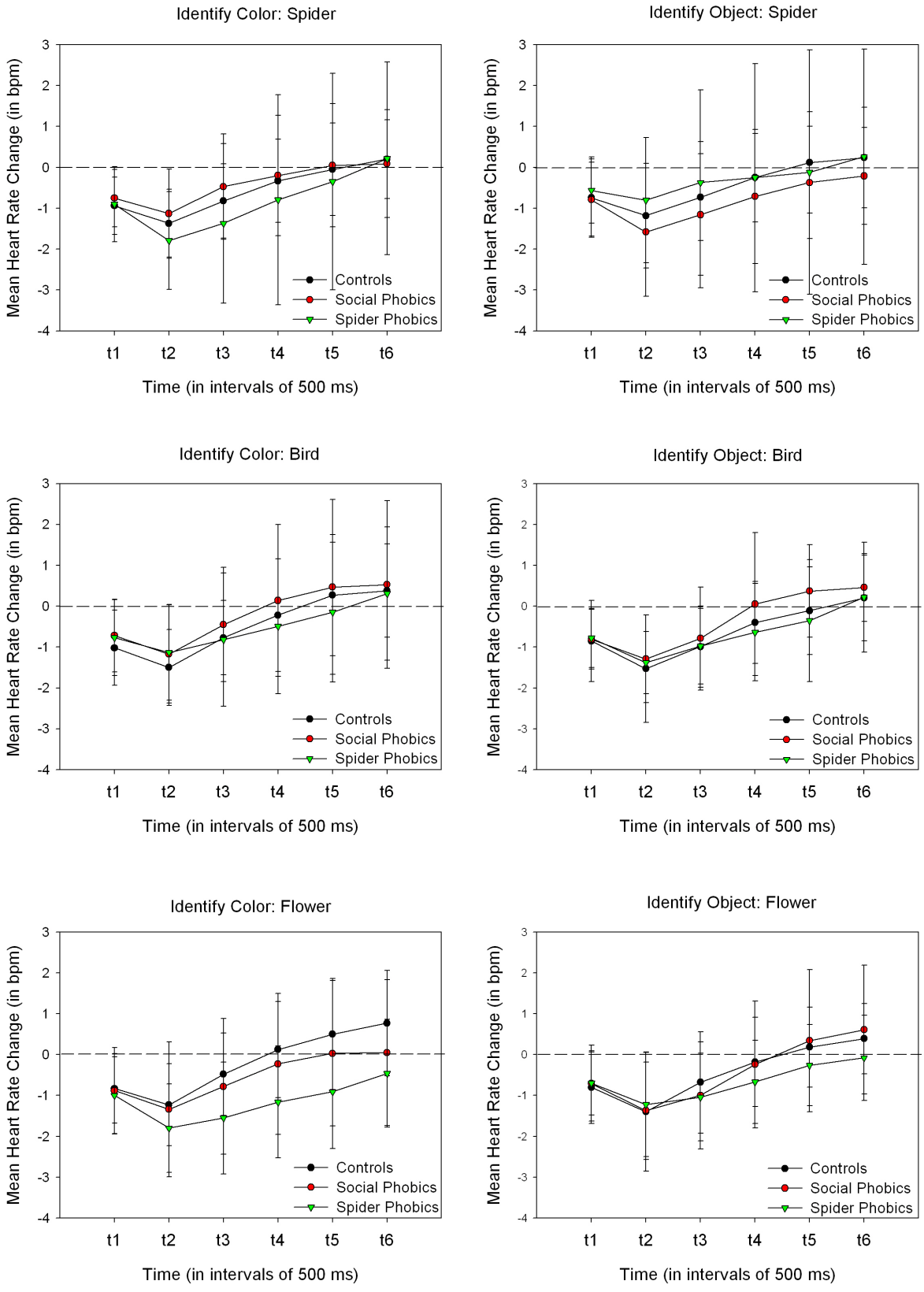


Figure 2.10.: Mean heart rate changes (in bpm) and SDs in response to spiders (top row), birds (center row), and flowers (bottom row) in the color (left) and object (right) identification task

and Group × Task × Object × Time ($F_{(20,530)} = 0.78$; $p = 0.59$; $\varepsilon = 0.31$) failed to be significant.

However, as can be seen in Figure 2.10, the variances in the spider phobic group were higher than those of the two other groups when identifying the color of a spider or the spider itself. This observation was substantiated by the results of the Levene test for unequal variances. For the identify color condition the Levene test showed significant differences in variances for t_4 ($F_{(2,53)} = 4.93$; $p = 0.01$) and t_5 ($F_{(2,53)} = 3.62$; $p = 0.03$) and for the identify object condition for t_5 ($F_{(2,53)} = 3.04$; $p = 0.056$) and t_6 ($F_{(2,53)} = 3.29$; $p = 0.045$). Therefore, the precondition of equal variances for calculating an ANOVA was violated, making the heart rate data difficult to interpret. However, since the group sizes were almost equal, the F statistic is robust for unequal variances (Stevens, 1996, 1999).

In a further analysis the factor *Gender* (male, female) was included in the above ANOVA design. Besides a main effect of Time ($F_{(5,250)} = 36.27$; $p = 0.0005$; $\varepsilon = 0.32$), there were various significant interactions with Group and Gender. The interactions Group × Gender ($F_{(2,50)} = 3.63$; $p = 0.03$), Object × Group × Gender ($F_{(4,100)} = 2.47$; $p = 0.07$; $\varepsilon = 0.76$), Task × Object × Group × Gender ($F_{(4,100)} = 3.56$; $p = 0.01$; $\varepsilon = 0.98$), Object × Time × Group × Gender ($F_{(20,500)} = 2.24$; $p = 0.06$; $\varepsilon = 0.24$), and even the four-way interaction Task × Object × Time × Group × Gender ($F_{(20,500)} = 2.03$; $p = 0.06$; $\varepsilon = 0.31$) were significant or almost significant. These results hint at a strong influence of gender on results, although again the Levene tests indicated that variances were unequal in some time intervals between groups.

Therefore, subsequent ANOVAs were calculated separately for each Object. The analysis of heart rates in response to spiders yielded a significant interaction of Time × Group × Gender ($F_{(10,250)} = 3.46$; $p = 0.02$; $\varepsilon = 0.32$). While male spider phobic subjects showed a brief deceleration of heart rate and then an acceleration when viewing spiders, female subjects showed a pronounced deceleration (see Figure 2.11). Such a difference between men and women was not present in the other groups. Furthermore, spider phobic subjects did not show such a gender difference for flowers or birds.

Thus, heart rates of spider phobics showed a specific response to their phobic object, but only when the factor Gender was included in the analysis. While a defense reaction was observed in male spider phobics, a pronounced orienting reaction was found in female spider phobics. Still, variances in the phobic group for spiders were very high, and these results have to be interpreted with caution.

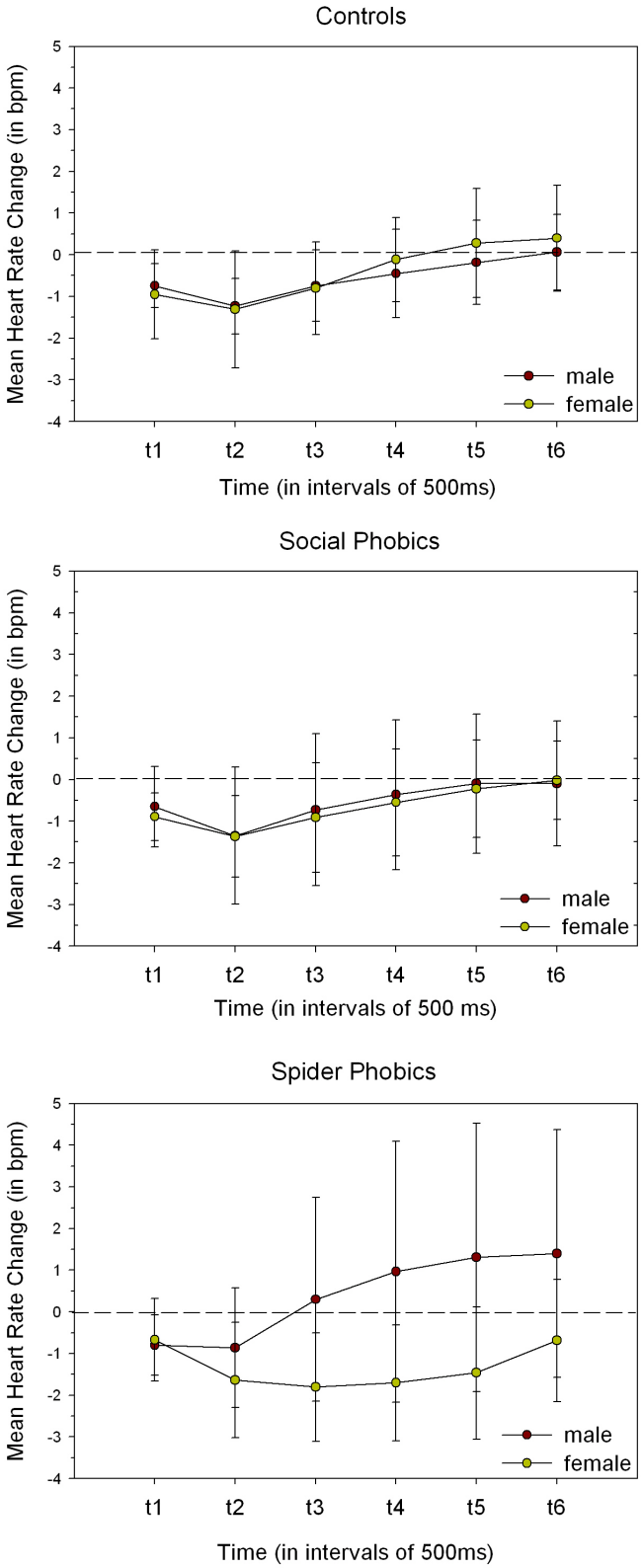


Figure 2.11.: Mean heart rate changes (in bpm) and SDs in response to spiders for male and female controls (top row), social phobics (center row), and spider phobics (bottom row)

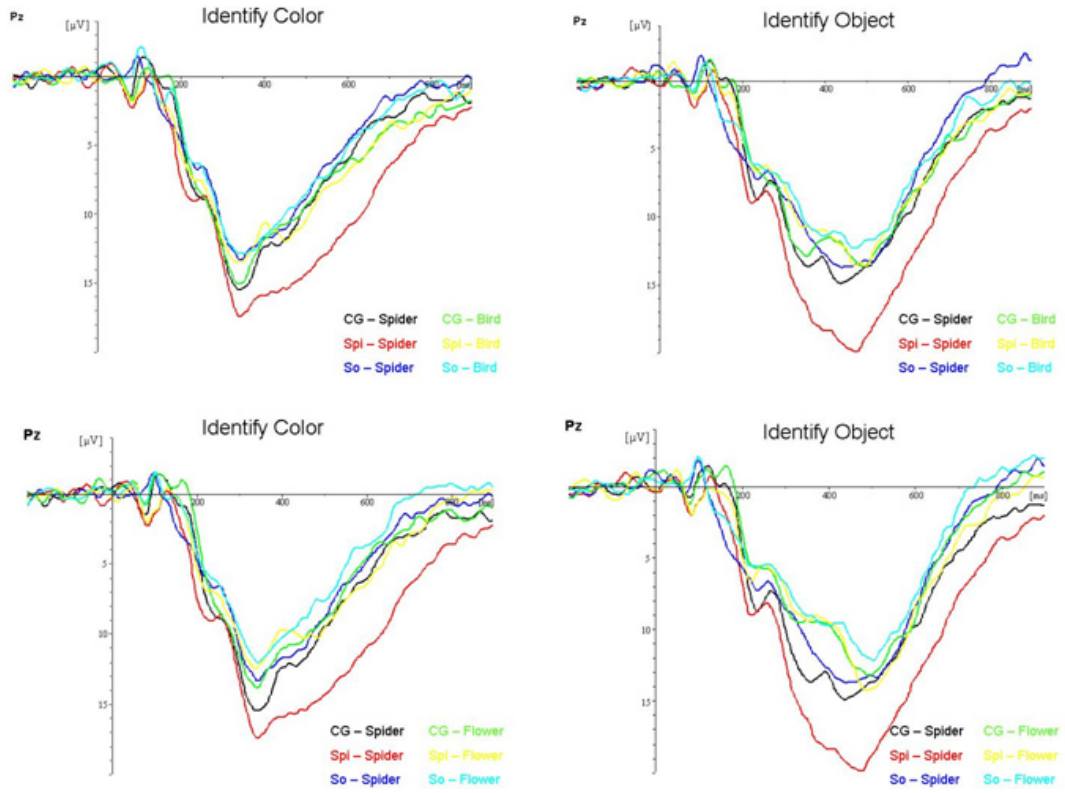


Figure 2.12.: Event-related potentials on electrode P_z for both color (left) and object (right) identification for each group. Top row: ERPs for spiders and birds; bottom row: ERPs for spiders and flowers

2.3.3. Event-Related Potentials

Event-related potentials on electrode P_z in response to spiders, birds and flowers are depicted for each group and for both tasks in Figure 2.12.

For the analysis of P3 and P4 amplitude a $3 \times 2 \times 3 \times 3 \times 4$ ANOVA with between factor *Group* and repeated measures factors *Task* (identify color, identify object), *Object* (spider, bird, flower), *Laterality* (left, central, right), and *Row* (Frontal: F, Central: C, Parietal: P, Occipital: O) was conducted. The design of the ANOVA is depicted in Figure 2.13.

P3 Amplitude Analysis revealed main effects of Row ($F_{(3,159)} = 106.85$; $p = 0.0005$; $\varepsilon = 0.46$) and of Laterality ($F_{(2,106)} = 33.29$; $p = 0.0005$; $\varepsilon = 0.89$) as well as a significant interaction of Row × Laterality ($F_{(6,318)} = 29.12$; $p = 0.0005$; $\varepsilon = 0.53$). As can be seen in Figure 2.14, P3 amplitude was maximal over parietal sites. Therefore,

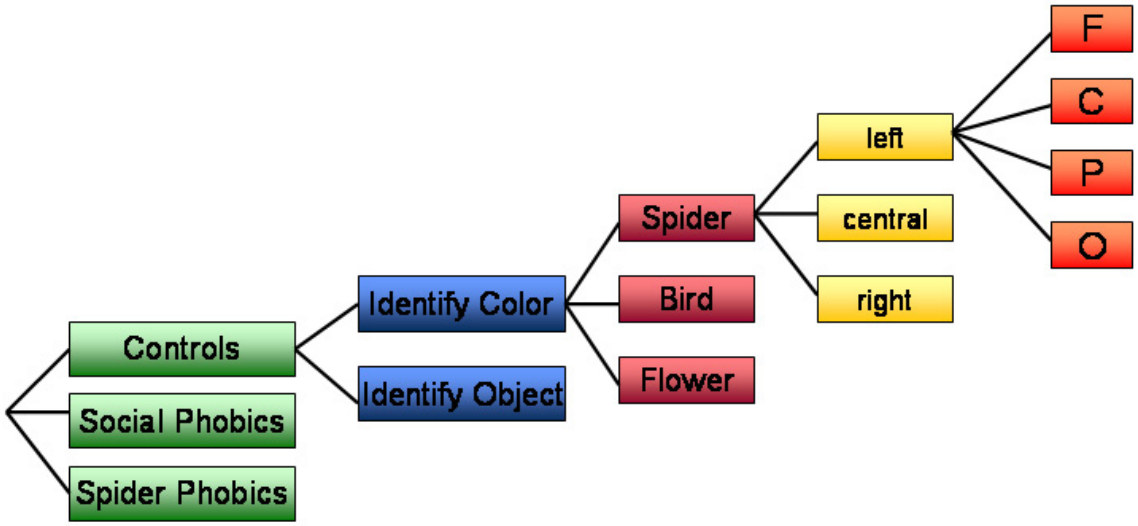


Figure 2.13.: ANOVA design for the analysis of P3 and P4 amplitudes

the factor Row was excluded from all further analyses, and all following analyses were based only on parietal sites.

A second ANOVA based only on data of P_3, P_z and P_4 was calculated. Main effects of Laterality ($F_{(2,106)} = 19.54$; $p = 0.0005$; $\varepsilon = 0.82$), of Task ($F_{(1,53)} = 12.33$; $p = 0.001$), and of Object ($F_{(6,106)} = 32.77$; $p = 0.0005$; $\varepsilon = 0.97$) were found. Furthermore, the interactions Object × Laterality ($F_{(4,212)} = 15.27$; $p = 0.0005$; $\varepsilon = 0.79$), Task × Laterality ($F_{(2,106)} = 10.82$; $p = 0.0005$; $\varepsilon = 0.8$), Group × Object ($F_{(4,106)} = 8.84$; $p = 0.0005$; $\varepsilon = 0.97$), and Task × Object ($F_{(2,106)} = 5.86$; $p = 0.004$; $\varepsilon = 1$) were highly significant.

A more detailed analysis of the main effect of Laterality (compare Figure 2.14) with simple contrasts showed that P3 amplitudes were significantly larger over right vs. central sites ($p = 0.01$) and over the right vs. the left hemisphere ($p = 0.0005$). However, this effect was dependent on Task, as the significant interaction Task × Laterality showed. The right hemisphere advantage was highly significant in the object identification task (comparison 'central–right': $p = 0.0005$; 'central–left': $p = 0.0005$). However, in the color identification task amplitudes were not significantly larger over right as compared to central sites, while the comparison right vs. left hemisphere was also significant ($p = 0.0005$).

P3 amplitudes were significantly larger for color than for object identification (main effect of Task). However, this effect has to be interpreted together with the significant interaction of Task × Object which indicated that P3 amplitudes differed in response to spiders, birds and flowers depending on task. Subsequent ANOVAs calculated sepa-

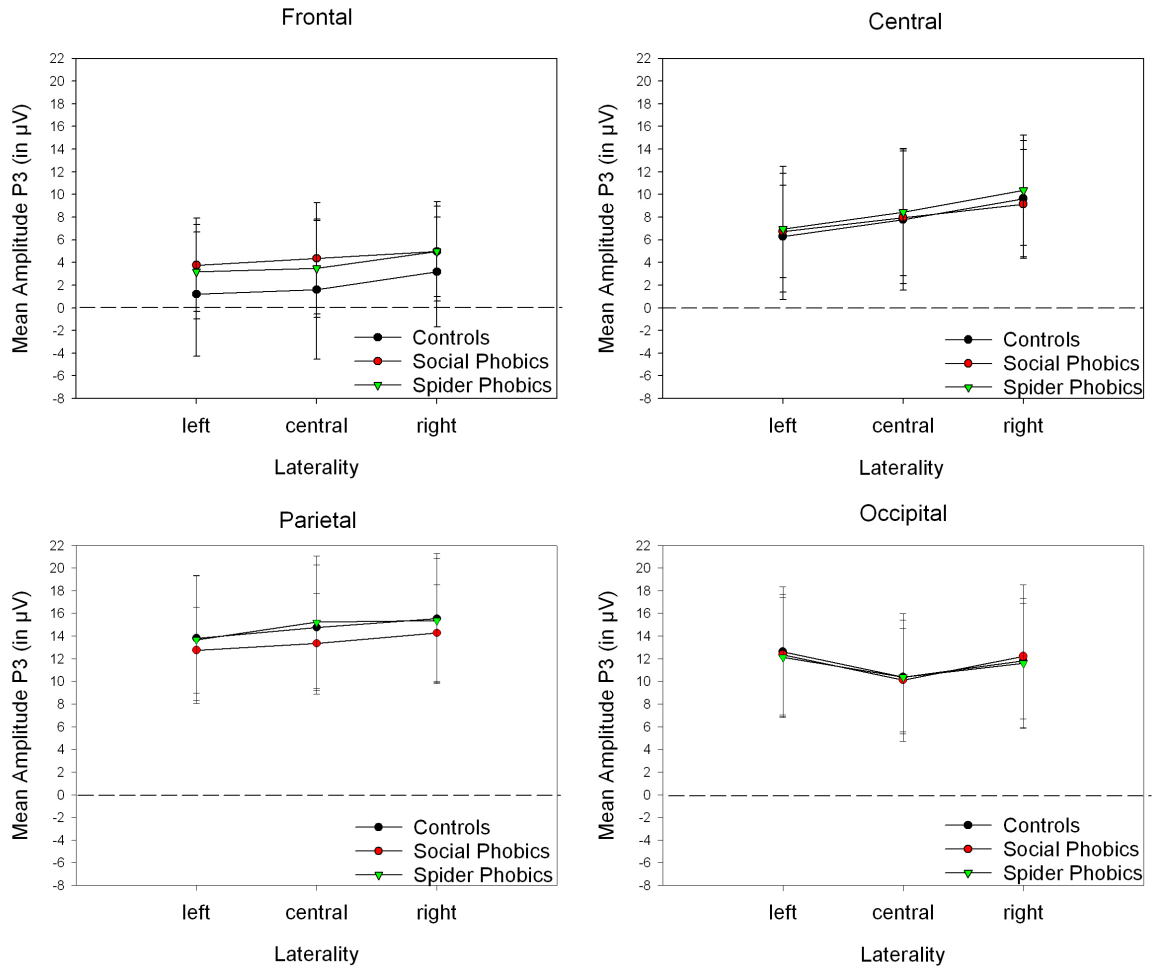


Figure 2.14.: Mean P3 amplitudes and SDs for frontal (top left), central (top right), parietal (bottom left), and occipital (bottom right) sites for each group

rately for each task indicated that the main effect of Object was present in both tasks but the difference in P3 amplitude due to task, i.e. the smaller P3 amplitude for identify object than identify color, was reduced for spiders compared to birds and flowers. In other words, P3 amplitudes in response to spiders were more similar for both tasks than P3 amplitudes in response to birds and flowers.

The main effect of Object and the significant interaction of Group × Object were analyzed by subsequent ANOVAs calculated separately for each group. These analyses indicated that the main effect of Object was mainly due to spider phobics: they showed a highly significant main effect of Object ($F_{(2,36)} = 37.71$; $p = 0.0005$; $\varepsilon = 0.85$), whereas controls showed a slightly less significant main effect of Object ($F_{(2,36)} = 6.83$; $p = 0.003$; $\varepsilon = 1$), and social phobics did not show such an effect ($F_{(2,34)} = 1.93$; $p = 0.17$; $\varepsilon = 0.86$). Simple contrasts revealed that spider phobics showed significantly

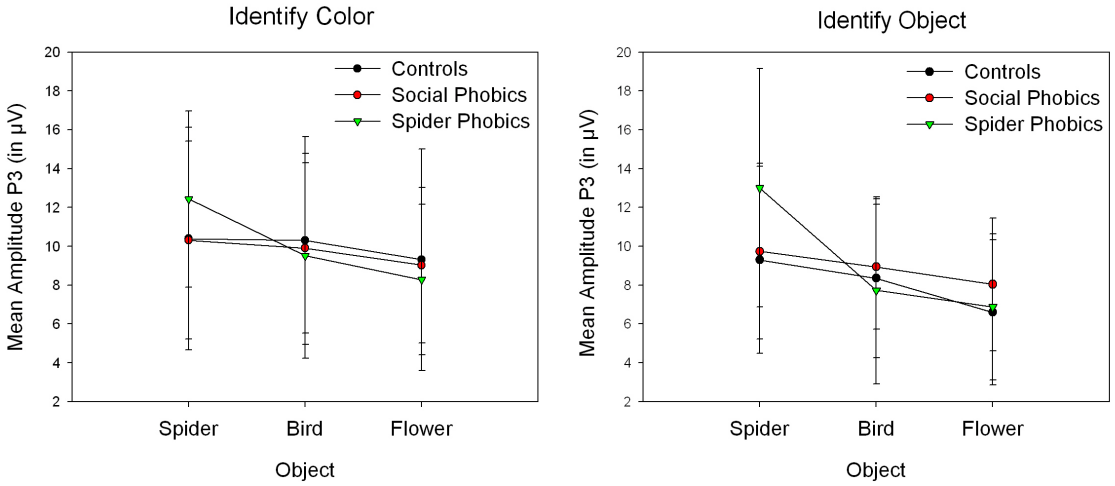


Figure 2.15.: Mean P3 amplitudes and SDs for the color (left) and object (right) identification of spiders, birds and flowers for each group

larger P3 amplitudes when viewing spiders compared to birds ($F_{(1,18)} = 48.64$; $p = 0.0005$) and compared to flowers ($F_{(1,18)} = 46.52$; $p = 0.0005$). For controls only the contrast 'spider–flower' was significant ($F_{(1,18)} = 13.63$; $p = 0.002$). Although it seemed that social phobics and controls showed at least a trend towards larger amplitudes for spiders than for birds and particularly for flowers (see Figure 2.15), other effects than the contrast 'spider–flower' for controls did not reach significance.

Furthermore, groups were directly compared in their amplitude in response to spiders. The results of subsequent ANOVAs with pairwise comparisons showed that spider phobics showed significantly larger P3 amplitudes in response to spiders than social phobics ($p = 0.04$), while the difference between spider phobics and controls failed to be significant ($p = 0.14$), but still can be interpreted as a tendency. In fact, when object and color identification were analyzed separately, spider phobics showed significantly larger P3 amplitudes than controls ($p = 0.05$) and social phobics ($p = 0.02$) in the object identification task.

Next, the significant interaction of Object × Laterality was analyzed in more detail (compare Figure 2.16). Subsequent ANOVAs were calculated separately for each object. Simple contrasts indicated that birds and flowers led to significantly larger P3 amplitudes over the right vs. the left hemisphere (Birds: $p = 0.0005$; Flowers: $p = 0.0005$) and over right vs. central sites (Birds: $p = 0.02$; Flowers: $p = 0.0005$). P3 amplitudes in response to spiders were also significantly larger over the right compared to the left hemisphere ($p = 0.001$); however, there was no significant difference in P3 amplitude between central sites and the right hemisphere.

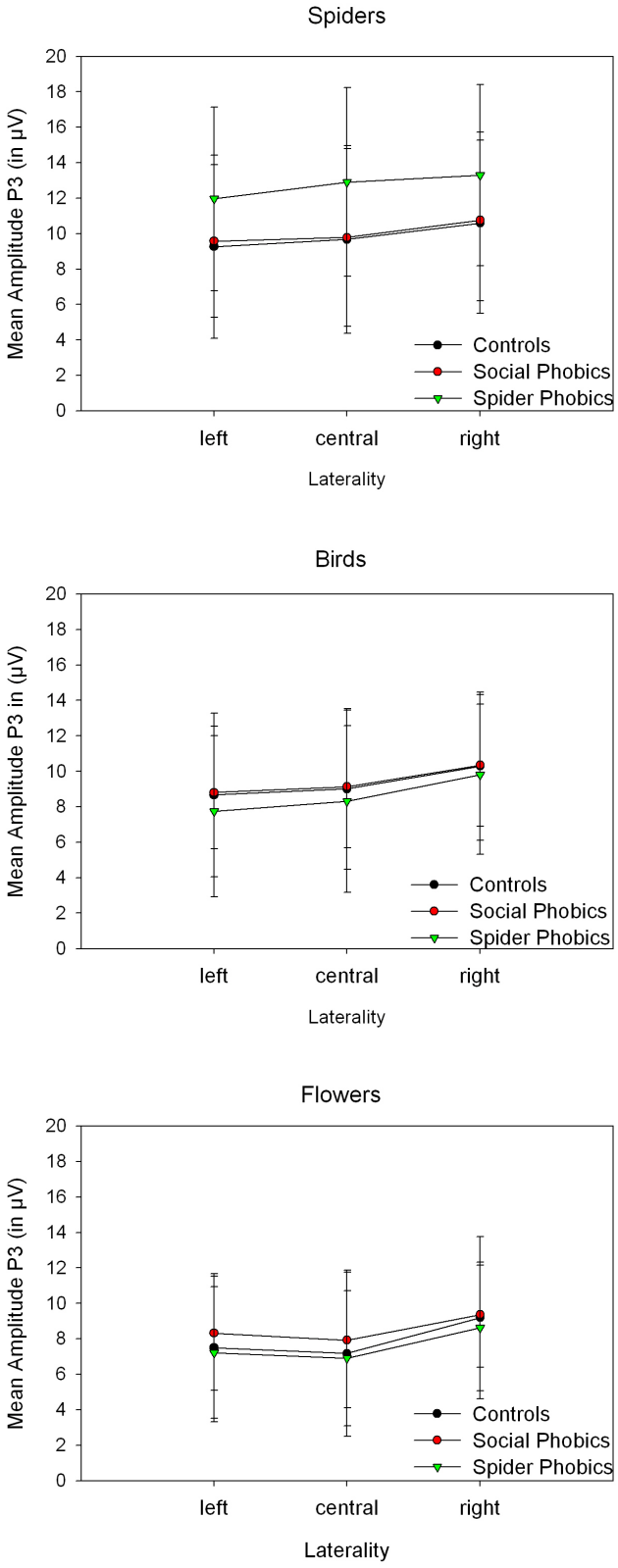


Figure 2.16.: Mean P3 amplitudes and SDs for spiders (upper row), birds (center row), and flowers (bottom row) depending on Laterality for each group

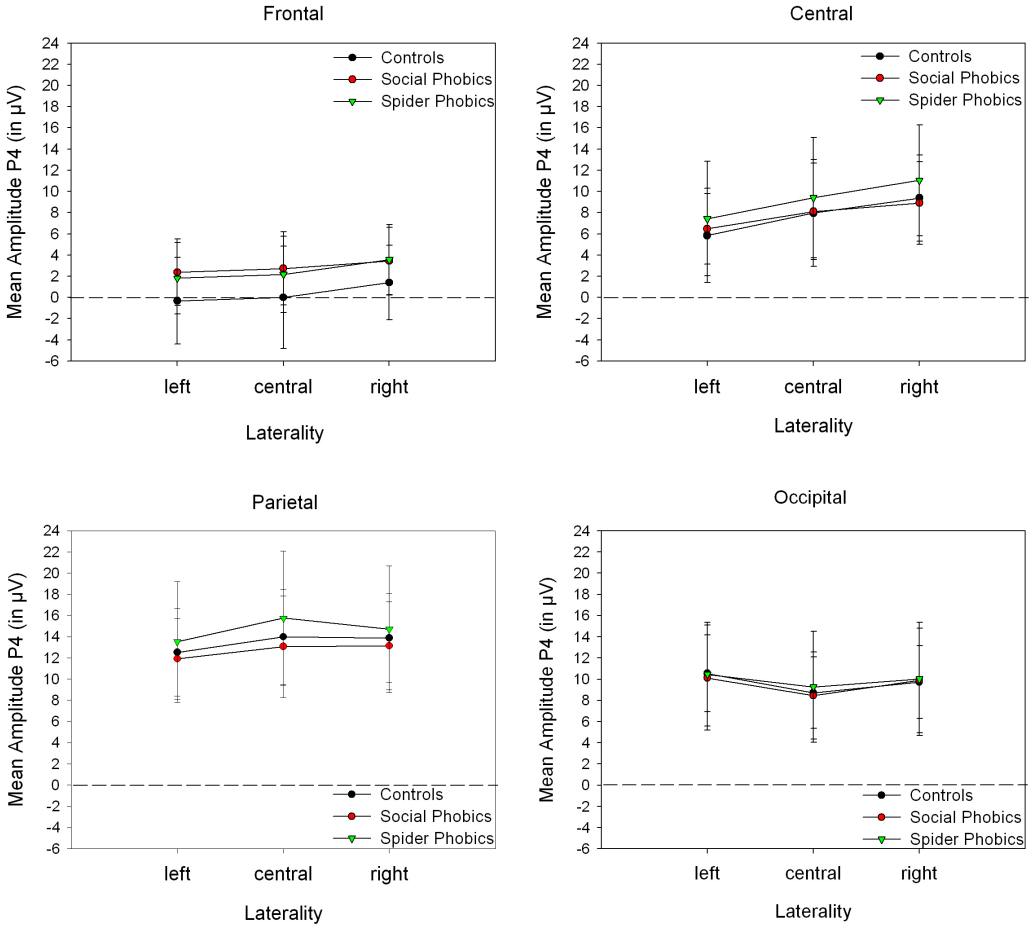


Figure 2.17.: Mean P4 amplitudes and SDs for frontal (top left), central (top right), parietal (bottom left), and occipital (bottom right) sites depending on Laterality for each group

Finally, correlations of SPQ values and mean P3 amplitude in response to spiders independent of task and laterality were calculated. For spider phobics a significant correlation of $r = .47$ ($p = 0.04$) was found, which indicated that higher SPQ values resulted in larger P3 amplitudes for spiders.

P4 Amplitude P4 amplitude was analyzed analogously to P3 amplitude, and the analysis yielded similar results. Compare Figure 2.13 for the ANOVA design.

There were main effects of Row ($F_{(3,159)} = 151.75$; $p = 0.0005$; $\varepsilon = 0.52$) and of Laterality ($F_{(2,106)} = 27.85$; $p = 0.0005$; $\varepsilon = 0.95$), and a significant interaction of Row × Laterality ($F_{(6,318)} = 36.68$; $p = 0.0005$; $\varepsilon = 0.62$). As can be seen in Figure 2.17, P4 amplitude was maximal over parietal sites, and therefore all further analysis will concentrate on this region. The factor Row was excluded from further analysis.

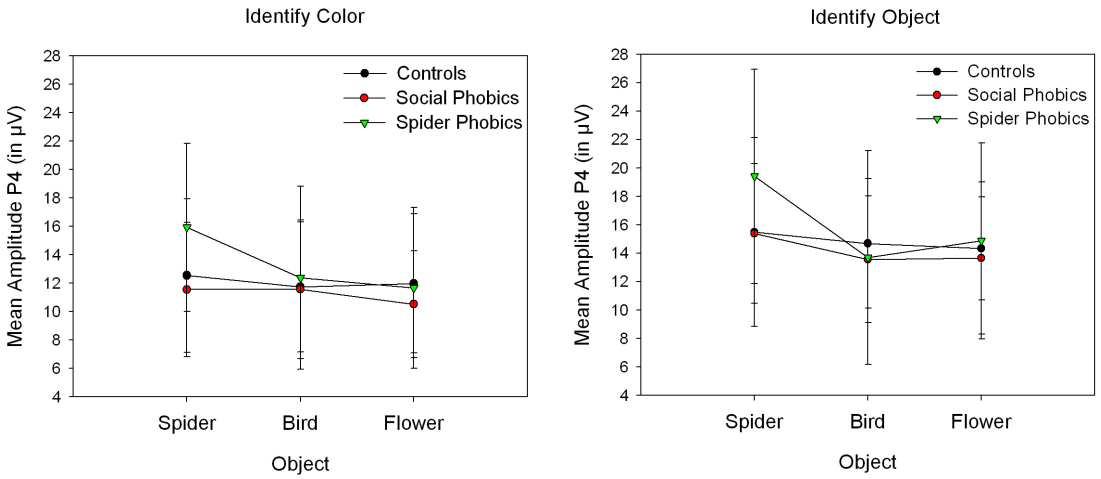


Figure 2.18.: Mean values and SDs of P4 amplitudes for the color (left) and object (right) identification of spiders, birds and flowers for each group

The reduced ANOVA yielded the following results: there were main effects of Laterality ($F_{(2,106)} = 20.66$; $p = 0.0005$; $\varepsilon = 0.95$), of Task ($F_{(1,53)} = 41.09$; $p = 0.0005$), and of Object ($F_{(2,106)} = 17.22$; $p = 0.0005$; $\varepsilon = 0.9$), and significant interactions of Group × Object ($F_{(4,106)} = 5.31$; $p = 0.001$; $\varepsilon = 0.9$), and Object × Laterality ($F_{(4,212)} = 18.98$; $p = 0.0005$; $\varepsilon = 0.83$). The mean P4 amplitudes in response to each object and for both tasks are shown in Figure 2.18.

The main effect of Laterality was further analyzed using simple contrasts. They revealed that P4 amplitude was significantly larger over the right compared to the left hemisphere ($F_{(1,53)} = 18.66$; $p = 0.0005$).

The main effect of Task ($F_{(1,53)} = 41.09$; $p = 0.0005$) indicated that in all groups object identification led to larger P4 amplitudes than color identification.

The main effect of Object should be interpreted together with the significant interaction of Group × Object. Subsequent ANOVAs calculated separately for each group revealed that this main effect of Object was only present in spider phobics ($F_{(2,36)} = 15.19$; $p = 0.0005$; $\varepsilon = 0.79$), but not in social phobics and controls. Spider phobics showed significantly larger P4 amplitudes for spiders compared to flowers ($p = 0.001$) and compared to birds ($p = 0.0005$). However, in social phobics the main effect of Object only narrowly failed to be significant ($F_{(2,34)} = 3.1$; $p = 0.059$; $\varepsilon = 0.98$). This tendency was mainly due to the difference in P4 amplitude between spiders and flowers ($p = 0.03$).

Furthermore, groups were directly compared in their amplitude in response to spiders. The results of subsequent ANOVAs with pairwise comparisons showed that spider

phobics showed significantly larger P4 amplitudes in response to spiders than social phobics ($p = 0.03$) and controls ($p = 0.05$).

The interaction Object × Laterality is depicted in Figure 2.19. Subsequent ANOVAs were calculated separately for each Object. Simple contrasts showed that there were generally larger P4 amplitudes over the right compared to the left hemisphere (birds: $p = 0.0005$; flowers: $p = 0.001$; spiders: $p = 0.007$). The comparisons 'central–right' were not significant for flowers and birds but for spiders ($p = 0.001$). Thus, while birds and flowers led to equally large amplitudes over central sites and the right hemisphere, spiders led to larger P4 amplitudes over central sites.

Finally, correlations of SPQ values and P4 amplitudes in response to spiders independent of task and laterality were calculated. A significant correlation of SPQ with mean P4 amplitude in response to spiders was found for the spider phobic group ($r = .57$; $p = 0.01$).

Frontal Positivity A large positivity in spider phobics beginning around 500 ms post-stimulus when identifying the color of spiders is clearly visible in Figure 2.20. The mean amplitudes in the time interval [500 ms; 700 ms] were analyzed with a $3 \times 2 \times 3 \times 3$ ANOVA with between factor *Group* and repeated measures factors *Task* (identify color, identify object), *Object* (spider, bird, flower), and *Laterality* (left, central, right).

Results showed main effects of Laterality ($F_{(2,106)} = 4.82$; $p = 0.0005$; $\varepsilon = 0.97$), of Task ($F_{(1,53)} = 12.01$; $p = 0.001$), and of Object ($F_{(2,106)} = 27.85$; $p = 0.0005$; $\varepsilon = 1$). Furthermore, there were significant interactions of Object × Laterality ($F_{(4,212)} = 13.4$; $p = 0.0005$; $\varepsilon = 0.87$), of Task × Object ($F_{(2,106)} = 4.12$; $p = 0.02$; $\varepsilon = 0.95$), and of Group × Object ($F_{(4,106)} = 4.18$; $p = 0.004$; $\varepsilon = 1$).

The main effect of Laterality was further analyzed with simple contrasts, which showed a significant difference between left and right hemisphere ($p = 0.0005$) and between central sites and the right hemisphere ($p = 0.0005$). As can be seen in Figure 2.21, this pattern was similar for all objects. The significant interaction of Object × Laterality resulted from a significant difference between left and central sites for flowers ($p = 0.01$), which was not observed for birds and spiders.

The interaction Group × Object was further analyzed by subsequent ANOVAs calculated separately for each Group. They showed that the main effect of Object was present in all groups (CG: $F_{(2,36)} = 4.43$; $p = 0.03$; So: $F_{(2,34)} = 5.55$; $p = 0.009$; Spi: $F_{(2,36)} = 19.97$; $p = 0.0005$). Simple contrasts revealed that in all groups spiders led to

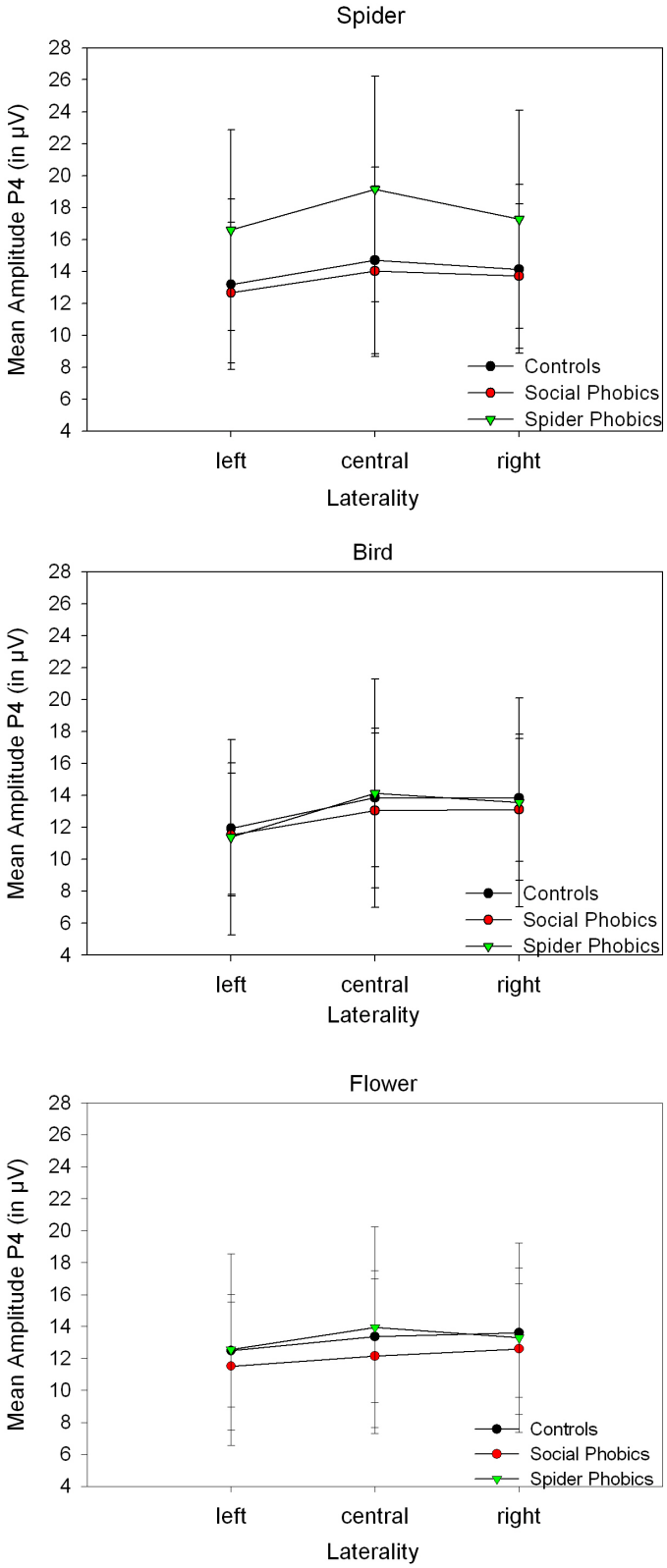


Figure 2.19.: Mean values and SDs of P4 amplitudes for spiders (top row), birds (central row), and flowers (bottom row) depending on laterality for each group

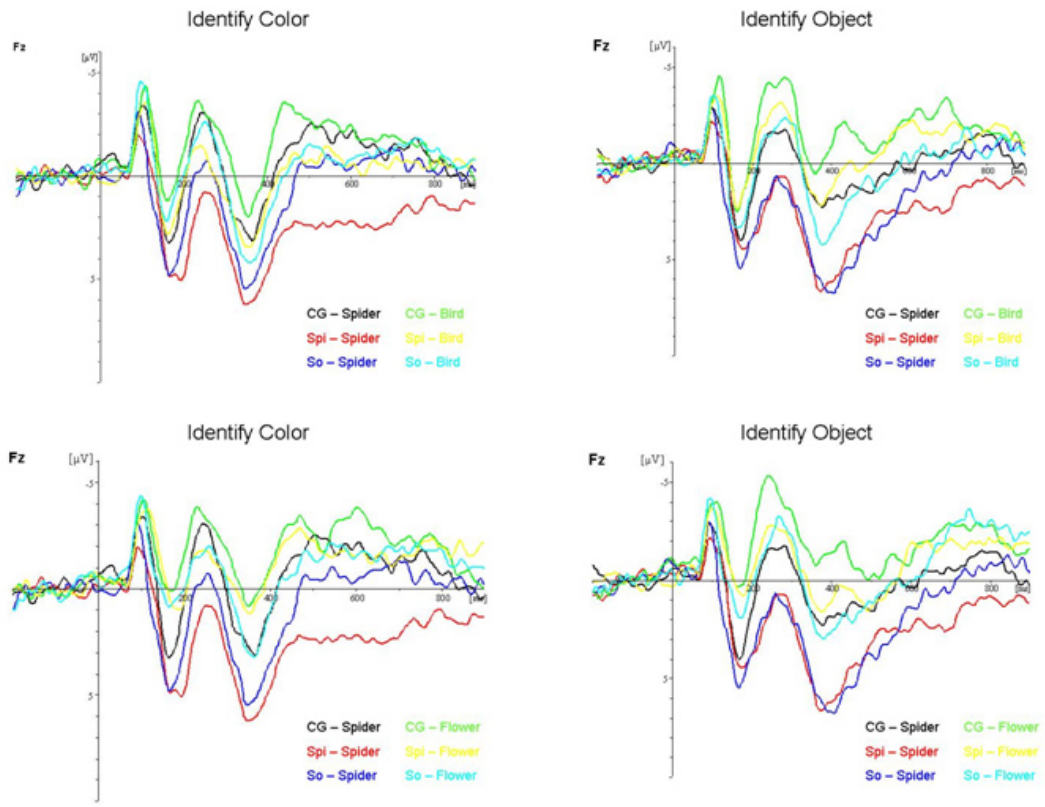


Figure 2.20.: Event-related potentials on electrode F_z for the color (left) and object identification (right) for each group. Top row: ERPs for spiders and birds; bottom row: ERPs for spiders and flowers

a significantly higher positivity than birds and flowers (comparison 'spider–bird': CG $p = 0.003$; So $p = 0.006$; Spi $p = 0.0005$; 'spider–flower': CG $p = 0.01$, So $p = 0.03$, Spi $p = 0.0005$). However, the effect was more pronounced for spider phobics, which explains the significant interaction of Group × Object. Therefore, separate ANOVAs for each object were calculated. Simple contrasts showed that spider phobics differed significantly from controls in their mean amplitudes in response to spiders ($p = 0.01$). The comparison 'spider phobics–social phobics' failed to be significant ($p = 0.12$) but can be interpreted as a tendency.

The main effect of Task and of Object as well as the significant interaction of Task × Object were further analyzed by subsequent ANOVAs calculated separately for each task. These analyses revealed that the main effect of Object was present in both tasks (identify color: $F_{(2,106)} = 16.01$; $p = 0.0005$; identify object: $F_{(2,106)} = 20.71$; $p = 0.0005$). Both times, spiders led to a significantly larger positivity compared to birds (identify color: $p = 0.001$; identify object: $p = 0.0005$) and compared to flowers

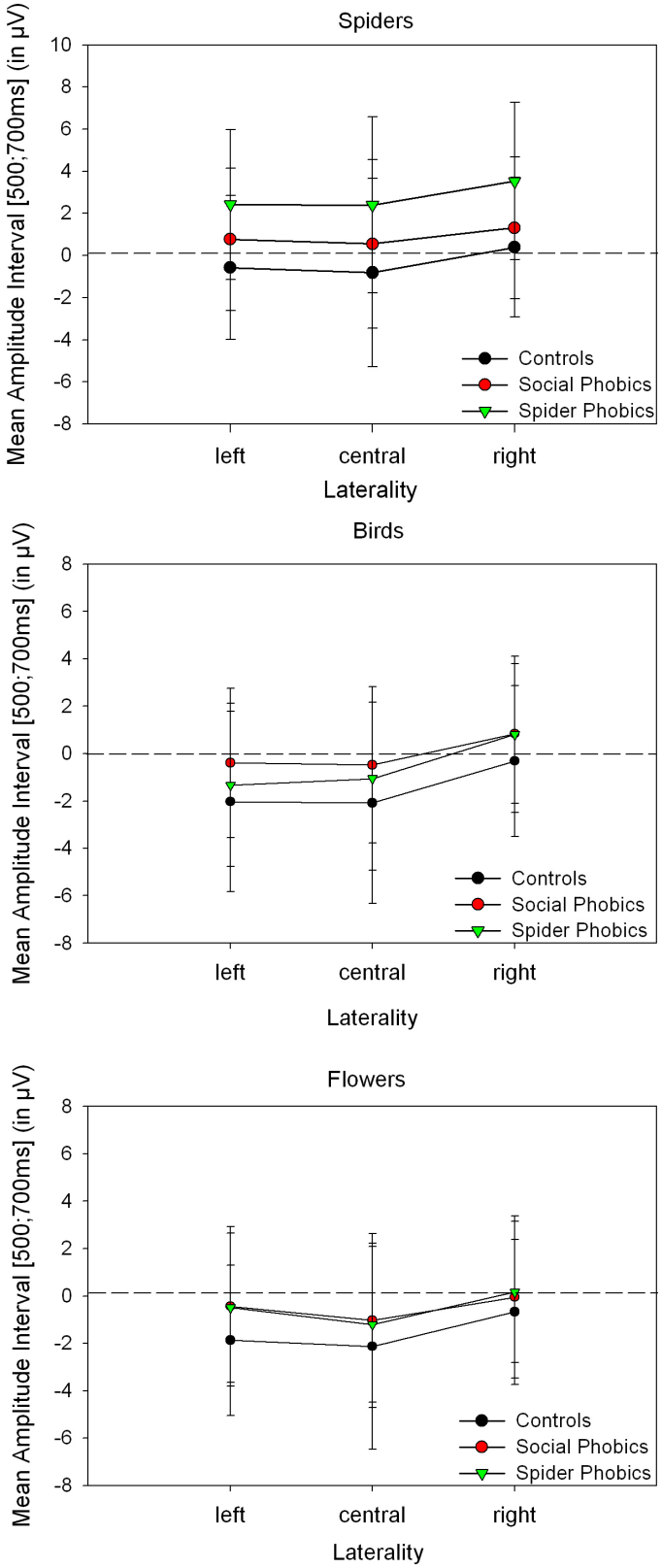


Figure 2.21.: Mean amplitudes and SDs of the late frontal positivity in the time interval of [500 ms; 700 ms] for spiders (top row), birds (center row), and flowers (bottom row) depending on laterality for each group

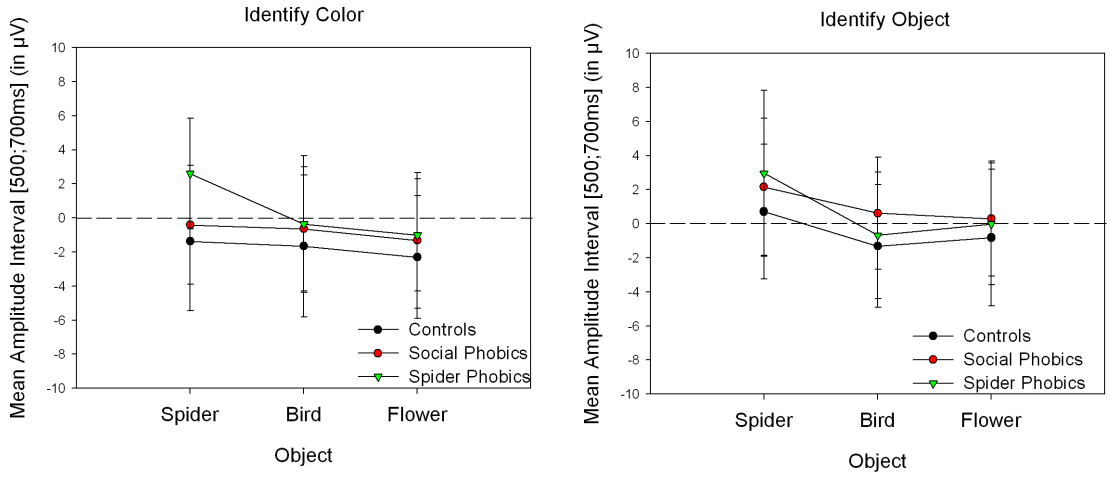


Figure 2.22.: Mean amplitudes and SDs of the late frontal positivity in the time interval of [500 ms; 700 ms] for the color (left) and object (right) identification of spiders, birds and flowers for each group

(identify color: $p = 0.0005$; identify object: $p = 0.0005$). Figure 2.22 depicts mean amplitudes and standard deviations in the latency range [500 ms; 700 ms] in response to spiders, birds and flowers for each task and each group.

However, this analysis also revealed that the interaction Group × Object was only present for color but not for object identification. The above ANOVA did not yield this result since the larger positivity in spider phobics in response to spiders was also present in the object identification task, but to a lesser extent than in the color identification task. Thus, while all subjects showed an enhanced frontal positivity for spiders when they had to allocate their attention to the object itself, only spider phobics showed this effect when allocating attention to the color of a spider. For the color identification task, the comparisons 'spider–flower' ($p = 0.0005$) and 'spider–bird' ($p = 0.001$) were highly significant in spider phobics. Furthermore, pairwise comparisons revealed that spider phobics differed significantly from controls ($p = 0.001$) and social phobics ($p = 0.02$) when identifying the color of spiders. However, in the object identification task there was no significant difference between spider phobics and the control groups for spiders.

Finally, correlations of mean amplitude in response to spiders independent of Task and Laterality with SPQ scores were calculated. In contrast to the results found for P3 and P4 amplitude, there was no significant correlation of SPQ with mean amplitude to spiders for spider phobics.

2.4. Discussion

This section will summarize the main results of this study and discuss possible causes for the failure to find Stroop interference. Furthermore, the ERP findings will be integrated with the results of previous studies. Finally, suggestions for future studies will be provided.

2.4.1. Summary of Results

Reaction Times

- This study could not find any evidence of a specific emotional interference effect in spider phobics when identifying the color of spiders.
- It also did not find evidence of a general facilitation effect for fear-relevant stimuli: neither social phobics nor controls responded faster to spiders than to birds or flowers.
- However, a specific facilitation effect in spider phobics could be confirmed: spider phobics identified spiders significantly faster than social phobics and controls. Yet, it has to be noted that spider phobics also identified birds and flowers significantly faster than social phobics, and they also tended to be faster than controls in this task.

Heart Rates

- Non-spider-fearful groups showed a normal orienting reaction in response to spiders, birds and flowers.
- Although non-spider-fearful subjects rated spiders as more arousing, this had no influence on heart rates.
- However, spider phobics showed a specific response to spiders which was dependent on gender. While male spider phobics showed a defense reaction, i.e. brief deceleration and then acceleration of heart rate (Lang et al., 1997), female spider phobics showed a pronounced orienting response.

However, since variances were very high in the phobic group, these data have to be interpreted with caution.

Event-Related Potentials: P3

- The hypothesis of a general arousal effect of spiders on P3 amplitude could only partially be confirmed. While controls showed significantly higher amplitudes for spiders compared to flowers, no such effect was present in social phobics.
- The results of this study provide evidence for a specific arousal effect on P3 amplitudes in spider phobics. Spider phobics showed significantly larger P3 amplitudes for spiders than for birds or flowers. This effect was independent of task, i.e. it did not matter whether they had to allocate their attention towards the color of the object or the object itself.
- Furthermore, this study found evidence for a greater involvement of the right hemisphere in the processing of visual stimuli as compared to the left hemisphere. In addition, while flowers and birds led to larger P3 amplitudes over right vs. central sites, spiders led to equal amplitudes over right and central sites.

Event-Related Potentials: P4 Similar effects were found for P4 amplitude:

- There was some evidence for higher P4 amplitudes in social phobics for spiders compared to flowers, but this effect narrowly failed to be significant.
- Spider phobics showed significantly higher P4 amplitudes in response to spiders compared to birds or flowers. Again, this effect was independent of task.
- Furthermore, this study found generally larger P4 amplitudes over the right compared to the left hemisphere for all objects. In addition, P4 amplitudes were largest centrally for spiders.

Although spiders did not lead to generally larger P3 and P4 amplitudes in all subjects, it can be concluded that for P3 in controls and for P4 in social phobics there was at least a tendency towards higher amplitudes for spiders compared to flowers.

Finally, evidence for an association between severity of spider phobia and magnitude of P3 and P4 amplitudes in response to spiders was found, as shown by the significant correlations of both amplitudes with SPQ values in spider phobics.

Event-Related Potentials: Late Frontal Positivity

- The lack of emotional interference in spider phobics precluded the investigation of the neuronal correlates of emotional Stroop interference which we hypothesized to be located in frontal areas.
- Yet, in the color identification task, a larger frontal positivity 500–700 ms post-stimulus was observed in spider phobics viewing spiders compared to flowers and birds. This frontal positivity was not present in social phobics and controls.
- In the object identification task, on the other hand, all subjects showed a larger frontal positivity in this latency range when shown spiders compared to flowers and birds. This effect was somewhat more pronounced in spider phobics.

Thus, after responding, all subjects showed larger frontal positivities when directly allocating their attention to the more aversive spider object. Spider phobics showed this positivity even when their attention was directed towards the color of the spider, while controls and social phobics did not show such an effect.

2.4.2. Possible Causes for the Absence of Stroop Interference

The most striking result of this study was the unexpected absence of Stroop interference: spider phobics were not slower when identifying the color of spiders than for flowers and birds. In this section, possible explanations for this result are discussed.

One could argue that Stroop interference was not found because the spider phobic subjects were *not sufficiently spider phobic*. However, this argument seems unconvincing, since spider phobics did show spider phobia-specific responses in reaction times, heart rates and ERPs. Furthermore, mean SPQ values in other studies investigating Stroop interference effects were comparable (e.g. Lavy & van den Hout, 1993) or even lower (e.g. Kindt & Brosschot, 1997) than 21 as in this study.

It is possible that *different formats* of the emotional Stroop task are not psychometrically equivalent instruments. For example, Kindt, Bierman, and Brosschot (1996) reported a noted lack of convergent validity for card vs. computer Stroop, and other studies reported that different effects can be observed with blocked vs. randomized designs (Ballesteros, Reales, & Manga, 2000; Holle, Neely, & Heimberg, 1997; Richards,

French, Johnson, Naparstek, & Williams, 1992; Waters & Feyerabend, 2000). In particular, Holle et al. (1997), Richards et al. (1992), and Waters and Feyerabend (2000) reported that Stroop effects present in a blocked condition design can be greatly diminished or even absent in an unblocked design.

One explanation for this discrepancy between blocked and unblocked designs might be so-called *carry-over effects*, which have been investigated by Waters, Sayette, and Wertz (2003) in an emotional Stroop study with smokers. Smoking words, matched neutral words, and filler words were presented in a mixed sequence in four different colors. Subjects' task was to color-name the words. Results showed that words appearing after smoking-related items were responded to more slowly than words appearing after neutral items. It was argued that smokers might have difficulty in disengaging attention from the semantic content of the smoking word (rumination effect), or that they experience a conditioned response (e.g. conditioned withdrawal; Niaura et al., 1988). Carry-over effects might explain why more studies using card Stroop or blocked designs find Stroop effects (Waters et al., 2003). In blocked designs, interference caused by a phobia-relevant word or picture influences the processing of the following word, which is also a phobia-relevant word, and the effect sums up. Thus, carry-over effects may increase the size of Stroop effects in blocked relative to unblocked designs. On the other hand, in mixed designs carry-over effects would lead to increased reaction times to neutral stimuli presented directly after feared ones, thus reducing Stroop interference.

This explanation could also account for the results of Constantine et al. (2001) and Martin and Jones (1995), who both used a pictorial emotional Stroop design. While Martin and Jones, using a pictorial card Stroop design with 40 pictures of one category on each card, found an emotional interference effect for phobia-related pictures relative to control pictures, Constantine et al. could not find such an effect with a mixed pictorial computer Stroop design. Only when analyzing a subgroup of intensely snake-fearful individuals (n = 5) of their population could they find evidence for additional interference for snake pictures.

Likewise, it could make a large difference whether *pictorial or linguistic stimuli* are used. No study so far reported larger interference effects for pictorial compared to linguistic stimuli – a surprising result in light of the higher ecological validity of pictorial stimuli. While Kindt and Brosschot (1997) found a comparable interference for pictorial and linguistic stimuli in spider phobic children, Lavy and van den Hout (1993) found only a smaller attentional bias for spider words compared to pictures in spider phobic women, and Kindt and Brosschot (1999) even found no bias at all for pictorial stimuli

in spider phobic children.

As discussed in the introduction, there is some evidence that *integrated spider words* lead to more interference than *non-integrated ones* (Kindt & Brosschot, 1997). This stands in contrast to the situation for *pictorial stimuli*, where evidence exists that integrated pictures lead to no interference (Constantine et al., 2001), while a few studies found interference for non-integrated pictures (Kindt & Brosschot, 1997; Lavy & van den Hout, 1993). The present study also did not find emotional interference for integrated spider pictures. In contrast to the colored stimuli used in the present experiment, the stimuli used by Kindt and Brosschot as well as Lavy and van den Hout were spider photographs encircled by borders whose color participants had to name. In such a paradigm, spider phobics could have difficulties in shifting their attention away from the threatening spider to the color information presented in a different spatial location, thus leading to emotional interference. In other words, *delayed disengagement effects* (Derryberry & Reed, 2002) could play a major role in causing interference effects. However, when integrated stimuli are used, such a shift of attentional spotlight is not necessary since object and color information are presented in the same spatial location, and consequently interference effects would not arise.

Finally, whether a *verbal or a manual response mode* is used in an emotional Stroop design could also influence results. In the classical Stroop paradigm it is a common result that interference is reduced when response modality is switched from oral to manual (see MacLeod, 1991). For incongruent color words Redding and Gerjets (1977), for example, found 177 ms of interference when the response was oral but only 98 ms when the response was manual. The influence of oral vs. manual responses on emotional Stroop interference and facilitation has not been systematically investigated so far.

It has been observed that interference effects often seem to reflect specificities of *task structure* rather than *task difficulty* (McLeod, 1977, 1978; Kinsbourne & Hicks, 1978). While simple explanations of interference effects postulate one common undifferentiated reservoir of attentional resources which are allocated to the different tasks to be performed, a structural account of capacity limitations assumes that specific information-processing mechanisms exist, each with its own attentional reservoir (capacity). Multiple mechanisms can be engaged at the same time without interference occurring, unless tasks which need to use the same mechanism compete for its specific resources (Williams et al., 1997). Interference effects would arise if two tasks compete for attentional capacity in the same processing pathway. It seems that in a linguistic emotional Stroop paradigm with verbal response modality such interference effects occur, while

in a pictorial emotional Stroop paradigm with manual responses different processing mechanisms are required which do not compete for attentional resources, and therefore no interference occurs.

This raises the question whether emotional Stroop interference effects found so far were mainly due to verbal processing specificities and the incompatibility of naming the color of a spider-related word when the verbal processing pathway is occupied with the spider-related content of the word. This may be a provocative hypothesis. However, it is supported by the fact that pictorial stimuli never resulted in more Stroop interference than verbal ones as well as the inconsistent results of studies reported so far.

This argument is further substantiated by the finding that classical Stroop interference was generally larger when an oral instead of a manual response mode was used. This study was the first emotional Stroop study using a manual response mode, and it found no evidence for an emotional Stroop interference effect. It seems plausible that visual processing and manual reactions are more compatible than verbal processing and vocal responses. Thus, the findings of this study point to a verbal source of interference in classical Stroop paradigms, which is to some extent transferable to emotional Stroop paradigms if linguistic stimuli and oral responses are used, but which is not present when using pictorial stimuli and manual responses.

2.4.3. How Findings Fit in Previous Results

Reaction Times Despite the lack of emotional interference, this study found evidence for facilitated processing of spiders in spider phobics in the object identification task. This matches the findings of Öhman et al. (2001) in a visual detection paradigm with spider phobics and snake phobics: phobic subjects were particularly fast in detecting their feared stimulus in a matrix of neutral, fear-relevant, and feared stimuli. Similarly, Gilboa-Schectman et al. (1999) reported faster detection of angry faces in a visual search paradigm in social phobics than in controls. Thus, evidence for an attentional bias in spider phobics for their feared object was found. However, the question still remains whether this facilitated response is due to faster detection and processing or to faster responses to fear-relevant stimuli.

Within the scope of Öhman's model (cf. Section 1.3.5), this finding could be explained by differences between spider phobics and controls on the level of the feature detectors or of the significance evaluator and the expectancy system. Spider phobics' feature

detectors could be specifically tuned to spider-related features, facilitating the detection of such features, selecting this information for preferential treatment by the significance evaluators, and activating the arousal system. Alternatively, the significance evaluator, which assesses stimuli for their full meaning, could be biased by the content of the expectancy system to interpret spider stimuli as threats. Öhman himself suggests that the crucial difference between phobics and non-phobics lies in the feature detectors (Öhman, 1993, p. 527; Öhman & Soares, 1994), which could be especially sensitive to spider-related information in incoming stimuli as a result of conditioning (Öhman & Soares, 1993; Öhman, Dimberg, & Esteves, 1989).

Reaction times were significantly longer for object than for color identification. This effect is probably due to two factors: first, subjects had three possible choices for object identification and only two for color identification. It is well established that increasing the number of response alternatives prolongs reaction times since response selection becomes more complex (Frith & Done, 1986). Second, color identification might in general be a less complex task than object identification.

Finally, spider phobics were significantly faster than social phobics and showed a tendency to be faster than controls in the object identification task, i.e. they identified spiders particularly fast, but also identified birds and flowers significantly faster than social phobics and (non-significantly) faster than controls. This is in accordance with the *hypervigilance* proposed by Beck et al. (1985) and elaborated by Eysenck (1991, 1992, 1997) for trait-anxious individuals. According to Beck et al. (1985), "The [anxious] patient is hypervigilant, constantly scanning the environment for signs of impending disaster or personal harm ... The anxious patient selectively attends to stimuli that indicate possible danger ..." (p. 31).

According to Eysenck, there are two ways in which individuals high in trait anxiety show hypervigilance: general hypervigilance or distractability is demonstrated by a propensity to attend to any task-irrelevant stimuli presented, and specific hypervigilance is demonstrated by a tendency to attend selectively to threat-related rather than neutral stimuli. Hypervigilance involves a high rate of environmental scanning, a broadening of attention prior to the detection of a threat-related or task-relevant stimulus, and a narrowing of attention when such a stimulus is being processed.

The hypervigilance effect should be particularly obvious in the object identification task, since the color identification task is per se a less complex task accompanied by faster responses than the object identification task, especially since there were three possible answers for the object identification and only two for color identification. It

is possible that spider phobics showed no further facilitation in the color identification task due to hypervigilance because reaction times were already very fast in all subjects in this task (a ceiling effect).

However, a problem with Eysenck's theory is that spider phobics did not differ significantly from controls in their trait anxiety (STAI) values. In the light of the STAI results, one would have expected hypervigilance effects only for social phobics, who showed significantly higher trait anxiety than spider phobics and controls, but who were significantly slower than spider phobics and comparable to controls in the object identification task.

In conclusion, hypervigilance provides a coherent explanation for the generally faster object identification by spider phobics, but the non-elevated trait anxiety values in the spider phobic group pose a problem for Eysenck's assumption that high trait anxiety is accompanied by hypervigilance.

Late Positive Potentials The results of this study – larger P3 and P4 amplitudes in spider phobics when viewing spiders compared to flowers and birds – replicate previous findings by Miltner and colleagues (Gutberlet & Miltner, 1999, 2001; Krieschel, 2003) who found larger P3 amplitudes in animal phobics when viewing pictures of their feared object.

A first explanation of these results is provided by studies investigating the influence of affective valence and arousal on parietal late positive components in ERPs. Several studies found evidence for larger late positive potentials (LPPs) for emotional compared to neutral stimuli (e.g. Cuthbert et al., 1995, 2000; Johnston et al., 1986; Mini et al., 1996; Palomba et al., 1997) and in particular larger LPPs for negative compared to positive stimuli (e.g. Ito, Larsen, Smith, & Cacioppo, 1998). Furthermore, like Johnston et al. (1986), this study found multiple P3s to emotional stimuli. The factor solution was very similar to the one described by Johnston and colleagues who found a P3 (maximal at 300 ms), a P4 (maximal at 540 ms), and a slow wave (maximal at 920 ms). In their study, both P3 and P4 amplitudes varied with the emotional value of the stimuli.

Following the arguments of Schupp et al. (2000), it might seem that the enhanced late positive components (P3 and P4) in spider phobics when viewing pictures of spiders reflect that such pictures are highly arousing for these subjects. However, as noted before, attributing the entire LPP effect to arousal rather than valence in this way

would be too strong a conclusion to draw, since valence and arousal are confounded (Lang et al., 1997).

A second explanation, compatible with a main influence of arousal on LPPs, is provided by Johnson's model (cf. Section 1.6.1; Johnson, 1986). According to this model, the larger emotional significance of spiders for spider phobics would result in larger P3 amplitudes, since it would increase the *stimulus value* and thus the *meaning* variable in his model.

However, since all subjects rated spiders as more arousing and unpleasant than birds and flowers in the pilot study, one would have expected larger P3 and P4 amplitudes in response to spiders for social phobics and controls as well. A possible explanation is that although spider pictures were evaluated as significantly more arousing than birds or flowers, these ratings were still relatively low, yielding little influence on LPPs. Besides, controls did show significantly larger P3 amplitudes and social phobics almost significantly larger P4 amplitudes for spiders than for flowers. Thus, a general tendency is obvious (cf. Figure 2.15).

A third explanation comes from two studies by Diedrich et al. (1997) and Naumann, Becker, Maier, Diedrich, and Bartussek (1997), who found larger P3 amplitudes for emotional stimuli even when the task distracted subjects' attention from the emotional content of the stimuli. They explained these results in the context of Öhman's and LeDoux's theoretical models and assumed that according to Öhman, after emotional stimuli have been processed automatically and preattentively, conscious cognitive information processes are initiated. These additional controlled processes lead to larger P3 components (compare also Donchin & Coles, 1988; Roesler, 1982). Thus, according to this theory, the larger amplitudes in response to spiders in spider phobics result from additional conscious and controlled stimulus processing. However, this does not explain why spider phobics showed larger amplitudes than the non-spider-fearful groups.

One important finding of the present study is that, independently of the task subjects had to perform, larger LPPs were found for spider phobics when viewing pictures of spiders. This is consistent with the studies by Diedrich et al. (1997) and Naumann et al. (1997) in which subjects had to perform an emotion-focused task (judging the subjective emotional valence of slides) or a structural task (counting the number of lines inserted on each slide). These tasks are comparable with the object and color identification tasks in the present study. Diedrich et al. and Naumann et al. found larger P3 amplitudes for emotional stimuli (positive or negative), even when the task distracted subjects' attention from the emotional content of the stimuli. In accordance

with this finding, spider phobics showed larger P3 and P4 amplitudes in the present study, even if the task distracted them from the emotional content of the pictures.

Late Frontal Positivity The above-mentioned study by Diedrich et al. (1997) found a positive-going wave at frontal electrode sites for emotion-focused processing beginning 600 ms after stimulus onset. This positivity was not present in the structural processing task. There were no differences between neutral, negative or positive slides in this frontal positivity. Yet, the results by Diedrich et al. lend some support to the notion that the frontal positivity is associated with emotion-focused processes. This matches the findings of the present study, in which subjects showed a larger frontal positivity 500–700 ms post-stimulus for the object identification task, i.e. emotion-focused processing. However, this neither explains the larger frontal mean amplitudes in all subjects when identifying spiders as compared to flowers and birds, nor the higher amplitudes in spider phobics identifying the color of spiders as compared to control groups.

One possible explanation is that spiders are more emotional (i.e. more arousing and more unpleasant) stimuli. It is possible that in an emotion-focused task highly emotional stimuli capture attention for a longer time than less emotional stimuli. This would explain why all subjects showed larger mean amplitudes for spiders in the object identification task. However, when subjects had to identify the color of the object, i.e. in the structural processing task, this positivity was only observed in spider phobics identifying the color of spiders, but not in the other groups. It is possible that spider phobics focused not only on the color of the spider but also processed the spider emotionally, which led to the larger frontal positivity. Controls, on the other hand, only focused on the color of the stimuli without being distracted by their emotional content. This, however, is a purely hypothetic explanation which lacks empirical evidence but could be investigated in future studies.

Since the late frontal positivity occurs after subjects' response, another possible explanation would be that spider phobics had difficulties in *disengaging their attention* from spider stimuli, instead dwelling on the feared object they had just seen. Evidence for such an explanation comes from studies with high and low trait anxious subjects: a study by Yiend and Mathews (2001) suggested that the attentional biases associated with anxiety could be due, at least in part, to differences in the ease of disengagement from threat in high compared to low trait anxious individuals. This explanation also matches the results of Derryberry and Reed (2002) and Fox et al. (2002), who suggested

that emotional interference in Stroop and dot-probe paradigms may reflect delayed disengagement from threat due to enhanced dwell-time on threat-related stimuli.

Fox et al. (2002), for example, showed that heightened trait anxiety resulted in increased *attentional dwell-time* on emotional facial stimuli, relative to neutral faces. Subjects were shown angry, happy or neutral schematic faces to the right or to the left of a fixation cross for 250 ms. 50 ms after this face disappeared, a circle or a box appeared either at the same location as the face (at the *validly cued location*) or on the other side of the screen (at the *invalidly cued location*). Subjects had to categorize this geometrical shape. High trait anxious subjects were slower to respond to invalidly cued locations if the face had been emotionally valenced (angry or happy) as compared to an emotionally neutral face. Thus, the presence of an emotionally valenced face resulted in delayed disengagement in high trait anxious subjects.

The mean frontal positivity found in the present study could be an electrophysiological indicator of the enhanced attentional dwell-time in spider phobics when identifying the color of spiders. It could reflect activity in the ACC, which plays a major role in cognitive and selective attentional tasks (cf. Section 1.4), e.g. conflict monitoring. Such a hypothesis of increased attentional dwell-time reflecting ACC activation is supported by the fact that the affective subdivision of the ACC has been found to be activated in response to negative words in an emotional counting Stroop paradigm (Whalen et al., 1998).

In conclusion, in the color identification task only spider phobics showed a larger frontal positivity for spiders compared to neutral stimuli. Two alternative explanations are possible: first, that in the color identification task, spider phobics could not focus only on the color of the object but also processed this picture emotionally, while non-fearful subjects performed only the structural processing task. Second, the late frontal positivity could be interpreted as reflecting an enhanced attentional dwell-time on spiders in spider phobics during the color identification task. Although the nature of this component is still unclear, it could originate in the ACC, which is supposed to be involved both in classical Stroop and in emotional counting Stroop experiments.

2.4.4. Suggestions for Future Studies

The influence of different experimental formats on Stroop interference is still unclear. Therefore, future studies should systematically investigate the influence of verbal vs. manual response modes as well as that of pictorial vs. linguistic stimuli. Furthermore,

the effect of integrated vs. non-integrated pictorial stimuli should be systematically investigated. It is possible that attentional bias effects arise only when at least two pictures, presented in different spatial locations, compete for attention.

Waters et al. (2003) reported evidence for carry-over effects in an emotional Stroop paradigm with smokers identifying the color of smoking-related words. It is not yet clear whether such carry-over effects also influence the results of studies of the attentional bias in anxiety disorders. However, such possible influencing factors should be systematically investigated. Future studies could avoid contamination from carry-over effects, as Waters et al. (2003) suggested, by presenting filler items after the phobia-relevant stimuli, or by increasing intertrial intervals.

Furthermore, future studies should investigate whether the enhancement of P3 and P4 amplitudes in response to phobic stimuli is an effect only of the high arousal of these stimuli for phobics or whether it is phobia-specific. A possible research design could investigate ERPs in spider-fearful and non-fearful subjects in response to feared/fear-relevant, neutral, and high-arousing pictures. The latter could depict, for example, pictures of mutilations (high arousing negative) or erotic pictures (high arousing positive). One research question would be whether spider phobics show comparable P3 and P4 amplitudes to aversive pictures and spider pictures they rate equally arousing.

In addition, it would be interesting to investigate the influence of cognitive-behavioral therapy (CBT) on the late positive components (P3/P4) and on the valence and arousal ratings in spider phobics. One interesting question would be whether the valence and arousal ratings normalize after CBT or whether they remain elevated in spider phobics. If they remain elevated although spider phobia therapy was successful, this could explain why Gutberlet and Miltner (2001) still found higher P3 amplitudes in response to spiders even after CBT.

Future studies should also investigate whether the late frontal positivity investigated in this study actually is an electrophysiological indicator of attentional dwell-time on emotional stimuli and whether it reflects delayed disengagement from threatening stimuli in phobics. Yiend and Mathews (2001) and Fox et al. (2002) investigated delayed disengagement from threatening stimuli in high and low trait anxious subjects using a modified version of the attentional probe task. However, they only measured reaction times and recorded no ERPs. An analogous design could investigate delayed disengagement from feared and fear-relevant stimuli in spider-fearful and non-fearful subjects, respectively, while recording ERPs.

Finally, a further influencing factor could be the age of participants. Several authors have argued that selective attention towards threat is a common feature among younger children (Kindt & van den Hout, 2001; Merckelbach et al., 1996). Kindt and van den Hout argued that as age increases, selective attention towards threat decreases in nonanxious children, while it is maintained in anxious ones. Thus, emotional interference in emotional Stroop paradigms could be a normal characteristic of young children but decrease with age, while it is maintained in spider phobics. Possibly, a longitudinal study might clarify these mechanisms.

3. Experiment II – Pictorial Emotional Stroop Paradigm with Schematic Stimuli

3.1. Introduction: Aims and Hypotheses

So far, no study has investigated whether *schematic* pictures of spiders are sufficient to provoke a fear reaction. However, if this could be proved, it would be important for future studies on the attentional bias in spider phobia and would provide some clues to the question as to which properties make a spider fear-relevant. Furthermore, no study has yet investigated whether similar effects can be observed with schematic stimuli as with non-schematic pictures in an emotional Stroop paradigm. This study investigated the electrocortical correlates of the processing of schematic fear-relevant stimuli in a pictorial emotional Stroop paradigm.

The advantages of schematic stimuli are obvious: they are simpler and unequivocal. Schematic spiders show less variance and are not confounded with spider species, hairiness or size. Finally, it is easier to design a control condition which is matched for factors as color, size, and spatial frequency: if one shifts the angles of the legs of a schematic spider image a schematic flower picture results and vice versa (cf. Appendix C.3). Thus, schematic pictures of flowers are ideal control stimuli for schematic spider pictures, because they consist of the same basic visual elements as the spider pictures.

This study aimed to replicate the results of the emotional Stroop experiment described in Chapter 2 with schematic stimuli. More specifically, we wanted to compare the results attained with non-schematic spider pictures to those of schematic spiders.

Group	SPQ	SPAI	SPAI (orig.)	BDI	STAI
Spider Phobics: Mean	20.61	30.53	44.41	4.94	33.50
SD	2.66	10.66	15.51	4.76	8.05
Social Phobics: Mean	2.58	87.18	126.81	9.42	50.47
SD	1.95	12.49	18.17	7.09	6.61
Controls: Mean	2.47	23.05	33.53	2.68	30.79
SD	1.78	11.61	16.89	2.71	5.92
Kruskal-Wallis $\chi^2_{df=2}$	36.41	38.40	38.40	12.06	32.41
p-value	0.0005	0.0005	0.0005	0.002	0.0005

Table 3.1.: Mean questionnaire values and SDs per group; results of Kruskal-Wallis Test (χ^2 and p-values)

A pictorial emotional Stroop paradigm with integrated schematic stimuli was designed. Three groups of subjects participated in the study: spider phobics, social phobics, and controls. Subjects saw schematic pictures of spiders and flowers, colored either red or blue. The stimuli consisted of identical basic visual elements, making them ideal control stimuli for each other. Subjects' task was either to identify the color of the stimulus or the object itself by pressing different buttons.

Our hypotheses were the same as for Experiment I, as detailed in Section 2.1.

3.2. Methods

3.2.1. Subjects

All subjects of Experiment I participated in this study, with the exception of one female spider phobic. The analysis of the population parameters therefore changed only slightly and in no significant way. For the sake of completeness, the entire analysis is presented below.

56 subjects (mean age 23 yrs, SD 3.5 yrs; age range: 19–32 yrs) participated in the study: 19 social phobics (10 male, 9 female), 18 spider phobics (9 male, 9 female), and 19 normal controls (10 male, 9 female). There was no significant difference between groups regarding age (Kruskal-Wallis Test: $\chi^2_{df=2} = 5.58$; $p = 0.06$) or gender (Pearson $\chi^2_{df=2} = 0.03$; $p = 0.98$). However, there was a tendency for social phobics to be older than spider phobics. 53 of the subjects were right-handed and 3 left-handed as measured by the Edinburgh handedness questionnaire (Oldfield, 1971).

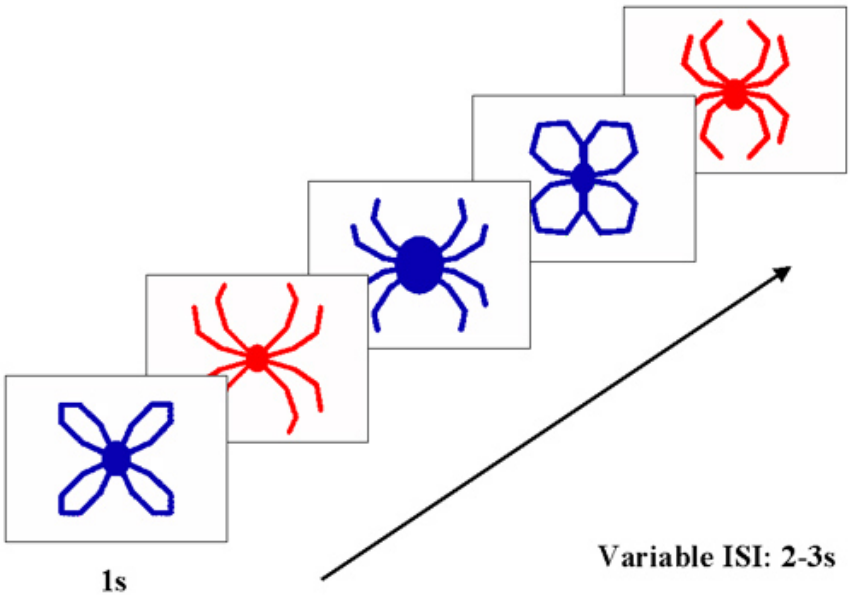


Figure 3.1.: Emotional Stroop paradigm with integrated schematic stimuli

The Kruskal-Wallis Test showed that groups differed significantly in all questionnaires. See Table 3.1 for mean values and standard deviations for each test per group as well as exact χ^2 and p-values. Subsequent group comparisons with Mann-Whitney-U Tests showed that social phobics differed significantly from controls in SPAI value ($U = 0$; $p = 0.0005$) but also on the BDI ($U = 65.5$; $p = 0.001$) and the STAI ($U = 6.5$; $p = 0.0005$). Controls and spider phobics differed only on the SPQ ($U = 0$; $p = 0.0005$). Social phobics and spider phobics differed on the SPQ ($U = 0$; $p = 0.0005$), the SPAI ($U = 0$; $p = 0.0005$), the BDI ($U = 103$; $p = 0.04$), and the STAI ($U = 20.5$; $p = 0.0005$). Thus, again, social phobics scored on average higher on the BDI than controls and spider phobics. In order to estimate the influence of depression on results of social phobics, ANCOVAs with BDI values as a covariate as well as correlations of dependent variables and BDI scores for social phobics were calculated. No consistent significant influence of depression was found. The results are reported on the CD-ROM accompanying this dissertation.

3.2.2. Paradigm

The experiment consisted of two blocks plus a training phase. In each block, 60 pictures of schematic spiders and flowers (30 of each) were presented. Of the 30 flower pictures, 15 had been colored red and the other 15 blue, and the same applied to the spider

pictures (see Figure 3.1). In one block, subjects had to identify the color (blue or red) of the stimulus, in the other they had to identify the category of the object (spider or flower). Subjects were instructed to react as quickly and as correctly as possible. They indicated their selection by pressing one of two buttons on a button box with the index finger of their dominant hand. Each block started with a practice task in which 6 stimuli were shown. The subjects could repeat the practice task as long as they thought it was necessary so that they could react without looking at the button box. The stimuli were presented for 1 s with a variable interstimulus interval of 2–3 s (2 s plus an exponential distribution with mean 500 ms, truncated at 1 s, as generated by ERTS).

The order of the two conditions as well as the sequence of keys which had to be pressed to categorize the stimuli were randomized across subjects. Also, the order of the stimuli in each block was pseudo-randomized with the following conditions: the same color was only allowed four times in a row and the same object only two times in a row. This was done to avoid expectations about which color or object would be presented next.

Stimuli The stimuli used in this study were similar to those used by Vuilleumier and Schwartz (2001). There were 4 different schematic spider stimuli, differing in the size of the spider body and the angularity of the spider legs, and 4 different schematic flower stimuli, differing in the size of the interior of the flower and the angularity of the petals. Flowers differed from spiders only insofar as four legs of the spiders were reflected about a diagonal axis. In Appendix C.2 all stimuli are depicted.

3.2.3. Subjective Ratings of Valence and Arousal

The stimuli had been rated as to their affective valence and physiological arousal in the context of another study, using the Self-Assessment Manikin (SAM; Bradley & Lang, 1994; Lang, 1980, see Appendix B).

56 subjects rated the pictures: 19 controls (10 male, 9 female), 19 spider phobics (8 male, 11 female), 18 social phobics (10 male, 8 female). Mean age was 23, SD 3.6, age range 19–34 years. 44 of the subjects also participated in Experiment II. The additional subjects were recruited according to the same criteria reported above.

For both valence and arousal ratings a 3×2 ANOVA was calculated with between factor *Group* and repeated measures factor *Object* (spider, flower). Mean valence and

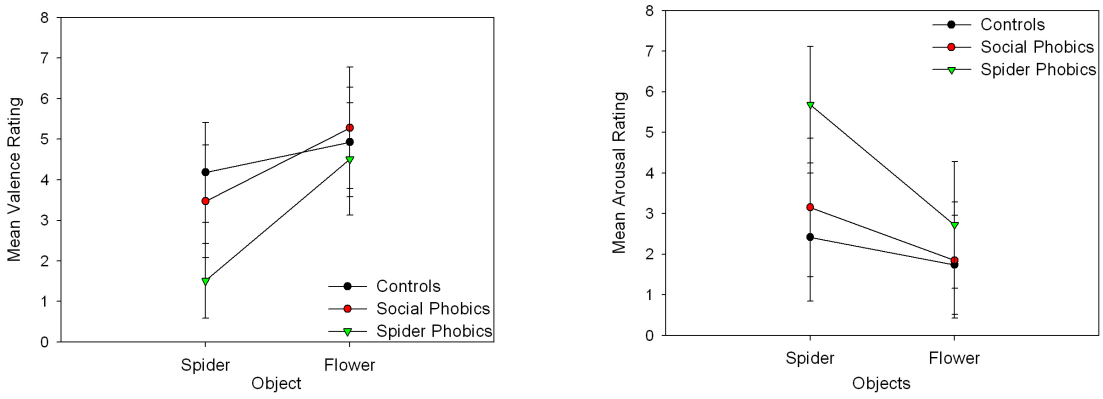


Figure 3.2.: Mean valence (left) and arousal (right) ratings and SDs for spiders and flowers for each group

arousal ratings with standard deviations for each object are depicted separately for each group in Figure 3.2.

The analysis of **valence ratings** yielded main effects of Group ($F_{(2,53)} = 12.2$; $p = 0.0005$), of Object ($F_{(1,53)} = 88.43$; $p = 0.0005$) and a significant interaction of Group $\times$ Object ($F_{(2,53)} = 11.7$; $p = 0.0005$).

The main effect of Object indicated that all groups rated spiders as significantly more unpleasant than flowers. Subsequent t-tests comparing each group in their valence ratings for spiders and flowers confirmed this finding (controls: $p = 0.04$, social phobics: $p = 0.0005$, spider phobics: $p = 0.0005$).

To further analyze the interaction Group $\times$ Object, subsequent ANOVAs were calculated for each object. They showed that the groups did not differ significantly in their valence ratings for flowers, but the differences in their valence ratings for spiders were highly significant ($F_{(2,55)} = 27.87$; $p = 0.0005$). Tukey HSD post hoc tests revealed that spider phobics rated spiders as significantly more arousing than controls ($p = 0.0005$) and social phobics ($p = 0.0005$).

Similarly, the analysis of **arousal ratings** showed main effects of Group ($F_{(2,53)} = 13.78$; $p = 0.0005$) and of Object ($F_{(1,53)} = 76.8$; $p = 0.0005$), and a significant interaction of Group $\times$ Object ($F_{(2,53)} = 13.34$; $p = 0.0005$).

The main effect of Object was further analyzed by subsequent t-tests. They revealed that all groups showed significantly higher arousal ratings for spiders than for flowers (controls: $p = 0.02$; social phobics: $p = 0.0005$; spider phobics: $p = 0.0005$).

The interaction Group × Object was further analyzed by subsequent one-way ANOVAs calculated separately for spiders and flowers. The analysis showed no significant difference between groups in arousal ratings for flowers. However, there were highly significant differences in arousal ratings between groups for spiders ($F_{(2,55)} = 22.41$; $p = 0.0005$). Post hoc tests (Tukey HSD) revealed that spider phobics rated pictures of spiders as significantly more arousing than controls ($p = 0.0005$) and social phobics ($p = 0.0005$).

In conclusion, all subjects rated spiders as more unpleasant and more arousing than flowers. However, spider phobics rated the spider pictures as significantly more unpleasant and more arousing than controls and social phobics. Thus, the pictures are suitable to elicit the specific reactions in each group.

3.2.4. Assessment of EEG and Further Psychophysiological Variables

All recording parameters of EEG, heart rate, respiration etc. were the same as in Experiment I, as detailed in Section 2.2.4.

3.2.5. Analyses of Dependent Variables

Analysis of Performance and Reaction Times in the Stroop Task

All trials in which no reaction occurred were excluded from further analysis, i.e. when subjects pressed no button in response to a stimulus. Also, all trials were excluded in which the reaction was wrong or the reaction time was below 200 ms. Mean reaction times were calculated for each subject for each condition, i.e. *Task* (Identify Color, Identify Object) × *Object* (Spider, Flower). The data processing was performed with EXCEL 2002 and JMP 5.01, and the data were screened for extreme values and outliers (data points deviating more than 3 standard deviations from the group mean) using JMP 5.01 and SPSS 11.5.

Analysis of Heart Rates

Heart rates (HRs) were analyzed in an interval of [−500 ms; 3000 ms] around stimulus onset in intervals of 500 ms using Brain Vision Analyzer 1.04. As in Experiment I, HR changes were computed by subtracting the baseline heart rate [−500 ms; 0 ms] from the heart rate in each time interval after stimulus presentation (cf. Section 2.2.5).

Analysis of Event-Related Potentials

ERPs were analyzed as in Experiment I (cf. Section 2.2.5).

The EEG data was filtered (low pass = 30 Hz, 24 dB/oct; high pass = 0.1 Hz, 24 dB/oct; 50 Hz notch), segmented [−200 ms; 1000 ms], corrected for blinks and eye movements (Gratton et al., 1983), and screened for artifacts using the software Brain Vision Analyzer 1.04 (Brain Products GmbH, München, Germany). The mean averages for each condition and for each subject were baseline corrected using the [−200 ms; 0 ms] period as a baseline and then rereferenced to the averaged linked earlobes. Data of 4 subjects (2 controls, 1 social phobic, and 1 spider phobic) were excluded from further analysis because of extreme alpha activity and in one case because of atypical EEG structure.

As in Experiment I, a temporal Principal Components Analysis (PCA) was performed on the data set to reduce its dimensionality and disentangle overlapping ERP components. For a description of parameters compare Section 2.2.5. While screening the data it already became apparent that there were at least two positive components: one between 250–400 ms and one between 400–600 ms. The factor solution of the PCA confirmed the existence of multiple late positive components.

The number of factors was limited to six as a compromise between taking all relevant factors into account and keeping complexity manageable. They are depicted in Figure 3.3. Factor 1 accounted for 51.8% of total variance, factor 2 for 16.3%, factor 3 for 7%, factor 4 for 5.4%, factor 5 for 4%, and factor 6 for 3.2%.

Of particular importance are factors 2 and 5 which can be interpreted as a positive component between 200–400 ms (P3) and a second positive component between 400–600 ms (P4). Spatial distributions of these two factors are depicted in Figure 3.4. Again, the posterior spatial distribution of these two components fits very well with the interpretation as a P3 and a P4 component. As can be seen in Figure 3.4, the P3 component (factor 2) shows its maximum over the occipitoparietal lobe and the P4 component (factor 5) over parietal sites. Factor 1 was interpreted as a slow wave, which is commonly observed in P3 experiments. However, factor 1 as well as factors 3, 4, and 6 are of no relevance for the further analysis of the study and are therefore not elaborated any more in this context.

Since both data screening and PCA hinted at the existence of multiple positive components, namely P3 and P4, further data analysis was carried out separately for both components, as in Experiment I (see Section 2.2.5).

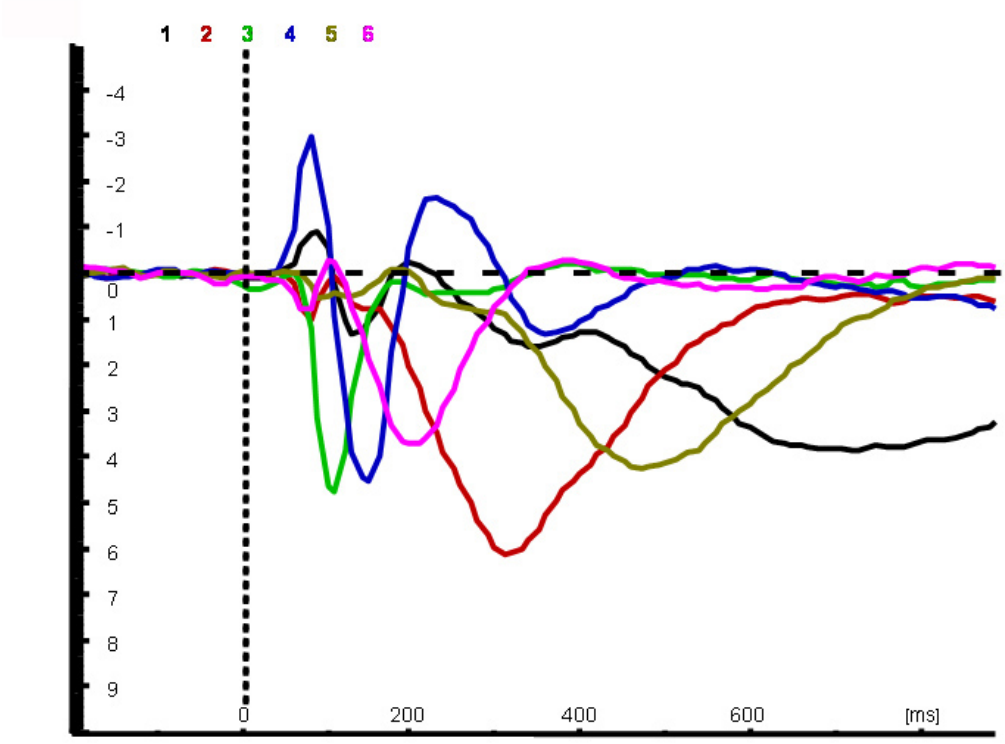


Figure 3.3.: Results of Principal Components Analysis (PCA)

Figure 3.4.: Mean component values over subjects for factors 2 (left) and 5 (right)

Furthermore, it was analyzed whether a comparable late frontal positivity as in Experiment I was present in spider phobics when identifying the color of spiders. Mean amplitudes in the time interval of [500 ms; 700 ms] were exported for leads F_3, F_z, and F_4.

Data screening for extreme values and outliers was performed as in Experiment I (see Section 2.2.5). Two subjects (one male control, one male spider phobic) were classified as outliers. The data of these subjects was excluded from further analysis. Thus, the data of 50 subjects was included in the statistical analysis of ERPs (16 controls, 18 social phobics, and 16 spider phobics).

3.3. Results

For ANOVAs with repeated measurements Greenhouse-Geisser (ε) adjustments were used to correct for violations of sphericity (Greenhouse & Geisser, 1958). See also the introduction to the Results Section of Experiment I (Section 2.3) for a discussion of the preconditions for ANOVAs.

3.3.1. Performance and Reaction Times in the Stroop Task

There was neither a significant difference in missing responses (Kruskal-Wallis Test: $\chi^2_{df=2} = 0.001$; $p = 1$), nor in wrong responses (Kruskal-Wallis Test: $\chi^2_{df=2} = 3.4$; $p = 0.18$), or in total mistakes (missings & errors; Kruskal-Wallis Test: $\chi^2_{df=2} = 1.7$; $p = 0.43$) between groups. Overall, subjects failed to react in 1.08% of all trials, and incorrect responses were observed in 1.16% of all trials.

A $3 \times 2 \times 2$ repeated measures ANOVA was calculated with the between factor *Group* and the repeated measures factors *Task* (identify color, identify object) and *Object* (spider, flower). Figure 3.5 depicts the ANOVA design, and Figure 3.6 shows mean reaction times and standard deviations for each group and for each condition.

Results showed main effects of Group ($F_{(2,53)} = 3.67$; $p = 0.03$), of Task ($F_{(1,43)} = 13.52$; $p = 0.001$), and of Object ($F_{(1,53)} = 9.36$; $p = 0.003$). Furthermore, the interaction Task × Object ($F_{(1,53)} = 15.02$; $p = 0.0005$) was highly significant. However, the interaction Group × Object ($F_{(2,53)} = 0.15$; $p = 0.87$) and Group × Task × Object ($F_{(2,53)} = 0.42$; $p = 0.66$) failed to be significant.

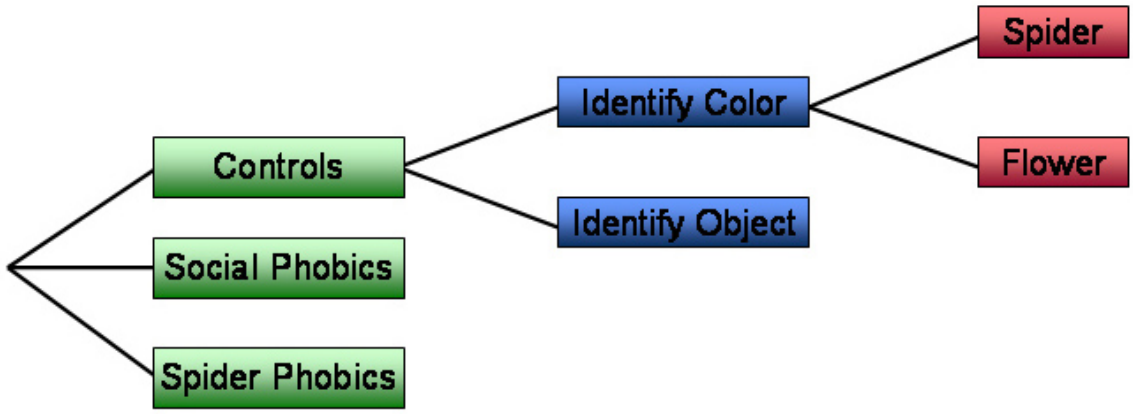


Figure 3.5.: ANOVA design for the analysis of reaction times

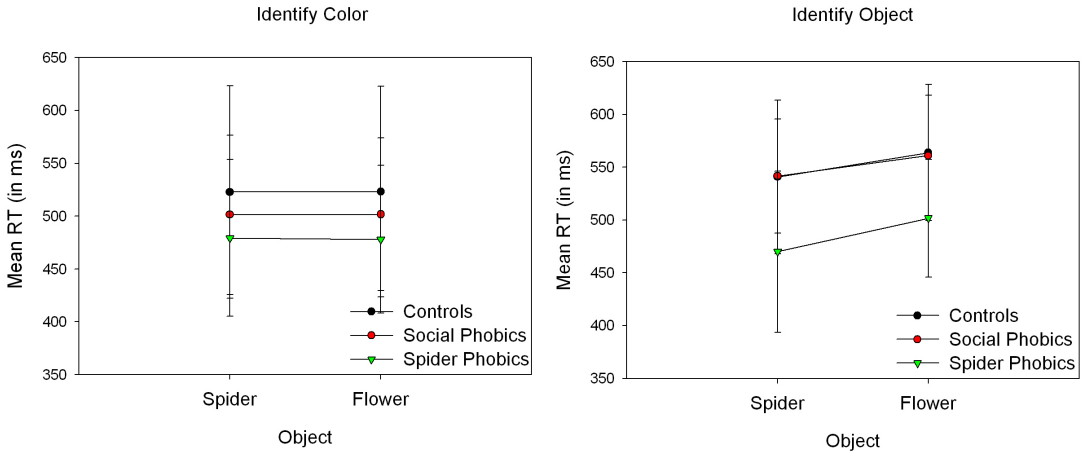


Figure 3.6.: Mean reaction times and SDs for each group in response to spiders and flowers for color identification (left) and object identification (right)

The main effect of Group was further analyzed by post hoc tests (Tukey's HSD). On the whole, spider phobics reacted significantly faster than controls ($p = 0.03$). The comparison spider phobics vs. social phobics failed to be significant ($p = 0.11$) but showed that spider phobics also tended to react faster than social phobics. In Figure 3.6 it seems that reaction time differences between groups were largest for the object identification task. Indeed, the interaction Task × Group ($F_{(2,53)} = 2.45$; $p = 0.096$) narrowly failed to be significant but can be interpreted as a tendency. Subsequent ANOVAs calculated separately for each task showed that spider phobics did not identify the color of an object significantly faster than controls or social phobics. But when the task was to identify the object itself, they were significantly faster than controls ($p = 0.004$) and social phobics ($p = 0.004$).

The main effects of Task and Object should be interpreted together with the interaction of Task × Object. Overall, subjects responded faster when identifying the color of an object (Mean RT: 501 ms) than when identifying the object itself (Mean RT: 530 ms). However, while subjects showed no significant difference between spiders and flowers in the color identification task (Mean RT: spiders 502 ms; flowers 501 ms), they showed significantly faster reaction times for spiders than for flowers in the object identification task (Mean RT: spiders 518 ms; flowers 543 ms). Thus, when the stimulus category had to be identified, all subjects responded faster to spiders than to flowers, and spider phobics did not deviate from this pattern, as the interactions Group × Object and Group × Task × Object were not significant.

3.3.2. Heart Rates

There were no significant differences between groups in baseline heart rates, i.e. in the interval [−500 ms; 0 ms] (one-way ANOVA: $F_{(2,53)} = 0.34$; $p = 0.71$).

Heart rates in the interval [0 ms; 3000 ms] were analyzed with a 3×2×2×6 ANOVA with between factor *Group* and repeated measures factors *Task* (identify color, identify object), *Object* (spider, flower), and *Time* (the intervals t_1 =[0 ms; 500 ms], t_2 =[500 ms; 1000 ms], t_3 =[1000 ms; 1500 ms], t_4 =[1500 ms; 2000 ms], t_5 =[2000 ms; 2500 ms], t_6 =[2500 ms; 3000 ms]). Compare Figure 3.7 for the ANOVA design.

Again, there was a main effect of Time ($F_{(5,265)} = 29.53$; $p = 0.0005$; $\varepsilon = 0.31$), but no further significant effects. See Figure 3.8 for the time course of mean heart rate changes (in bpm) per group for each condition.

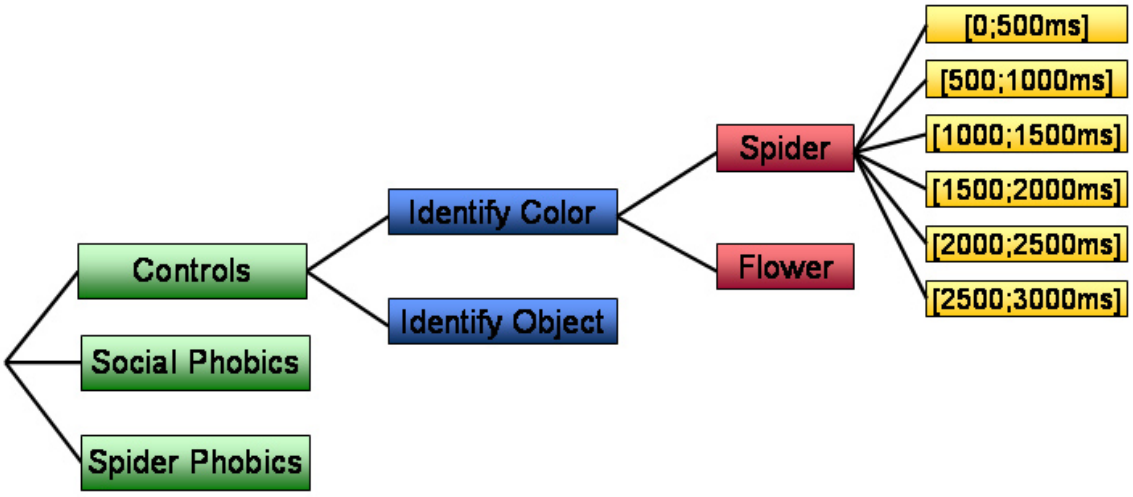


Figure 3.7.: ANOVA design for the analysis of heart rate changes

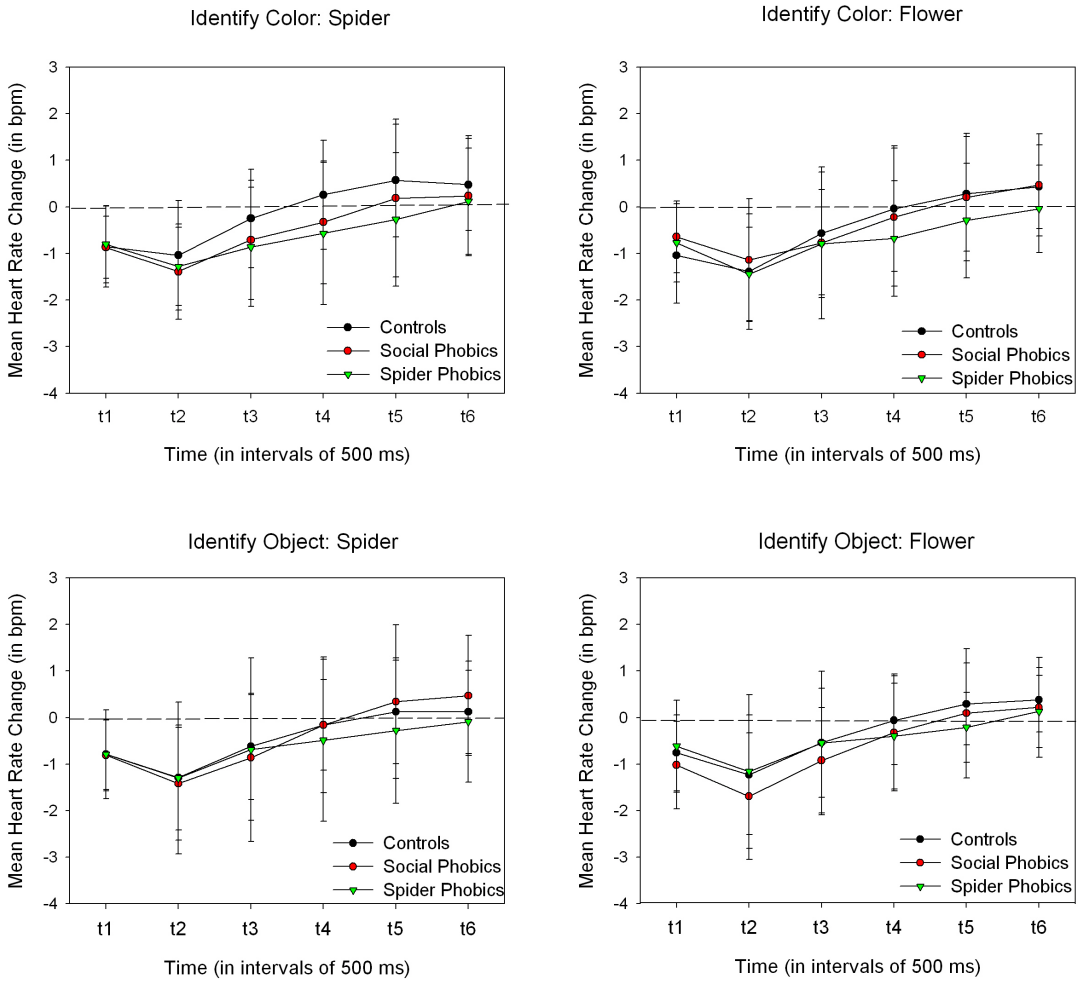


Figure 3.8.: Mean heart rate changes and SDs per time interval of 500 ms for the color (top row) and object (bottom row) identification of spiders (left) and flowers (right) for each group

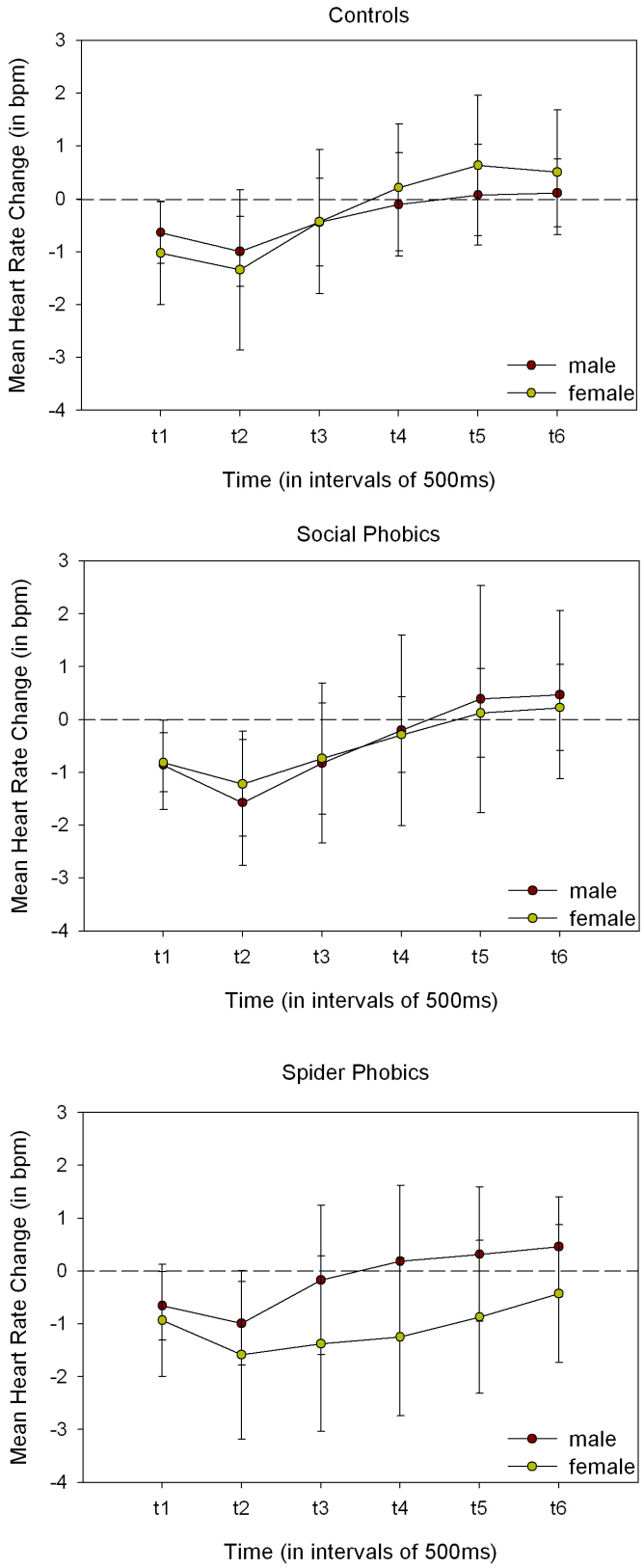


Figure 3.9.: Mean heart rate changes and SDs per time interval of 500 ms in response to spiders for male and female controls (top row), social phobics (center row), and spider phobics (bottom row)

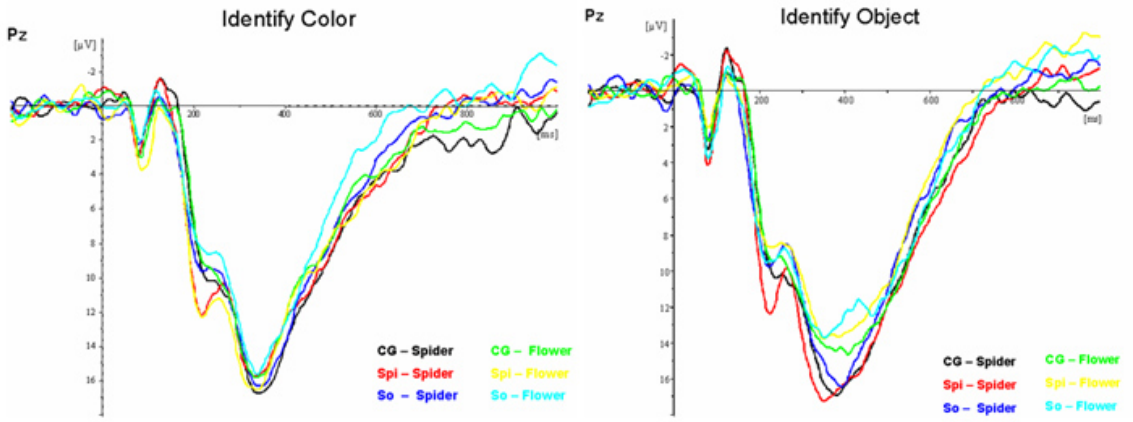


Figure 3.10.: Event-related potentials on electrode P_z. Comparison 'spider–flower' for color (left) and object (right) identification for each group

To analyze whether there were again differences between male and female spider phobics in response to spiders, the between factor *Gender* was included in the above ANOVA design.

Besides a main effect of Time ($F_{(5,250)} = 29.2$; $p = 0.0005$; $\varepsilon = 0.31$), there was a significant interaction of Group × Gender ($F_{(2,50)} = 3.1$; $p = 0.05$) and a nearly significant interaction of Object × Gender ($F_{(1,50)} = 3.64$; $p = 0.06$) as well as a significant interaction of Task × Time × Group × Gender ($F_{(10,250)} = 2.78$; $p = 0.03$; $\varepsilon = 0.4$).

Therefore, subsequent analyses were calculated separately for flowers and spiders. For flowers there was neither a main effect of Gender nor any significant interaction with Gender or Group × Gender. However, for spiders there was a significant interaction of Group × Gender ($F_{(2,50)} = 3.42$; $p = 0.04$). Subsequent ANOVAs calculated separately for each group revealed that while there were no significant differences between males and females for controls and social phobics, there was a significant difference between male and female spider phobics ($p = 0.008$). As can be seen in Figure 3.9, female spider phobics showed a pronounced heart rate deceleration while male spider phobics showed a brief deceleration and then a small acceleration.

3.3.3. Event-Related Potentials

Event-related potentials on electrode P_z in response to spiders and flowers are depicted for each group and both tasks in Figure 3.10.

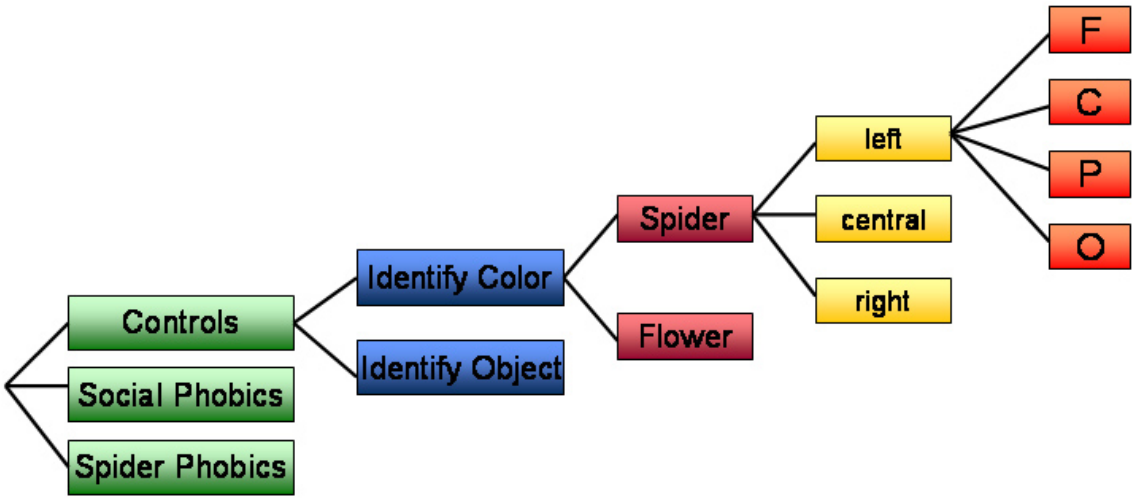


Figure 3.11.: ANOVA design for the analysis of P3 and P4 amplitudes

For the analysis of P3 and P4 amplitude a $3 \times 2 \times 2 \times 4 \times 3$ ANOVA was calculated with between factor *Group* and repeated measures factors *Task* (identify color, identify object), *Object* (spider, flower), *Row* (F, C, P, O), and *Laterality* (left, central, right). The ANOVA design is depicted in Figure 3.11.

P3 Amplitude Besides other effects, there were main effects of Row ($F_{(3,141)} = 60.95$; $p = 0.0005$; $\varepsilon = 0.43$) and of Laterality ($F_{(2,94)} = 14.37$; $p = 0.0005$; $\varepsilon = 0.95$), and a significant interaction of Row × Laterality ($F_{(6,282)} = 34.86$; $p = 0.0005$; $\varepsilon = 0.68$).

As can be seen in Figure 3.12, P3 amplitudes were maximal on parietal sites. Further analyses were therefore conducted only for parietal sites, and the factor Row was excluded.

The second ANOVA, based only on parietal P3 amplitudes, found main effects of Laterality ($F_{(2,94)} = 25.43$; $p = 0.0005$; $\varepsilon = 0.85$) and of Object ($F_{(1,47)} = 17.59$; $p = 0.0005$). Furthermore, there were significant interactions of Task × Object ($F_{(1,47)} = 8.98$; $p = 0.004$), Task × Laterality ($F_{(2,94)} = 3.62$; $p = 0.03$; $\varepsilon = 0.95$), and Object × Laterality ($F_{(2,94)} = 12.29$; $p = 0.0005$; $\varepsilon = 0.88$). The hypothesis-relevant interactions Group × Object ($F_{(2,47)} = 0.3$; $p = 0.74$) and Task × Object × Group ($F_{(2,47)} = 2.7$; $p = 0.08$) failed to be significant.

As can be seen in Figure 3.12, P3 amplitude on parietal sites was maximal centrally. Simple contrasts showed a significant difference between central and right sites ($p = 0.0005$), but no significant difference between the right and the left hemisphere ($p = 0.26$).

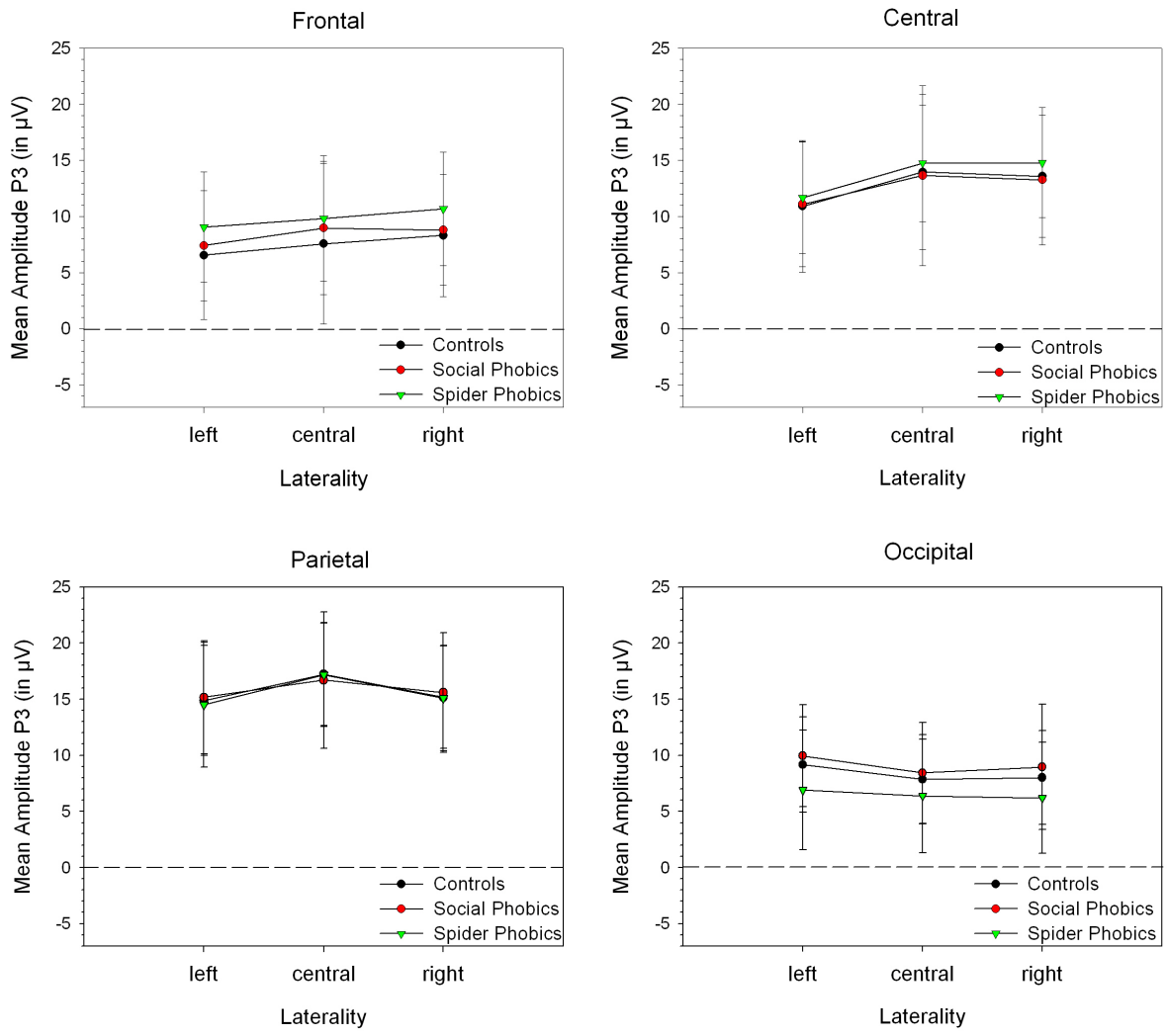


Figure 3.12.: Mean P3 amplitudes and SDs depicted for each group for frontal (top left), central (top right), parietal (bottom left), and occipital (bottom right) sites depending on laterality

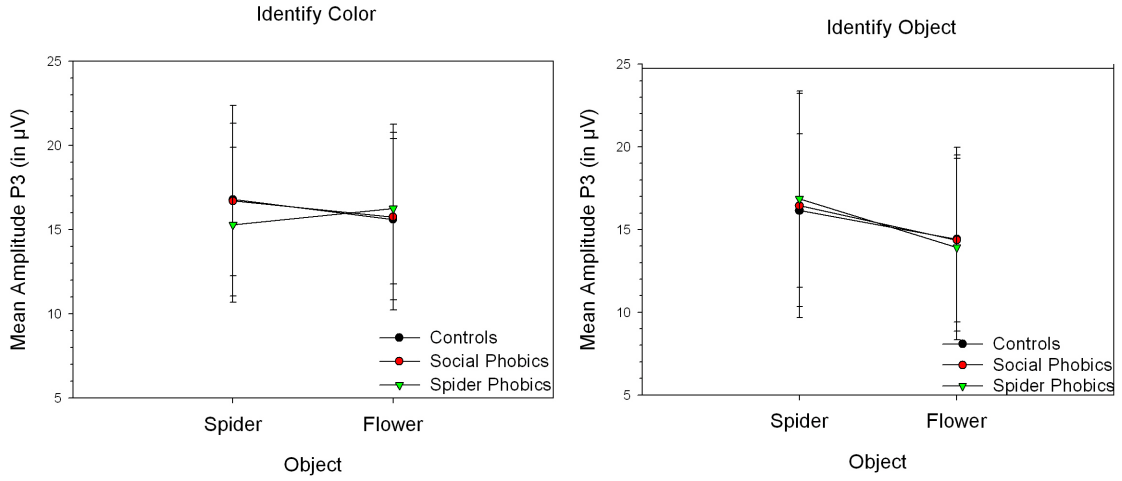


Figure 3.13.: Mean P3 amplitudes and SDs for the color (left) and object (right) identification of spiders and flowers for each group

The above ANOVA found no significant effect of Task but only a tendency for larger P3 amplitudes for color compared to object identification ($F_{(1,47)} = 2.69$; $p = 0.11$).

The main effect of Object showed that in all groups spiders led to larger P3 amplitudes than flowers, and spider phobics did not differ from controls and social phobics in their P3 amplitudes for spiders (compare Figure 3.13).

However, the effect of Object on P3 amplitudes depended on Task as the significant interaction Task × Object indicated. Subsequent ANOVAs were calculated separately for each Task and showed a significant difference between spiders and flowers for object identification ($F_{(1,47)} = 20.36$; $p = 0.0005$) but not for color identification. Schematic spiders did not lead to significantly higher P3 amplitudes when their color had to be identified, but P3 amplitudes were generally larger when a schematic spider had to be identified than when a schematic flower had to be identified. The hypothesis-relevant interaction Task × Object × Group narrowly failed to be significant, although it can be interpreted as a tendency which resulted from the slightly reduced P3 amplitudes in spider phobics when they had to identify the color of a spider (see Figure 3.13).

There was a significant interaction of Object × Laterality, which is depicted in Figure 3.14. For spiders and flowers P3 amplitudes were maximal on electrode P_z. However, only flowers led to slightly larger right vs. left hemispheric P3 amplitudes ($p = 0.06$), while for spiders there was no significant difference between the right and the left hemisphere.

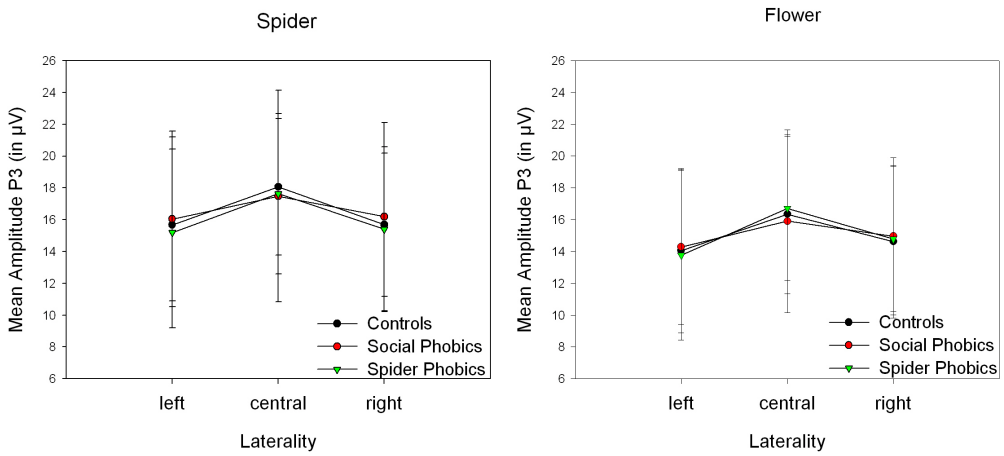


Figure 3.14.: Mean P3 amplitudes and SDs for spiders (left) and flowers (right) per group depending on laterality

Finally, correlations of SPQ values and mean amplitudes in response to spiders independently of task and laterality were calculated. Spider phobics showed a significant correlation of $r = .59$ ($p = 0.017$), indicating that higher SPQ values resulted in larger P3 amplitudes in response to schematic spiders. Such an effect was not found for controls or social phobics.

P4 Amplitude The analysis was performed with a $3 \times 2 \times 2 \times 4 \times 3$ repeated measures ANOVA with between factor *Group* and repeated measures factors *Task*, *Object*, *Row*, and *Laterality*. Compare Figure 3.11 for the ANOVA design.

Again, besides other effects, there were main effects of Row ($F_{(3,141)} = 84.24$; $p = 0.0005$; $\varepsilon = 0.49$) and of Laterality ($F_{(2,94)} = 7.23$; $p = 0.001$; $\varepsilon = 1$), and a significant interaction of Row × Laterality ($F_{(6,282)} = 34.34$; $p = 0.0005$; $\varepsilon = 0.68$).

As can be seen in Figure 3.15, P4 amplitudes were maximal centrally on parietal sites. Thus, the factor Row was excluded from analysis, and all further calculations were based on parietal sites only.

This reduced ANOVA revealed significant main effects of Laterality ($F_{(2,94)} = 25.35$; $p = 0.0005$; $\varepsilon = 0.94$), Task ($F_{(1,47)} = 41.63$; $p = 0.0005$), and Object ($F_{(1,47)} = 7.8$; $p = 0.008$). Furthermore, there was a significant interaction of Task × Laterality ($F_{(2,94)} = 13.84$; $p = 0.0005$; $\varepsilon = 0.92$), but no significant interaction of Object × Laterality ($F_{(2,94)} = 0.44$; $p = 0.6$; $\varepsilon = 0.8$).

Pairwise comparisons showed that P4 amplitudes were maximal centrally (comparison 'left–central': $p = 0.0005$; 'right–central': $p = 0.0005$) and that there was no significant

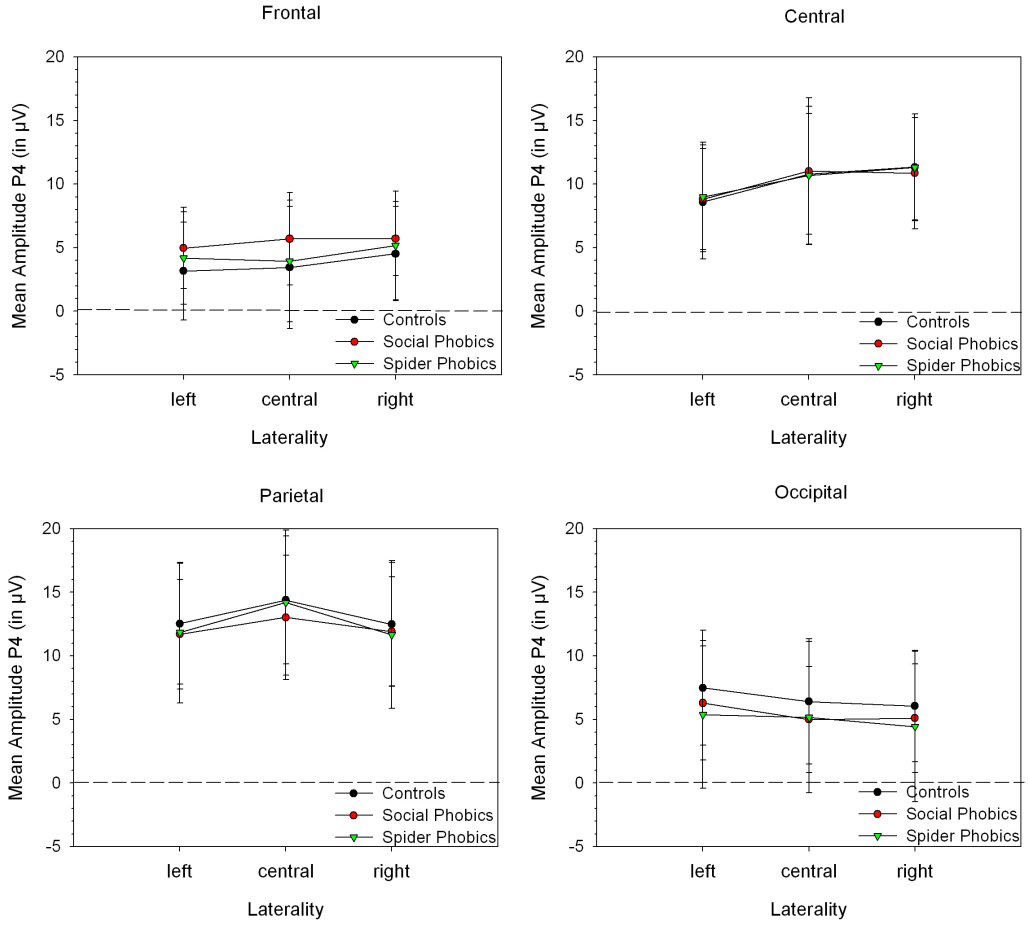


Figure 3.15.: Mean P4 amplitudes and SDs for each group for frontal (top left), central (top right), parietal (bottom left), and occipital (bottom right) sites depending on laterality

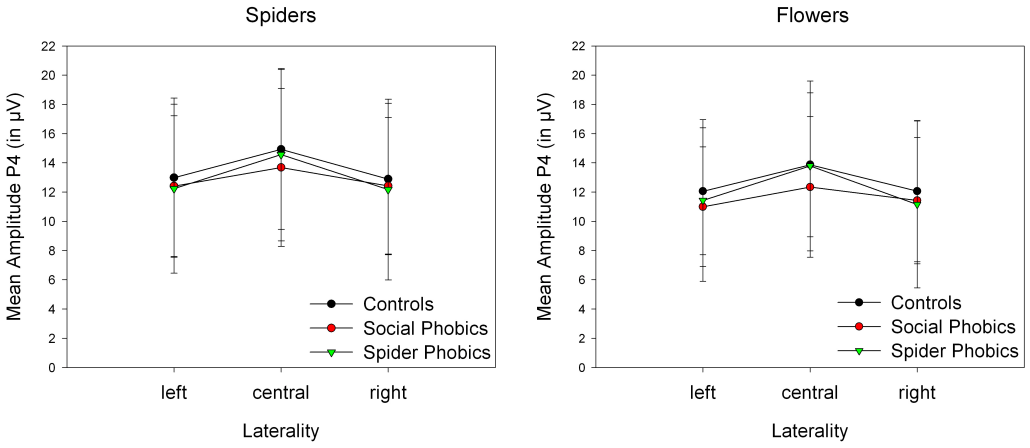


Figure 3.16.: Mean P4 amplitudes and SDs for spiders (left) and flowers (right) depending on laterality for each group

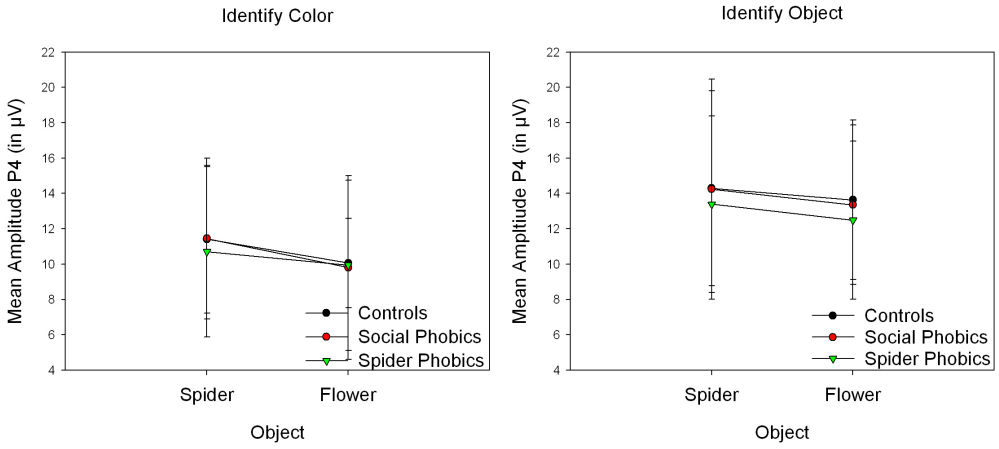


Figure 3.17.: Mean P4 amplitudes and SDs for the color (left) and object (right) identification of spiders and flowers for each group

difference between the right and the left hemisphere ($p = 0.83$). Mean P4 amplitudes and standard deviations in response to spiders and flowers depending on laterality are depicted in Figure 3.16.

Furthermore, the main effect of Task ($F_{(1,47)} = 41.63$; $p = 0.0005$) showed that P4 amplitudes were significantly larger for object than for color identification (see Figure 3.17).

In addition, the main effect of Object ($F_{(1,47)} = 7.8$; $p = 0.008$) indicated that spiders generally led to larger P4 amplitudes than flowers. As can be seen in Figure 3.17, all subjects showed higher P4 amplitudes in response to spiders as compared to flowers, and this effect was not specific for spider phobics. Correspondingly, the interactions Group × Object and Group × Task × Object were not significant.

Finally, correlations of SPQ values with mean P4 amplitudes in response to spiders were calculated independently of task and laterality. For spider phobics a significant correlation of $r = .53$ ($p = 0.04$) was found.

Frontal Positivity The late frontal positivity in the time interval [500 ms; 700 ms] was analyzed by a $3 \times 2 \times 2 \times 3$ ANOVA with between factor *Group* and repeated measures factors *Task*, *Object*, and *Laterality*. Event-related potentials on electrode F_z in response to spiders and flowers for both tasks and each group can be seen in Figure 3.18. Mean amplitudes and standard deviations are depicted in Figure 3.19.

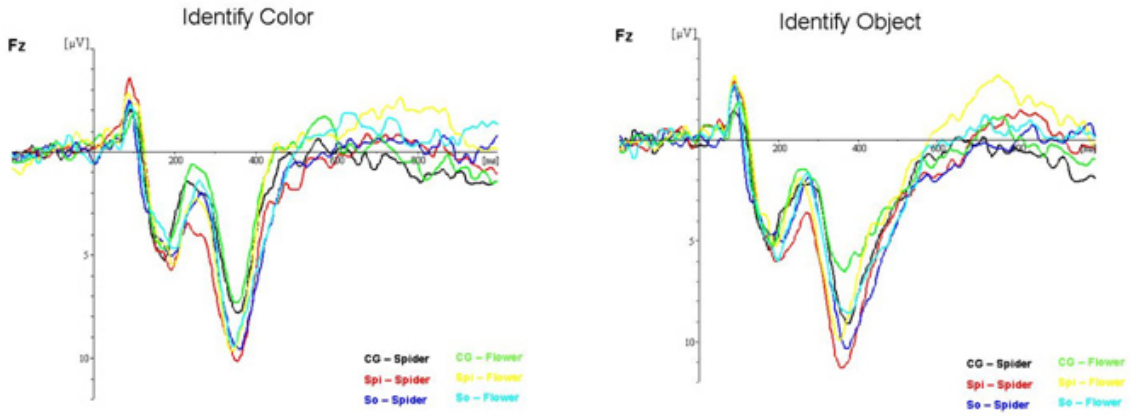


Figure 3.18.: Event-related potentials on electrode F_z: comparison 'spider–flower' for color (left) and object (right) identification for each group

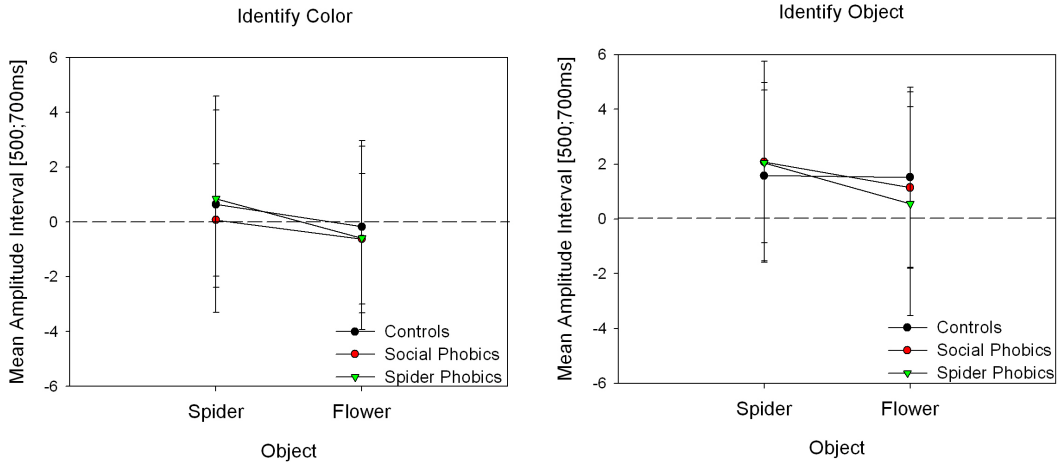


Figure 3.19.: Mean frontal amplitudes and SDs in the time interval [500 ms; 700 ms] for the color (left) and object (right) identification of spiders and flowers for each group

Results showed main effects of Task ($F_{(1,47)} = 19.24$; $p = 0.0005$), Object ($F_{(1,47)} = 14.58$; $p = 0.0005$), and Laterality ($F_{(2,94)} = 17.67$; $p = 0.0005$; $\varepsilon = 0.99$). Simple contrasts revealed that mean frontal positivity was larger over right compared to central ($p = 0.0005$) and compared to left sites ($p = 0.0005$). Furthermore, object identification led to a larger positivity in this time interval than color identification. Also, the main effect of Object indicated that spiders led to a larger positivity in this time range than flowers. However, there were no significant interactions of Group × Object or Group × Task × Object. Thus, an enhanced frontal positivity in spider phobics when identifying the color of spiders, as observed in Experiment I, could not be found.

3.4. Discussion

In this section, the main results of this study will be summarized and the findings of Experiment I and the present study will be compared. Finally, suggestions for future studies will be given.

3.4.1. Summary of Results

Reaction Times

- Reaction times showed no specific emotional Stroop interference in spider phobics when identifying the color of schematic spiders.
- Instead, in the object identification task, all subjects identified spiders significantly faster than flowers, which is consistent with the hypothesis of a general facilitation effect for spiders.
- The specific facilitation effect in spider phobics was confirmed: spider phobics identified spiders significantly faster than controls and social phobics. However, it must be noted that spider phobics also identified flowers significantly faster than controls and social phobics.

Heart Rates

- Analysis of heart rates showed an orienting response in all groups in response to flowers and spiders.

- Although spiders are generally more arousing than flowers (as shown in the pilot study), spiders did not lead to a larger heart rate deceleration than flowers in social phobics and controls.
- Furthermore, no spider phobia-specific effects were found unless gender was included in the analysis. Female spider phobics showed a pronounced orienting reaction in response to spiders which was not observed in male spider phobics. In particular, no defense reaction was observed.

Event-Related Potentials: P3

- Analysis of ERPs showed significantly larger parietal P3 amplitudes in all subjects when identifying spiders as compared to flowers. This effect was not present in the color identification task. Thus, a general arousal effect of spiders on P3 amplitudes was partially confirmed.
- Spider phobics did not differ in P3 amplitudes in response to spiders from control groups. Thus, no additional specific arousal effect on P3 amplitudes was found in spider phobics.
- For both spiders and flowers, P3 amplitudes were maximal centrally over parietal sites, with no significant differences between the right and the left hemisphere.

Event-Related Potentials: P4

- P4 amplitudes were larger in response to spiders in all subjects independently of the task they performed. Thus, a general effect of arousal on P4 amplitudes was found.
- Again, spider phobics did not show enhanced P4 amplitudes in response to spiders compared to controls and social phobics, i.e. no specific arousal effect on P4 amplitudes in spider phobics was found.
- For both spiders and flowers, P4 amplitudes were maximal centrally over parietal sites, with no significant differences between the right and the left hemisphere.

Finally, the significant correlations of P3 and P4 amplitudes with SPQ values in spider phobics provide evidence for an association between severity of spider phobia and magnitude of P3 and P4 amplitudes in response to spiders. This parallels the results in Experiment I.

Event-Related Potentials: Late Frontal Positivity Finally, this study did not find evidence for an enhanced frontal positivity in spider phobics when viewing pictures of spiders.

3.4.2. Comparisons of Findings in the Emotional Stroop Paradigm with Schematic and Non-Schematic Pictures

Reaction Times As in the emotional Stroop paradigm with non-schematic pictorial stimuli, this study could not find evidence of *emotional Stroop interference* in spider phobics. Possible explanations for this finding were already discussed in Section 2.4.2. As in Experiment I, this result again raises the question how strongly Stroop interference depends on verbal processing specificities, i.e. on the combination of verbal stimuli and a verbal response mode.

In Experiment I, spider phobics showed a specifically facilitated response for non-schematic pictures of spiders, while in Experiment II, all subjects showed faster reaction times for schematic spiders compared to flowers. The latter finding supports the theory of Öhman (1993) that fear-relevant stimuli are processed with high selectivity and priority in all subjects, whether phobic or not. In Section 2.4.3, a possible explanation for the result of Experiment I was suggested, in accordance with Öhman (1993): feature detectors in spider phobics might be set to filter incoming stimuli preferentially for spider-related features. This would also account for the finding in Experiment II that spider phobics identified schematic spiders even faster than social phobics and controls.

However, two open questions must still be answered to account for the findings of Experiments I and II: first, why did social phobics and controls not also show facilitated responses for non-schematic spiders but only for schematic spiders? Second, why did spider phobics also identify non-schematic flowers and birds significantly faster than social phobics and, as a tendency, faster than controls, and similarly, why did they also identify schematic flowers faster than social phobics and controls?

Concerning the first question, one possible interpretation of the reported data is that "generalization" plays a role: schematic spider images might depict fear-relevant features to which the feature detectors postulated by Öhman (1993) are tuned in all humans independently of whether individuals are phobic or not. It appears possible that spider phobics generalize better from the real-life spider to the spider schematic, which could explain their faster reaction to spiders found in Experiment I.

As an answer to the second question, the concept of hypervigilance in anxious individuals was already introduced in Section 2.4.3. It would explain why spider phobics responded generally faster than controls and social phobics in Experiment II, and it would be consistent with the non-significant tendency of spider phobics to identify all objects faster than controls and social phobics in Experiment I. The differences between Experiment I and II might be due to varying task difficulties of both experiments: while Experiment I required a decision between three response alternatives (Spider, Flower, Bird), Experiment II only required a choice between two possible responses (Spider, Flower). The easier task might have potentiated the faster responses in spider phobics, resulting in generally faster responses for schematic spiders and flowers.

Heart Rates In Experiment I and II, the analysis of heart rate data revealed normal *orienting reactions* in response to neutral objects in all subjects, which was consistent with our hypotheses. However, contradictory to our hypotheses the orienting response was not more pronounced in social phobics and controls for the more arousing spider stimuli than for the neutral stimuli, as was suggested by Lang et al. (1997).

In contrast to previous studies investigating heart rate changes in phobics in response to their feared object (Fredrikson, 1981; Globisch et al., 1999; Hare & Blevings, 1975; Krieschel, 2003), neither Experiment I nor Experiment II found evidence for a *defense reflex* in spider phobics in response to spiders. However, when gender was included in the analysis of heart rates, there was evidence that male and female spider phobics showed specific, but distinct, peripherphysiological reactions to their feared object. In Experiment I, male spider phobics showed a defense pattern of heart rate change, while female spider phobics showed a pronounced orienting reaction in response to spiders. In Experiment II, only female spider phobics showed a deviating response pattern, i.e. a pronounced orienting reaction in response to pictures of spiders. Thus, the data are consistent in that in both experiments female spider phobics showed a pronounced orienting response to spiders, but inconsistent in that male spider phobics showed a defense reaction in response to non-schematic spiders but not in response to schematic spiders.

However, due to the high variances between subjects in Experiment I and because of the small group sizes the heart rate data should be interpreted with caution. No final conclusions as to whether differences between male and female spider phobics in their response to the feared object exist should be drawn unless the data are replicated and corroborated by further studies.

Event-Related Potentials While Experiment I found significantly enhanced *P3 and P4 amplitudes* in spider phobics when viewing pictures of spiders independently of task, Experiment II could not find evidence for a spider phobia-specific effect. Instead, all subjects showed larger P3 and P4 amplitudes when identifying spiders compared to flowers. It has to be noted that in Experiment I controls also had higher P3 amplitudes for spiders compared to flowers, and social phobics had higher P4 amplitudes for spiders compared to flowers. However, these effects were more of a tendency.

In Experiment II, the larger P3 and P4 amplitudes for schematic spiders than for schematic flowers in all subjects fit the well documented finding that parietal late positive components are influenced by the affective arousal of stimuli (e.g. Cuthbert et al., 2000; Schupp et al., 2000), which is higher for schematic spiders than flowers (see results of the pilot study). However, the results by Gutberlet and Miltner (1999, 2001) and Krieschel (2003), who found larger P3 amplitudes in spider phobics for their feared object, could not be replicated with schematic spider stimuli. This finding still has to be explained.

It is possible that although subjects rated schematic and non-schematic stimuli as nearly equivalently aversive (arousal and valence dimension), the schematic stimuli were not as frightening (or disgusting?) for the spider phobics as the non-schematic pictures, which could explain the missing spider phobia-specific enhancements of LPPs. This would also account for the missing late frontal positivity in spider phobics when identifying the color of schematic spiders, which was hypothesized to be an indicator of attentional dwell-time in the discussion of Experiment I. Perhaps the schematic stimuli were not realistic enough, so that spider phobics did not dwell on them as they did on the more realistic non-schematic pictures. Future studies will have to replicate the results of the present study with schematic stimuli and will have to find answers for the unexpected results.

3.4.3. Suggestions for Future Studies

Essentially, the suggestions for future studies of Experiment I also apply to the present experiment, with the only difference that schematic stimuli would have to be used in the proposed study designs. Furthermore, a comparison of the results of Experiment I and II leads to some further unresolved questions:

In both experiments differences in heart rates between male and female spider phobics in response to their feared object were observed. We know of no study which explored

gender differences in spider phobics in the processing of feared stimuli. Therefore, it would be interesting to replicate both experiments with larger samples of male and female spider phobics to increase statistical power.

An explanation for the observed differences between male and female spider phobics could be differences in the *subjective emotional experiences* of fear of spiders. For example, it is possible that the high variances in heart rate data in Experiment I were due to different subjective experiences of spiders, e.g. strong *fear vs. disgust*. Recently, researchers have begun to consider the potential role of disgust in phobias, especially in animal phobia (Vernon & Berenbaum, 2002). It could be important to distinguish between fear and disgust, since the emotional reaction of disgust is very different from a reaction of fear. For example, while disgust is associated with nausea (Rozin & Fallon, 1987), the physical manifestation of fear is a pounding heart (Roseman, Wiest, & Swartz, 1994). In particular, while heart rate deceleration is likely to occur during a disgust response, heart rate acceleration is likely to occur during a fear response (Levenson, 1992). Thus, the gender differences in spider phobics observed in Experiment I and II could also be due to differences in emotional experiences (disgust and/or fear) in response to spiders. Therefore, it seems promising to study the relation between the subjective experience of the picture of a spider (fear vs. disgust) and physiological responses to spiders.

4. Experiment III – Which Properties Make a Spider Fear-Relevant? – A First Approach

4.1. Introduction: Aims and Hypotheses

The third experiment was a first approach to investigate which properties make a spider fear-relevant. In Öhman's evolutionary model, which was described in detail in Section 1.3.5, the existence of specific feature detectors has been postulated. These detectors preferentially pick up elementary threat features and, if such a threat feature is detected, automatically and still preattentively activate the arousal system and select this feature for preferential treatment by the significance evaluation system (Öhman, 1993). However, as Öhman et al. (2001, p. 475) admit, "such elementary threat features [...] still remain to be specified." Is it the typical sinusoidal shape of a snake that is picked up by feature detectors? Is it the shape of the body of a spider, its protruding legs, the angle in which the legs are positioned relatively to each other? Or is it not the shape, but rather the movement of a spider or a snake that is detected by these feature detectors? Or do the feature detectors respond to other features?

The feature detectors postulated by Öhman should presumably also respond to certain features of socially threatening stimuli, e.g. angry faces. Aronoff, Barclay, and Stevenson (1988) studied "sign vehicles" (Ekman, 1982), i.e. specific characteristics of facial displays which convey certain emotional expressions like threat. Therefore, they studied masks of non-Western cultures and American samples for specific characteristics that discriminate between threatening and non-threatening facial expressions.

Starting out from the results of this study, they designed a set of diagonal, angular, and curvilinear visual stimuli which subjects rated on three bipolar semantic differential scales according to Osgood, Suci, and Tannenbaum (1957): evaluation (e.g. pleasant–unpleasant), potency (e.g. weak–strong), and activity (e.g. calm–excitable). They concluded that the non-representational features of *angularity* and *diagonality* in the visual stimulus convey the meaning of threat, i.e. the more angular or diagonal pattern evoked a more negative, potent, and active subjective reaction in the observer than did the more curvilinear pattern. On the other hand, babyishness and cuteness in infants and facial attractiveness in young women all avoid sharp angles in preference to more curvilinear forms (Cunningham, 1986; Berry & McArthur, 1985, 1986).

More recently, Lundqvist, Esteves, and Öhman (1999) were able to show that the eyebrows are crucial in distinguishing between threatening and non-threatening facial expressions. The shape of the mouth and the eyes are important for subsequent processing. Therefore, it has been proposed that the ⋁-shaped eyebrows of a schematic angry facial expression are a powerful determinant for negative evaluation of faces and capture visual attention (Lundqvist et al., 1999; Lundqvist, 2003; Öhman et al., 2001). In line with these results, Öhman et al. (2001) reported that faces with ⋁-shaped eyebrows were more rapidly and accurately located in a visual search task than faces with ⋀-shaped eyebrows (friendly faces). Tipples, Atkinson, and Young (2002) could confirm the advantage of ⋁-shaped (angry and scheming expressions) compared to ⋀-shaped eyebrows (happy and sad expressions). However, they could find no advantage for ⋁-shaped lines if they were presented in a non-facelike object. Similarly, Lundqvist, Esteves, and Öhman (2004) found that single schematic facial features such as the eyebrows or the mouth can communicate a relatively strong facial impression on their own. Eyebrows were the single most important feature expressing threat in schematic faces. However, the effect of single features was modulated by configuration. Simple configurations of eyebrows and mouth significantly predicted the impression of complete faces they were part of.

Thus, what conveys threat in facial displays has already been systematically investigated. However, which properties make a spider fear-relevant, i.e. which visual features of spiders convey threat and activate the feature detectors postulated by Öhman (1993) has not yet been investigated. The present study attempted to fill the gap in this field of research by investigating the influence of Gestalt properties on behavioral and electrocortical measures in spider phobics and non-phobics, where *Gestalt* refers to the perception of a whole as a result of the relation of its parts to each other (Goldstein,

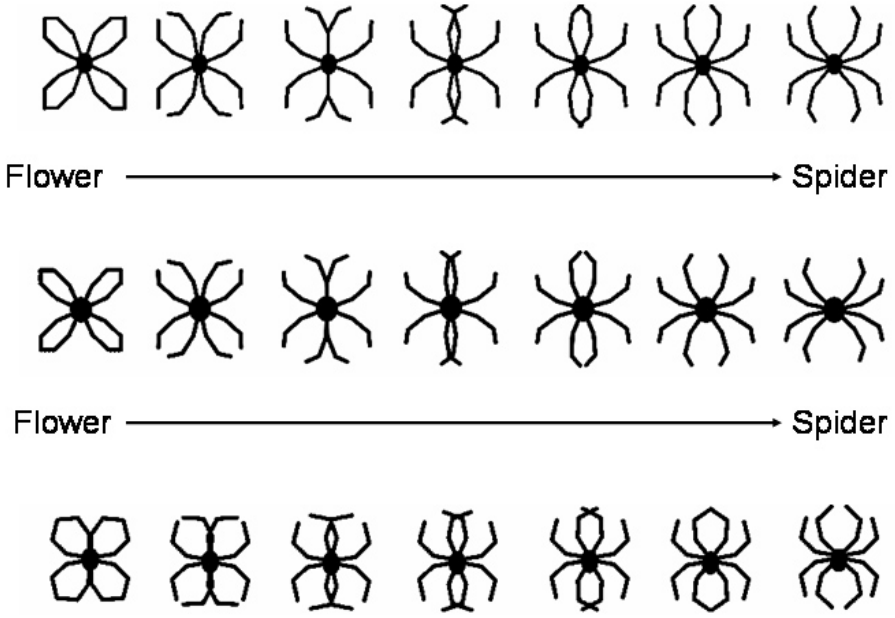


Figure 4.1.: The three different flower/spider series

1997)[1].

For this purpose, three series of schematic flower/spider pictures were designed: flower anchors differed with regard to the size of the interior of the flower and the angularity of the outlines of the petals, while spider anchors differed with regard to body size and angularity of spider legs (see Figure 4.1). Between the anchor pictures, the configurational position of the legs of a schematic spider in relation to its body was systematically varied. More specifically, each series contained seven pictures which, starting from the picture of a flower, gradually turned into a spider by shifting the angles of the outlines of the petals, turning them into spider's legs. The anchor stimuli of each series were similar to the spider and flower pictures used in Experiment II.

Three groups of subjects participated in this study: spider phobics, social phobics, and controls. All subjects rated the stimuli according to their valence and arousal. In the actual paradigm, subjects saw the stimuli detailed above and classified them into one of the three categories "flower", "spider" and "neither/nor" while ERPs were measured. Dependent variables were valence and arousal ratings, reaction times, classification

[1]The term 'Gestalt' became important for the field of psychology by the investigations of von Ehrenfels (1890). 'Gestaltpsychology' is a school of thought founded by Wertheimer (1912). Its central postulate is that the whole is more than the sum of its parts.

frequencies, and event-related potentials in response to each of the different stimuli.

In this setting, one could hypothesize that spider phobics show a 'stimulus generalization effect' or an 'interpretive bias', particularly for ambiguous stimuli. The term *stimulus generalization*, which was introduced by Pawlow (1927), comes from learning psychology and refers to the fact that a given response (conditioned or unconditioned) can be elicited to some degree by a range of similar stimuli. The most famous example of such a stimulus generalization effect is the experiment of Watson and Rayner (1920) with *Little Albert*. At first, the eleven month old boy did not show any sign of fear of a white rat. However, after five attempts of the child to reach for the rat which were always paired with a loud bang, the boy did not only show fear symptoms at the mere sight of the rat but also feared teddy bears.

In contrast, the term *interpretive bias* comes from cognitive psychology and was used above to describe a bias in social phobics to interpret ambiguous social situations as negative (compare Section 1.3). This study explored whether spider phobics showed a similar generalization effect or interpretive bias for ambiguous stimuli, which should be expressed in all dependent variables, as detailed below. Due to the lack of research in this field, this question was more exploratory.

We expected the following results:

Valence and Arousal Ratings

- It was expected that, as in Experiment II, all subjects rate schematic spider anchors as more aversive (arousing and unpleasant) than schematic flower anchors.
- Furthermore, spider phobics should rate their feared object, i.e. spider anchors, as specifically more unpleasant and arousing than controls and social phobics, as was already found in Experiment II.
- We hypothesized that spider phobics exhibit a stimulus generalization or interpretive bias effect, which leads to more aversive ratings for ambiguous pictures in the middle of the flower/spider series compared to social phobics and controls.

Reaction Times

- We hypothesized to find a *general facilitation effect* for fear-relevant stimuli. Since, according to Öhman, fear-relevant stimuli are processed with high

selectivity and priority, all subjects should identify spider anchors faster than flower anchors.

- It was expected that spider phobics show an additional *specific facilitation effect*, i.e. faster reaction times for spider anchors and pictures they judged to be similar to spiders than the other groups.
- The more ambiguous the stimuli, the more reaction times should increase, because it takes subjects longer to decide which stimulus they perceive in the presented configuration. In particular, the fastest reaction times were expected for the unequivocal flower/spider anchor pictures.
- We expected that spider phobics respond faster to ambiguous pictures they judge to be spider-like compared to controls and social phobics, expressing stimulus generalization or interpretive bias effects.

Classifications

- The closer the position of a picture in the flower/spider series to an anchor picture, the more often the individual picture should be classified as belonging to the corresponding anchor picture category, since it shares similar features with this anchor.
- Pictures in mid-positions should be classified more often into the category *"neither/nor"* due to their higher ambiguity.
- It was explored whether there were thresholds in the transition of a flower into a spider and vice versa at which a switch in perception towards a flower or a spider occurs.
- Finally, this study explored whether spider phobics differ from controls and social phobics in their classification of the different stimuli, in particular of the ambiguous ones as a result of a stimulus generalization or interpretive bias.

Event-Related Potentials

- It was hypothesized that all subjects show larger LPPs in response to spider anchors and spider-like pictures than in response to flower anchors due to their higher emotionality (valence and arousal).
- We originally expected larger LPPs in spider phobics than in social phobics and controls in response to spider anchor pictures as found in Experiment I

for non-schematic spider pictures, although Experiment II showed no such effect using schematic spider pictures.

- However, it was hypothesized that due to stimulus generalization or interpretive bias, spider phobics would show larger LPPs than social phobics and controls in response to ambiguous pictures they judged to be spider-like.
- Finally, according to Johnson (1986; see Section 1.6.1) information transmission influences LPP amplitudes: with increasing uncertainty in identifying the eliciting event, P3 amplitude is reduced. Thus, ambiguous pictures should lead to smaller LPPs than the more unequivocal anchor pictures.

4.2. Methods

4.2.1. Subjects

34 subjects of Experiment I also participated in Experiment III, but 10 new subjects were recruited to fill groups. Thus, altogether 44 subjects (mean age 23 yrs, SD 3.8 yrs, age range: 19–34 yrs) participated in the study: 16 spider phobics (8 male, 8 female), 13 social phobics (6 male, 7 female), and 15 normal controls (9 male, 6 female). 42 subjects were right-handed and 2 were left-handed as measured by the Edinburgh handedness questionnaire (Oldfield, 1971). There was no significant difference between groups regarding gender (Pearson $\chi^2_{df=2} = 0.59$; $p = 0.75$). However, the Kruskal-Wallis Test showed a significant difference between groups regarding age ($\chi^2_{df=2} = 8.66$; $p = 0.01$). Mean age of spider phobics was 22 yrs (SD = 3.3), of social phobics 26 yrs (SD = 4.6), and of controls 23 yrs (SD = 2.4). Subsequent pairwise comparisons showed that social phobics were significantly older than spider phobics (Mann-Whitney-U Test $U = 41$; $p = 0.005$). However, since all subjects were in a relatively narrow age range (19–34 yrs) these age differences seem to be of minor importance.

Subjects were recruited by newspaper advertisement and within the university student population. All participants provided informed consent, and the procedures were approved by the ethics committee of the Friedrich Schiller University Jena. To be accepted for the study, subjects completed the same questionnaires and had to fulfill the same criteria as in Experiment I and II. See Section 2.2.1 for a detailed description.

Kruskal-Wallis Tests showed that groups differed significantly in SPQ, SPAI and BDI. See Table 4.1 for each test per group as well as exact χ^2 and p-values. Subsequent

Group	SPQ	SPAI	SPAI (orig.)	BDI	STAI
Spider Phobics: Mean	20.31	31.54	45.88	4.81	33.75
SD	2.60	9.31	13.54	4.13	8.43
Social Phobics: Mean	2.23	88.13	128.19	8.62	51.31
SD	1.96	12.00	17.46	5.17	5.15
Controls: Mean	2.13	25.48	37.06	3.60	31.20
SD	1.73	12.16	17.69	3.44	6.82
Kruskal-Wallis Test: $\chi^2_{df=2}$	30.19	28.03	28.03	7.24	22.85
p-value	0.0005	0.0005	0.0005	0.03	0.0005

Table 4.1.: Mean questionnaire values and SDs per group; results of Kruskal-Wallis Test (χ^2 and p-values)

pairwise comparisons with the nonparametric Mann-Whitney-U Test showed that controls differed from spider phobics in the SPQ ($U = 0$; $p = 0.0005$) and from social phobics in the SPAI ($U = 0$; $p = 0.0005$), BDI ($U = 42.5$; $p = 0.01$), and STAI ($U = 5$; $p = 0.0005$). Furthermore, social phobics and spider phobics differed significantly in the SPQ ($U = 0$; $p = 0.0005$), SPAI ($U = 0$; $p = 0.0005$), BDI ($U = 59$; $p = 0.05$), and STAI ($U = 13.5$; $p = 0.0005$). Thus, again social phobics had on average higher BDI values than controls and spider phobics. However, all social phobics had BDI scores below 16 and were thus in a clinically non-significant range. Therefore, unlike in Experiment I and II, no ANCOVAs with BDI values as a covariate or correlations of BDI and dependent variables were calculated.

4.2.2. Assessment of Valence and Arousal Ratings

Prior to the experiment, all stimuli were rated as to their affective valence and physiological arousal using an adapted version of the self-assessment manikin scale (SAM; Bradley & Lang, 1994; Lang, 1980; cf. Appendix B). The pictures were presented in one of four different randomized orders for 10 s with an interstimulus interval of 12 s. Subjects were instructed not to speak while the stimuli were being presented but to give their valence and arousal ratings verbally after stimulus presentation. They practiced the procedure with 3 training trials. For reference, a sheet of paper with the rating scheme (cf. Appendix B) lay in front of the subjects.

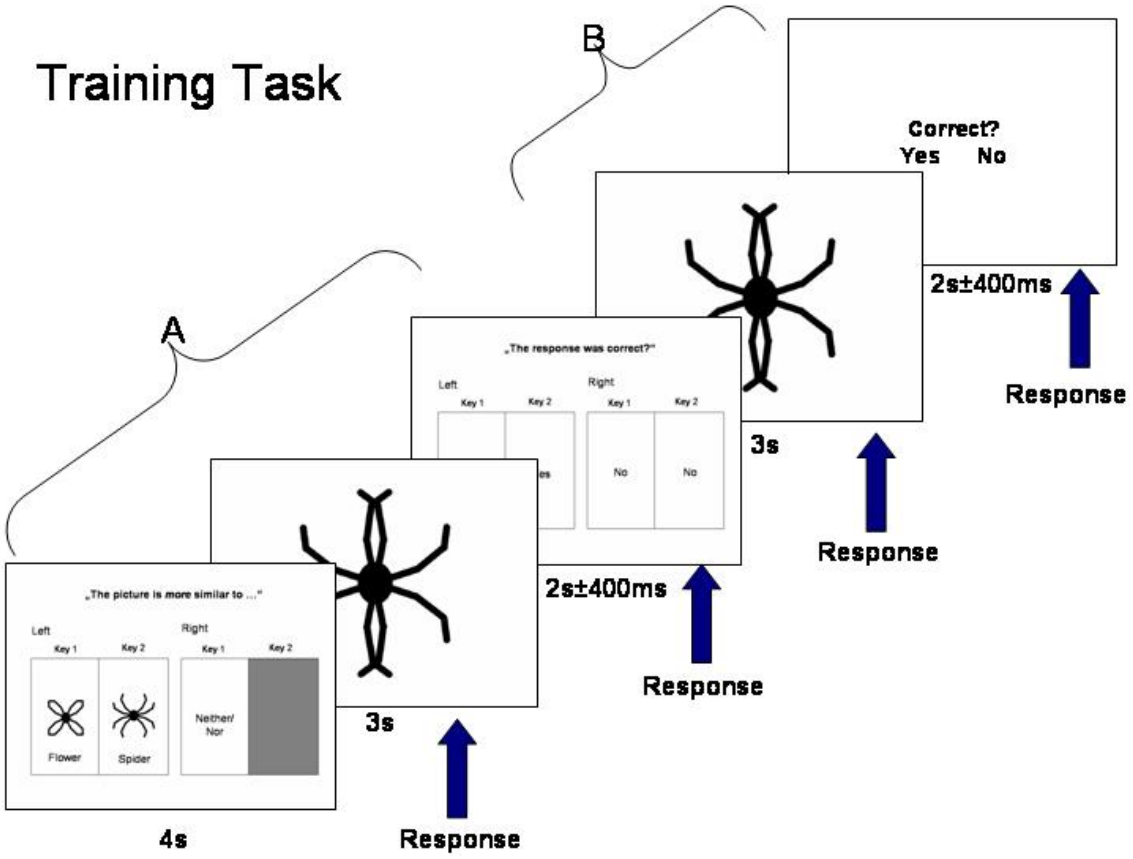


Figure 4.2.: The two phases A and B of the training task, which subjects could repeat independently as often as necessary

4.2.3. Paradigm

Subjects' task was to decide whether the stimuli detailed above were more similar to a "spider", a "flower", or "neither/nor".

Before the experiment started, participants performed two training tasks which they could repeat as often as necessary. The first training task (phase A) consisted of 9 trials. Before each trial, the key sequence for the buttons mounted on the arm-rests was shown for 4 s on the screen. Then one of the stimuli was presented on the screen for 3 s, and subjects indicated their classification by pressing the appropriate key. They were instructed to respond as quickly as possible.

After each classification the subject confirmed, again by pressing a button, whether the response had been correct or incorrect. Since we were interested in the subjective evaluation of stimuli there were no predefined right or wrong answers, but subjects could still have pressed an unintended button by mistake and would now indicate that they had made an error. This procedure was necessary for the later identification of

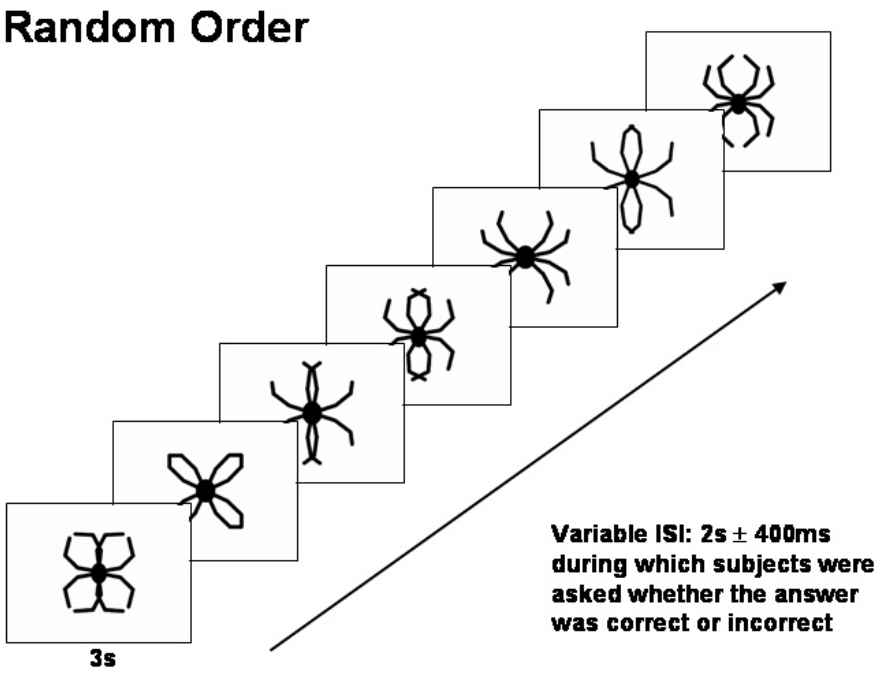


Figure 4.3.: The first paradigm: random stimulus presentation

errors which otherwise would have been impossible.

The second training task (phase B) also consisted of 9 trials. However, this time no key sequence was shown, and the confirmation screen was simplified to "Correct?" (see Figure 4.2).

The sequence of keys which had to be pressed to classify the stimuli was randomized across subjects. In case subjects forgot during the experiment which key stood for which response category, a sheet of paper showing the correspondence between keys and answer categories lay in front of them. However, to reduce movement artifacts, subjects were instructed to look at this sheet only if absolutely necessary.

The experiment itself consisted of two paradigms: a *random* (see Figure 4.3) and an *ascending/descending* (see Figures 4.4 and 4.5 as well as the discussion below) presentation of stimuli. These two paradigms were chosen to investigate whether individual stimuli were classified differently depending on stimulus context: in the random order presentation, stimuli should be judged relatively independently of preceding stimuli, while in the ascending/descending order paradigm, subjects could develop expectations and persevering response tendencies.

Each stimulus was presented for 3 s, during which subjects gave their answer by pressing the appropriate key. In the interstimulus interval of 2 s ± 400 ms (1600 ms plus

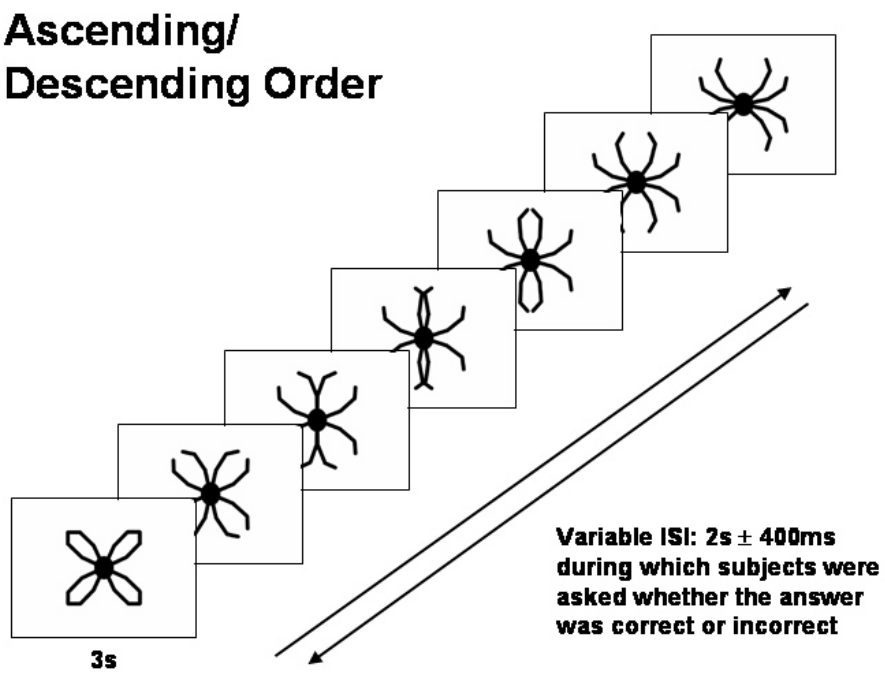


Figure 4.4.: The second paradigm: ascending/descending stimulus order

an exponential distribution with mean 400 ms, truncated at 800 ms, as generated by ERTS), the question "Correct?" appeared on the screen, and subjects indicated by pressing a button whether the answer given had been right or wrong.

Subjects always started with the random order paradigm, since we wanted to get the unbiased response of subjects to each individual stimulus. The order of the stimuli in this paradigm was pseudo-randomized so that no picture appeared twice in a row. The following ascending/descending order paradigm was available in two versions: one started with a flower anchor and went to the corresponding spider anchor, then switched to the spider anchor of another series and returned to the corresponding flower anchor. Then, again, the flower/spider series was switched. The other version started with the spider anchor, went to the corresponding flower anchor, switched to the flower anchor of another series and returned to the corresponding spider anchor and so on. Figure 4.5 illustrates the sequence of stimuli. Half of the subjects in each group started with the spider anchor, the other half started with the flower anchor.

After a switch to a new flower/spider series in the ascending/descending order paradigm, the new anchor picture was presented twice. The first presentation (which is called a *dummy picture* here) was later discarded, and only the second was used for further analysis. This was done to avoid a more pronounced orienting response due to the

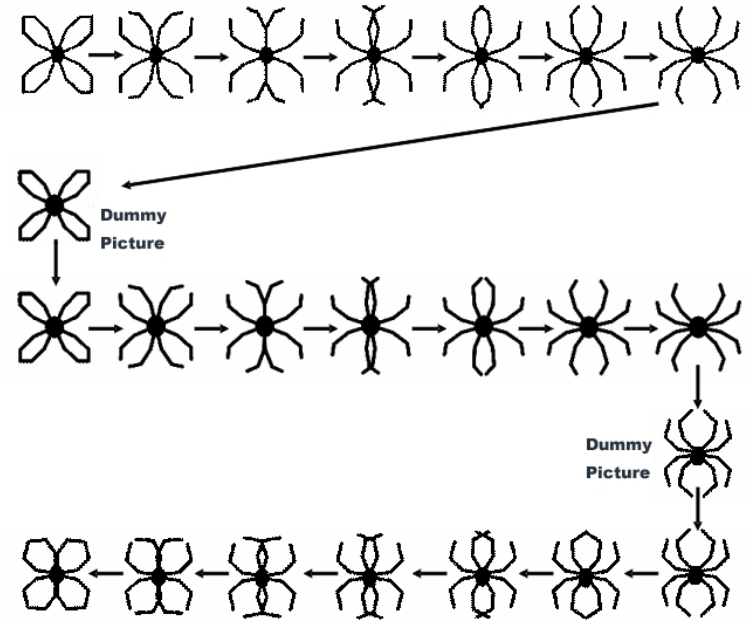


Figure 4.5.: Example of the succession of stimulus series in the ascending/descending order paradigm

switch of flower/spider series.

To avoid fatigue in subjects, both paradigms were split into two blocks with a short break between them. In both the random and the ascending/descending paradigm, each picture of the three flower/spider series was presented 14 times.

4.2.4. Assessment of EEG

All parameters of EEG data acquisition were the same as in Experiment I. Compare Section 2.2.4.

4.2.5. Analyses of Dependent Variables

Analysis of Relative Response Frequencies

Analyses were performed separately for both the random and the ascending/descending order paradigm. All wrong responses, i.e. when subjects indicated that they made a incorrect response, were excluded from further analysis. For each picture in each series the relative response frequencies for each category ("spider", "flower", "neither/nor") were calculated, i.e. the number of classifications of this picture as a "spider", a "flower" or "neither/nor", divided by the total number of correct answers to this picture by each

subject. Then, the relative frequencies of the corresponding pictures in each series (e.g. the three flower anchors) were averaged over the three different flower/spider series.

Analysis of Reaction Times

Before averaging, data were screened for outliers and extreme values. Values deviating more than 2 standard deviations from the mean were excluded from analysis. In this way, 4.95% of the correct trials were excluded. Mean reaction times in response to each picture were calculated. Then, the reaction times of the corresponding pictures in the three series were averaged.

Analysis of Event-Related Potentials

The EEG data were filtered (low pass = 30 Hz, 24 dB/oct; high pass = 0.1 Hz, 24 dB/oct; 50 Hz notch), segmented [−200 ms; 1300 ms], corrected for blinks and eye movements (Gratton et al., 1983), and screened for artifacts using the software Brain Vision Analyzer 1.04. Only those trials were included in the further analysis in which subjects had indicated that their classification was correct. The mean averages for each condition and for each subject were baseline corrected using the [−200 ms; 0 ms] period as a baseline and then rereferenced to the averaged linked earlobes.

While screening the data one could easily identify multiple late positive components, which were most apparent for the intervals [300 ms; 500 ms] and [600 ms; 800 ms]. As in Experiment I and II, temporal Principal Components Analyses (PCA) were calculated for the random order and ascending/descending order paradigm to confirm the existence of multiple positive components. For a description of parameters compare Section 2.2.5. First, the factor analyses were performed with eigenvalue 1 as limit, then the numbers of factors were limited to seven as a compromise between taking all relevant factors into account and keeping complexity manageable.

Random Order Paradigm The seven factors identified are depicted in Figure 4.6. Factor 1 accounted for 54.2% of total variance, factor 2 for 14.5%, factor 3 for 6.5%, factor 4 for 3.5%, factor 5 for 2.8%, factor 6 for 2.1%, and factor 7 for 1.7%.

In the latency range of 250 ms to 850 ms, at least four different late components were identified: factors 2, 4, 6, and 7. Their spatial distributions are depicted in Figure 4.7. Factor 7 occurred relatively early around 250 ms, and its spatial distribution was more

occipital. However, factors 2 and 4 had a clear posterior spatial distribution and factor 6 an extended fronto-centro parietal distribution. Factors 3 and 5 are of no relevance for the further analysis of the study and are therefore not further elaborated in this context.

The multiple late components found in the PCA fit the observations made while screening the data. There were pronounced late positive components in the time range of 250 ms to 750 ms, but individual variances were high, making P3 and P4 amplitude detections very difficult. Furthermore, it is questionable whether such an analysis would have been valid, considering the multiple overlapping components. Therefore, a different strategy for analyzing the data was applied. Mean amplitudes were exported for electrodes P_3, P_z, and P_4 in the time interval of [400 ms; 600 ms] for each subject and each condition. Furthermore, the late latency ranges [600 ms; 1000 ms] were analyzed by exporting mean amplitudes in time intervals of 100 ms on electrodes P_3, P_z, and P_4.

Ascending/Descending Order Paradigm The results of the PCA for the ascending/descending order paradigm were very similar to those of the random order paradigm. Seven factors were identified and are depicted in Figure 4.8. Factor 1 accounted for 54.6% of total variance, factor 2 for 13.2%, factor 3 for 6.3%, factor 4 for 3.4%, factor 5 for 2.9%, factor 6 for 2%, and factor 7 for 1.7%.

The spatial distributions of factors 2, 4, 6, and 7, i.e. their mean component values, are depicted in Figure 4.9. The spatial distributions of the different factors are very similar to the random order paradigm, especially if one considers that factor 7 in the random order paradigm corresponds to factor 6 in the ascending/descending paradigm and vice versa. Factors 3 and 5 are not elaborated in this context because they are of no further relevance.

Again, the findings of the PCA can be interpreted as supporting the existence of multiple late positive components, and it was correspondingly difficult to identify the different overlapping components in the individual ERPs. Therefore, as for the random order experiment, mean amplitudes were exported at electrodes P_3, P_z, and P_4 in the time interval [400 ms; 600 ms] and, in steps of 100 ms, in the interval [600 ms; 1000 ms].

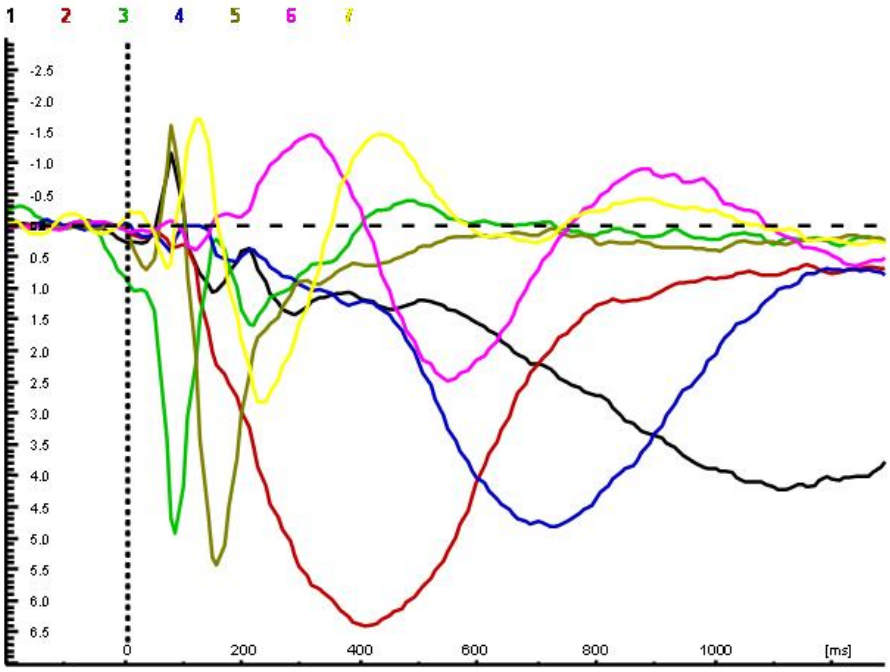


Figure 4.6.: Random order paradigm: factor solution of Principal Components Analysis

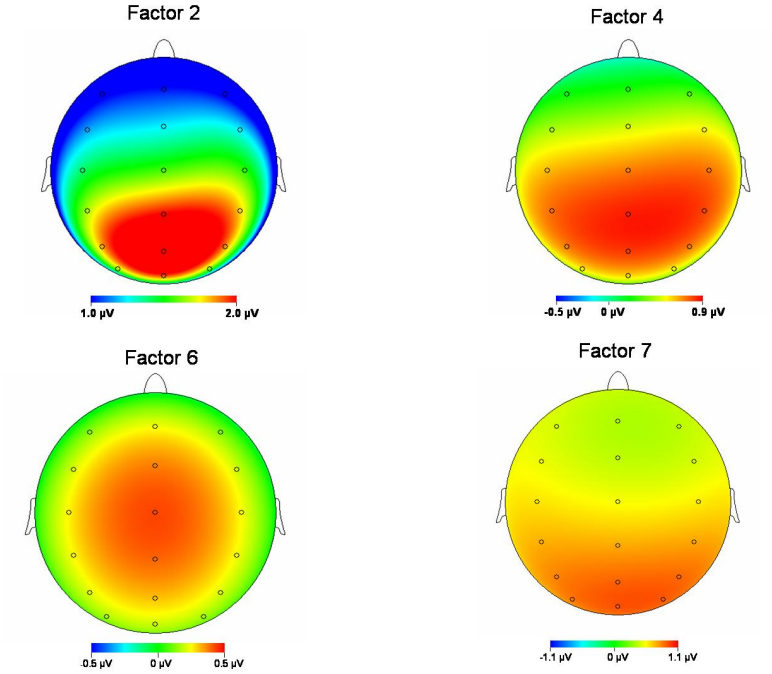


Figure 4.7.: Random order paradigm: mean component values for factors 2 (top left), 4 (top right), 6 (bottom left), and 7 (bottom right)

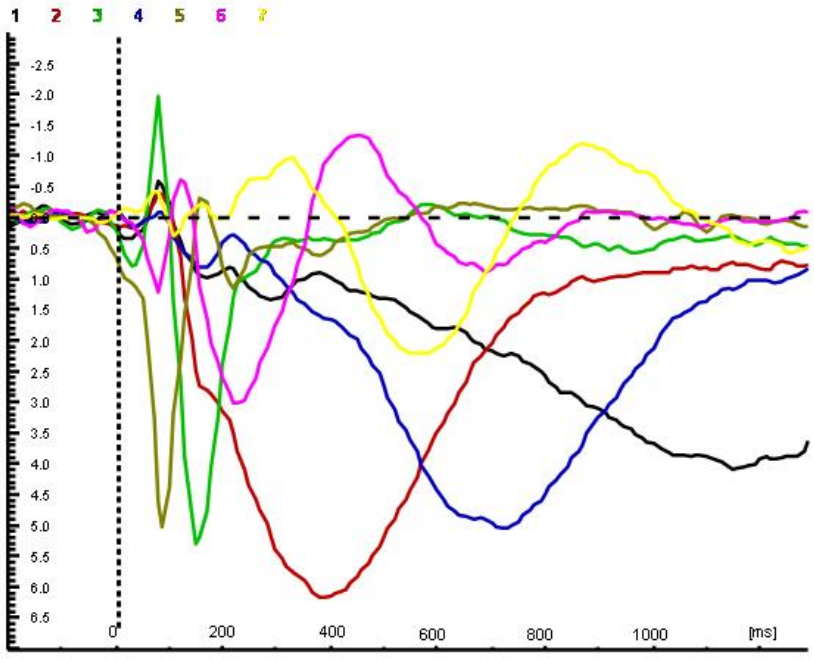


Figure 4.8.: Ascending/descending paradigm: factor solution of Principal Components Analysis

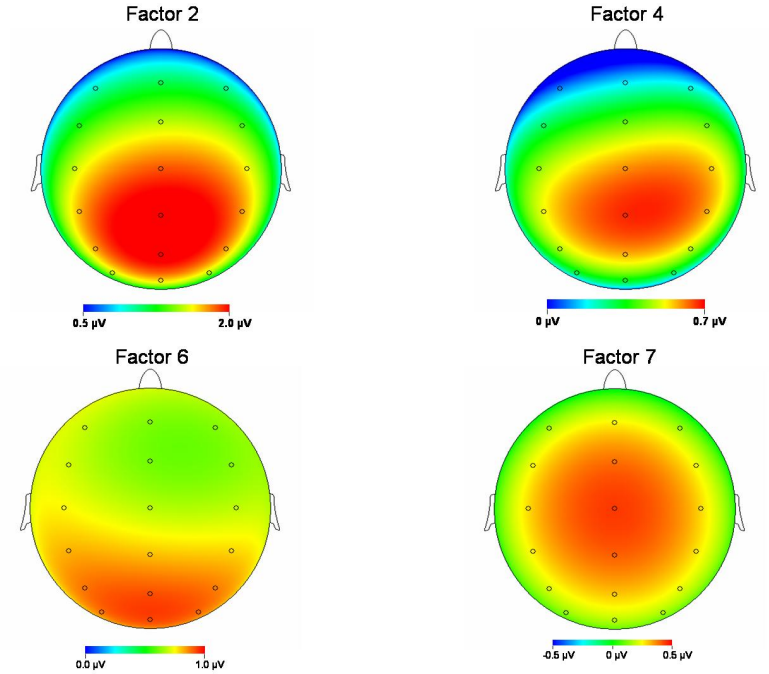


Figure 4.9.: Ascending/descending paradigm: mean component values over subjects for factors 2 (top left), 4 (top right), 6 (bottom left), and 7 (bottom right)

4.3. Results

First, the results of valence and arousal ratings will be described. Then, relative classification frequencies and reaction times will be presented. Finally, the focus will lie on event-related potentials. Again, Greenhouse-Geisser (ε) corrections were applied to adjust for violations of sphericity (Greenhouse & Geisser, 1958). See also the introduction to Section 2.3 for a discussion of the preconditions for ANOVAs.

4.3.1. Valence and Arousal Ratings

Figure 4.10 depicts mean valence and arousal ratings of each picture averaged over all three flower/spider series. Valence and arousal ratings were analyzed by a 3×7 ANOVA with between factor *Group* and repeated measures factor *Picture*. The factor Picture denotes here the position of each picture in the series: $1, 2, 3, 4, 5, 6,$ and 7. Picture 1 is the flower anchor, picture 7 the spider anchor. First, ANOVA results of valence ratings will be described, then the results of arousal ratings will be presented.

Valence Ratings Consistent with our hypotheses there were main effects of Group ($F_{(2,41)} = 21.24$; $p = 0.0005$) and of Picture ($F_{(6,246)} = 31.47$; $p = 0.0005$; $\varepsilon = 0.44$), as well as a significant interaction of Group $\times$ Picture ($F_{(12,246)} = 8.08$; $p = 0.0005$; $\varepsilon = 0.44$).

Subsequent ANOVAs calculated separately for each group revealed no significant effect of Picture for controls but highly significant effects for social phobics ($F_{(6,90)} = 32.73$; $p = 0.0005$; $\varepsilon = 0.51$) and for spider phobics ($F_{(6,72)} = 8.16$; $p = 0.0005$; $\varepsilon = 0.37$). Pairwise comparisons showed that social phobics rated the flower anchor (picture 1) as significantly more pleasant than all other pictures (all p-values ≤ 0.007), but there were no further significant differences between pictures 2 to 7. Spider phobics also rated the flower anchor as significantly more pleasant than all other pictures (all p-values ≤ 0.0005). From picture 2 to picture 7 they rated the stimuli as increasingly more aversive. Furthermore, at picture 4 there was another significant turning point of valence ratings towards more unpleasant ratings (comparisons of picture 3 with all following pictures: all p-values ≤ 0.005). As can be seen in Figure 4.10, picture 7, the spider anchor, was rated as most aversive by spider phobics. However, the difference in valence ratings between picture 6 and 7 failed to be significant ($p = 0.09$), which indicates that pictures 6 and 7 were nearly equivalently aversive, although there was a tendency for picture 7 to be rated more aversive.

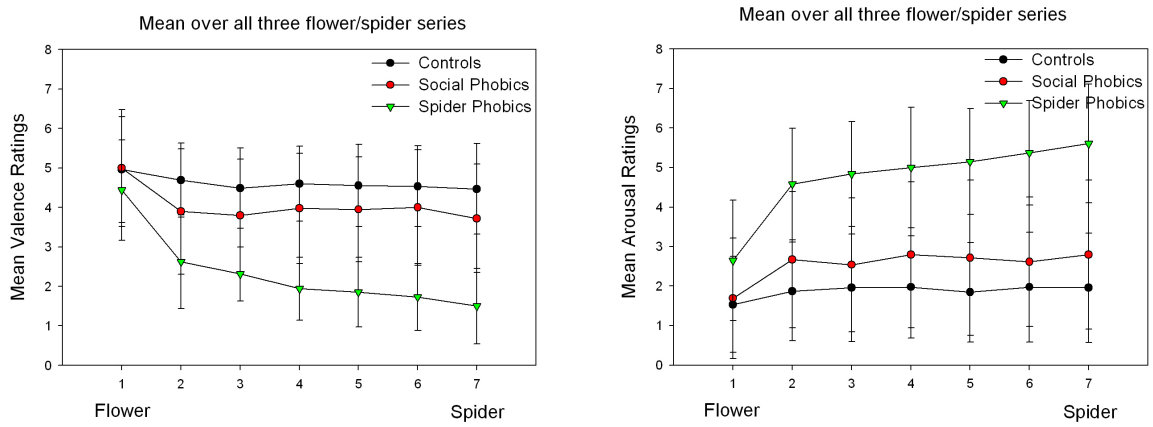


Figure 4.10.: Mean valence (left) and arousal (right) ratings and SDs for all pictures, averaged over the three Flower/Spider series

Group differences were analyzed by further ANOVAs calculated separately for each picture. They showed that groups did not differ significantly in their valence ratings for picture 1, the flower anchor, but for all other pictures (all p-values ≤ 0.0005). This means that beginning with the first opening of the petals of the flower anchor there were significant differences in valence ratings between groups. Post hoc tests revealed that social phobics and controls never differed significantly in their ratings, but all comparisons between spider phobics and controls were highly significant starting with picture 2 (all p-values ≤ 0.0005). In addition, all comparisons between spider phobics and social phobics were significant, beginning with picture 2 ($p = 0.02$) and becoming more and more significant (picture 3: $p = 0.002$; pictures 4 to 7: $p = 0.0005$).

Arousal Ratings For arousal ratings, ANOVA revealed main effects of Picture ($F_{(6,72)} = 28.31$; $p = 0.0005$; $\varepsilon = 0.41$) and of Group ($F_{(2,41)} = 18.31$; $p = 0.0005$), as well as a significant interaction of Group × Picture ($F_{(12,246)} = 7.69$; $p = 0.0005$; $\varepsilon = 0.41$). Mean arousal ratings and standard deviations are depicted in Figure 4.10.

Subsequent ANOVAs were calculated separately for each group and revealed that social phobics ($F_{(6,72)} = 7.63$; $p = 0.001$; $\varepsilon = 0.48$) and spider phobics ($F_{(6,90)} = 23.12$; $p = 0.0005$; $\varepsilon = 0.37$), but not controls, showed a main effect of Picture. Controls at most showed a tendency for higher arousal ratings for pictures 2 to 7 compared to picture 1. Pairwise comparisons indicated that social phobics rated the flower anchor (picture 1) as significantly less arousing than all other pictures (all p-values ≤ 0.01), but there were no further significant differences in arousal ratings between pictures 2 to 7. Spider phobics, on the other hand, also rated the flower anchor (picture 1) as less arousing than all other pictures, but they rated pictures 2 to 7 as increasingly more

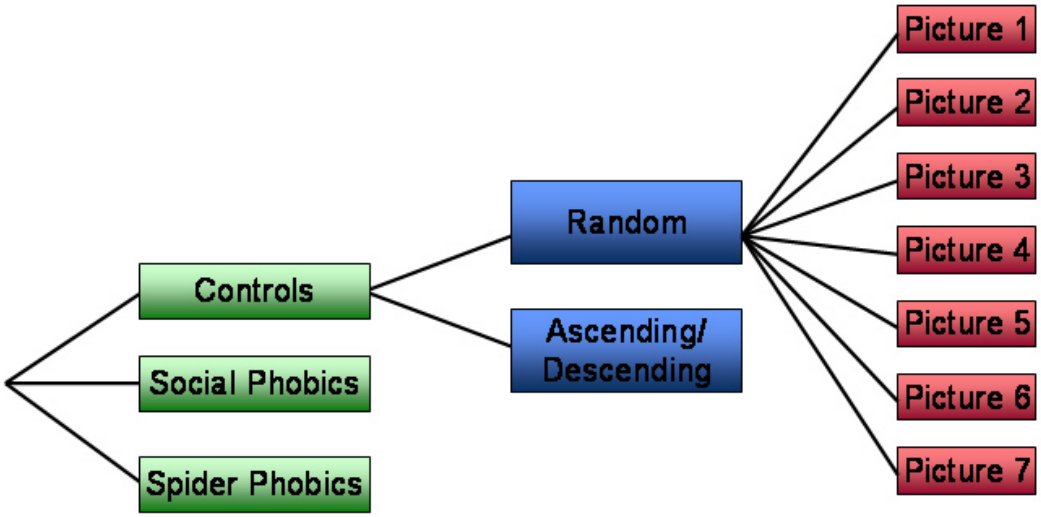


Figure 4.11.: ANOVA design for the analysis of reaction times

arousing. The spider anchor (picture 7) was rated most arousing. Furthermore, the unequivocal spider pictures 6 and 7 were rated as significantly more arousing than the ambiguous picture 4 (comparison '4–6': $p = 0.05$; '4–7': $p = 0.02$).

Finally, to analyze group differences, separate ANOVAs were calculated for each picture. Although spider phobics showed heightened arousal ratings for picture 1 (flower anchor), this difference was not significant ($F_{(2,41)} = 2.74$; $p = 0.08$) but can be interpreted as a tendency. However, from picture 2 to picture 7 there were highly significant group differences (all p-values ≤ 0.0005). This means that starting at picture 2, the first opening of the petals of the flower, there were significant group differences in arousal ratings. Post hoc comparisons showed that social phobics and controls did not differ significantly in their arousal ratings for any picture. However, the difference between spider phobics and controls was highly significant from picture 2 to picture 7 (all p-values ≤ 0.0005). Also, all comparisons between social phobics and spider phobics were significant, beginning with picture 2 ($p = 0.003$) and then becoming increasingly more significant (all p-values ≤ 0.001).

4.3.2. Performance and Reaction Times

Overall, subjects indicated having made a mistake in 4.1% of all trials in the random order paradigm and in 3.81% of all trials in the ascending/descending order paradigm.

Analysis of reaction times was performed with a $3 \times 2 \times 7$ ANOVA with between factor *Group* and repeated measures factors *Order* (random, ascending/descending)

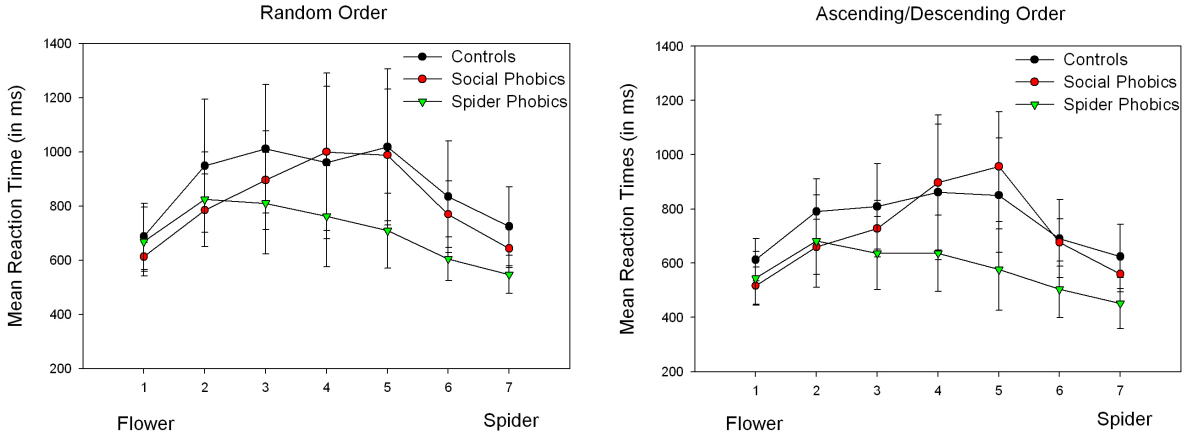


Figure 4.12.: Mean reaction times and SDs for random (left) and ascending/descending (right) stimulus presentation

and *Picture* (pictures 1 to 7). The ANOVA design is depicted in Figure 4.11, and mean reaction times and standard deviations in response to each picture in the series are shown in Figure 4.12.

Results showed main effects of Order ($F_{(1,41)} = 96.31$; $p = 0.0005$), of Picture ($F_{(6,246)} = 50.09$; $p = 0.0005$; $\varepsilon = 0.42$), and of Group ($F_{(2,41)} = 8.27$; $p = 0.001$). Furthermore, there were significant interactions of Group × Picture ($F_{(12,246)} = 6.58$; $p = 0.0005$; $\varepsilon = 0.42$) and of Order × Picture ($F_{(6,246)} = 6.33$; $p = 0.0005$; $\varepsilon = 0.68$). The two-way interaction Group × Order × Picture was not significant ($F_{(12,246)} = 1.73$; $p = 0.09$; $\varepsilon = 0.68$).

The main effect of Order indicated that mean reaction times were longer in the random paradigm than in the ascending/descending paradigm. The main effect of Picture indicated that ambiguous stimuli (pictures $2, 3, 4, 5$) led to significantly longer reaction times than more unequivocal stimuli (pictures $1, 6, 7$). However, both effects cannot be interpreted without considering the significant interaction of Order × Picture. While in the random paradigm reaction times were particularly prolonged for pictures 2 to 5, this effect was less pronounced for pictures 2 and 3 (the slightly opened petals of the flower) in the ascending/descending paradigm.

Furthermore, spider phobics responded overall significantly faster than controls (Tukey HSD: $p = 0.001$) and social phobics (Tukey HSD: $p = 0.03$). However, this effect has to be interpreted together with the significant interaction of Group × Picture. This effect will be further analyzed in the following sections. The following analyses were performed separately for the random and ascending/descending order paradigm.

Random Order Paradigm To analyze the interaction Group × Picture further, subsequent ANOVAs were calculated separately for each group. Each group showed a highly significant main effect of Picture (spider phobics: $F_{(6,84)} = 19.55$; $p = 0.0005$; $\varepsilon = 0.45$; social phobics: $F_{(6,72)} = 18.12$; $p = 0.0005$; $\varepsilon = 0.37$; controls: $F_{(6,90)} = 15.79$; $p = 0.0005$; $\varepsilon = 0.45$). Pairwise comparisons revealed that all groups showed a significant increase in reaction time from picture 1 to picture 2 (all p-values ≤ 0.0005). Similarly, they all showed a significant reduction in reaction times from picture 5 to picture 6 (all p-values ≤ 0.0005) and from picture 6 to picture 7 (all p-values ≤ 0.0005). While controls and social phobics showed further increases in reaction times as stimuli became increasingly ambiguous, the reaction times of spider phobics decreased as stimuli became increasingly spider-like. However, only pictures 6 ($p = 0.05$) and 7 ($p = 0.001$) yielded faster reaction times in spider phobics than the unequivocal flower anchor (picture 1). For social phobics and controls there was no significant difference in reaction times between the flower and the spider anchor (picture 1 vs. 7).

Finally, separate ANOVAs for each picture were calculated to analyze group differences, i.e. to answer the question in response to which pictures spider phobics were significantly faster than controls and social phobics. Results showed no significant group differences for the more flower-like pictures 1 and 2, but for all other pictures (3 to 7; all p-values ≤ 0.03). While controls and social phobics never differed significantly from each other, there were significant differences between spider phobics and controls from picture 3 on in that spider phobics were significantly faster than controls. This effect was most pronounced for pictures 6 and 7 ($p = 0.0005$). Social phobics differed from spider phobics beginning with picture 4. Differences for pictures 6 and 7 ($p = 0.01$ and $p = 0.04$, respectively) were not as pronounced as between spider phobics and controls.

Ascending/Descending Order Paradigm As for the random order paradigm, an ANOVA was calculated separately for each group. The main effect of Picture was observed in each group (spider phobics: $F_{(6,84)} = 15.23$; $p = 0.0005$; $\varepsilon = 0.46$; social phobics: $F_{(6,72)} = 23.8$; $p = 0.0005$; $\varepsilon = 0.31$; controls: $F_{(6,90)} = 11.7$; $p = 0.0005$; $\varepsilon = 0.37$). Pairwise comparisons revealed that all subjects showed a significant increase in reaction times with the first opening of the petals of the flower anchor (picture 1 vs. 2; all p-values ≤ 0.001). Furthermore, all groups showed a significant decrease in reaction time from the still ambiguous picture 5 to the relatively unequivocal picture 6 (all p-values ≤ 0.005) and from picture 6 to picture 7 (all p-values ≤ 0.0005). In addition, spider phobics showed faster responses for the spider anchor than for the

flower anchor ($p = 0.001$). In contrast, social phobics were slower to respond to the spider anchor than to the flower anchor ($p = 0.03$), and controls showed no difference in reaction times between the anchor pictures.

Finally, separate ANOVAs for each picture were calculated. Starting with picture 3, spider phobics responded significantly faster than controls. The most significant difference between controls and spider phobics was observed for the spider pictures 6 and 7 (both comparisons $p = 0.0005$). Spider phobics were significantly faster than social phobics from picture 4 on (all p-values ≤ 0.01). However, in the ascending/descending order paradigm, in contrast to the random order paradigm, social phobics responded faster than controls to picture 1 and 2, but no further significant differences between controls and social phobics were observed.

4.3.3. Classification Frequencies

Figure 4.13 shows the percentage of "spider", "flower" and "neither/nor" classifications for each picture in the stimulus series for the random and ascending/descending order paradigm.

It can be seen that in both paradigms, spider anchor pictures were rated by all subjects as a "spider" and the flower anchor pictures were classified by all subjects as a "flower". With the opening of the petals of the flower pictures were rated increasingly more frequently as "neither/nor" or "spider-like". In the random order paradigm, controls and social phobics classified pictures 2 and 3 (the slightly opened petals of the flower) rarely as "spider-like", while spider phobics rated these stimuli in 30–40% of trials as "spider-like". Furthermore, spider phobics classified picture 4 in more than 50% of trials as "spider-like" while controls and social phobics did not so until picture 5. Pictures 6 and 7 were classified by all subjects in more than 80% of cases as "spider-like".

In the ascending/descending order paradigm, the results were similar, but the differences between spider phobics and the control groups were even more pronounced. For example, while control groups rarely rated pictures 2, 3 and 4 as being "spider-like", spider phobics did so much more often. Social phobics and controls rated picture 5 in about half of the trials as "spider-like", while spider phobics did so in about 80% of all trials. The ratings of pictures 6 and 7 were again rather similar in all groups.

A modified mixed nonlinear Rasch model was used to analyze the response tendencies of each group. See Appendix D for a detailed description of the simple and the mixed Rasch model and the additional assumptions taken here to analyze the data set. The

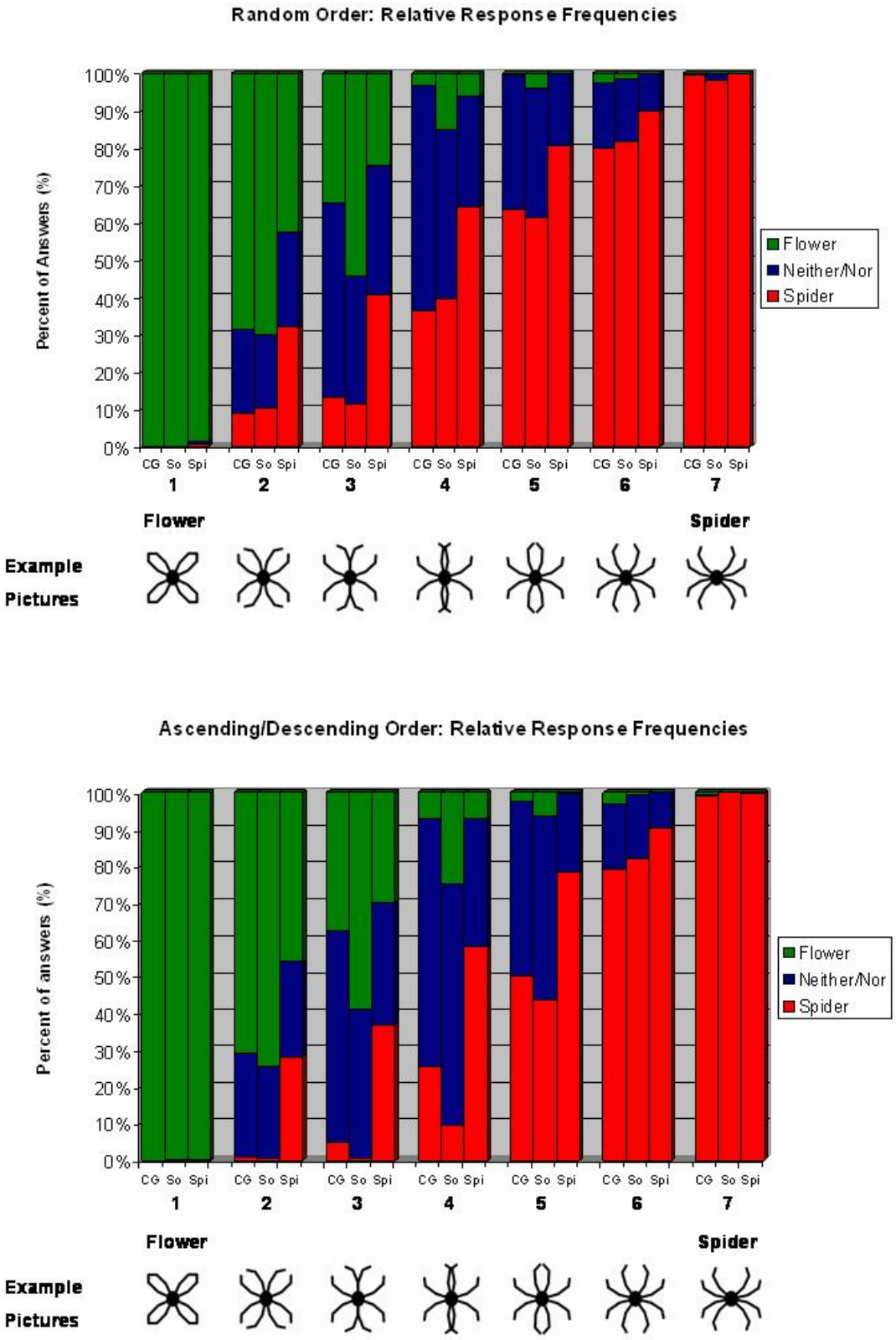


Figure 4.13.: Classification frequencies for each picture and each group. Upper picture: random paradigm, lower picture: ascending/descending paradigm

fitting of model parameters was performed with the nonlinear mixed models procedure (PROC NLMIXED) of SAS Version 8 (SAS Institute Inc.; see Wolfinger, 1999).

In Figure 4.14 the x-axis depicts the *latent trait* to see a spider in a picture, i.e. the tendency to classify a picture as belonging to the category "spider". The y-axis displays the probability (P) to recognize a spider in a picture, which is calculated as $P =$ "Spider"/"No Spider" when "No spider" = "Flower" or "Neither/Nor". Furthermore, the *item response curve* for each picture is displayed in the graphic. The model sets the mean latent trait to see a spider in a given picture for the control group to $\alpha_{\mathrm{CG}} = 0$ and calculates whether social phobics and spider phobics deviate significantly in their mean latent traits α_{So} and α_{Spi} from the control group.

For the random presentation of stimuli, spider phobics showed a significantly stronger tendency to classify a stimulus as a spider than controls ($\alpha_{\mathrm{Spi}} = 2.51$; $p = 0.01$). Social phobics did not differ significantly from controls in their response tendencies ($\alpha_{\mathrm{So}} = 0.08$; $p = 0.94$).

When pictures were presented in ascending/descending order, the difference between spider phobics and controls was even more pronounced ($\alpha_{\mathrm{Spi}} = 4.13$; $p = 0.0001$), while social phobics again did not differ significantly from controls ($\alpha_{\mathrm{So}} = -0.78$; $p = 0.38$).

4.3.4. Event-Related Potentials

Event-related potentials on electrode P_z in response to each picture averaged over all three flower/spider series are depicted in Figure 4.15 for each group and both paradigms. It can be seen that ERPs in response to unequivocal pictures returned relatively fast to baseline while ambiguous pictures led to more sustained positivity.

In Figure 4.16, spider phobics, social phobics, and controls are compared in their event-related potentials on electrode P_z in response to the flower anchor (picture 1) and the spider anchor (picture 7) in the random order paradigm. No differences between groups are obvious. ERPs in the ascending/descending order paradigm were similar and are therefore not shown here.

Mean amplitudes at parietal sites (electrodes P_3, P_z and P_4) were analyzed in two latency ranges: in the interval [400 ms; 600 ms] and in the interval [600 ms; 1000 ms]. ERPs in the latter interval were analyzed in steps of 100 ms.

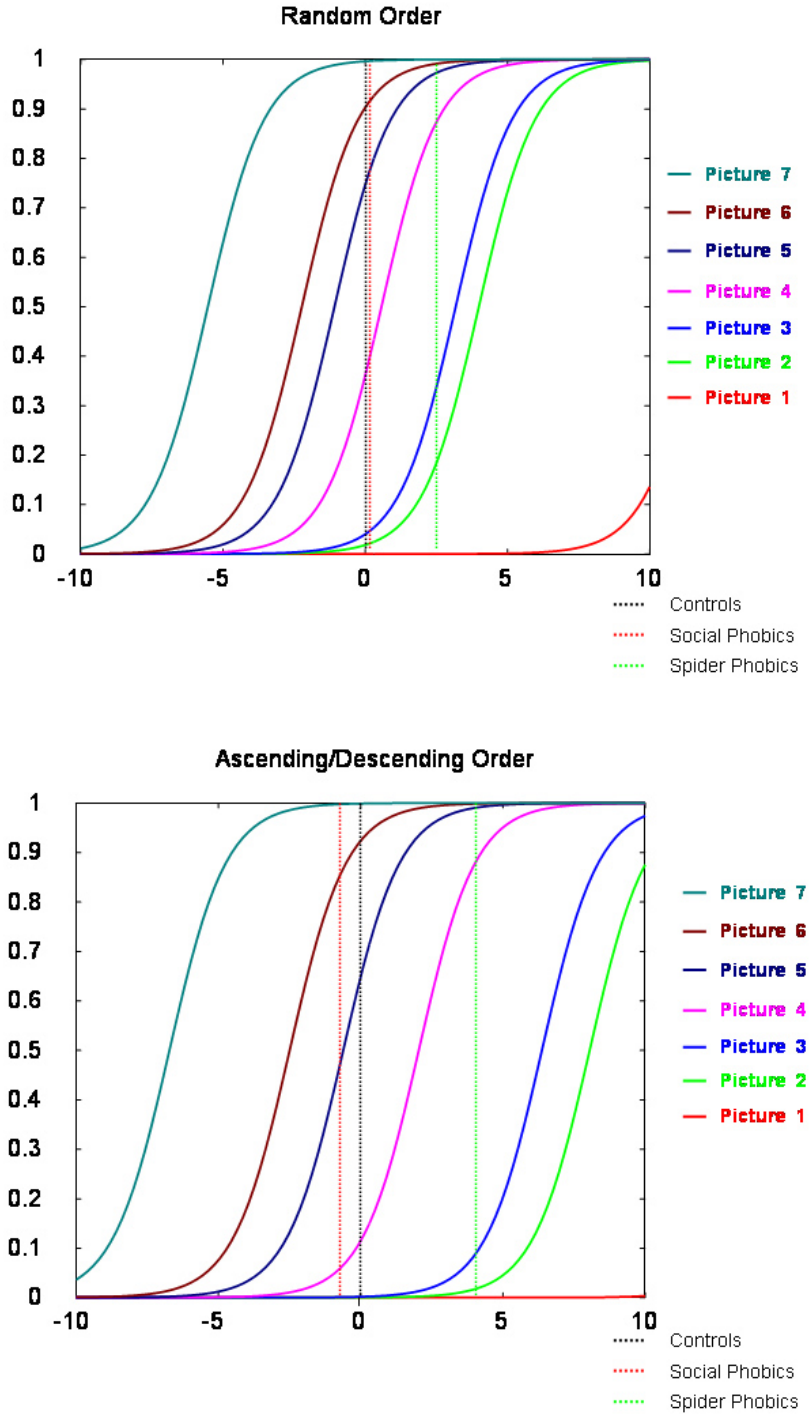


Figure 4.14.: Item response curves for the modified mixed Rasch model (random order top; ascending/descending order bottom). The x axis measures the latent trait θ_j of subject j – the higher it is, the more likely is subject j to classify any stimulus as a spider. The dotted lines show the estimated mean latent trait in each of the three groups. Each curve corresponds to one of the seven pictures, with picture 1 being the flower and picture 7 the spider anchor. The y axis shows the probability of subject j to identify item k as a spider. See Appendix D for a detailed description of the mixed Rasch model used.

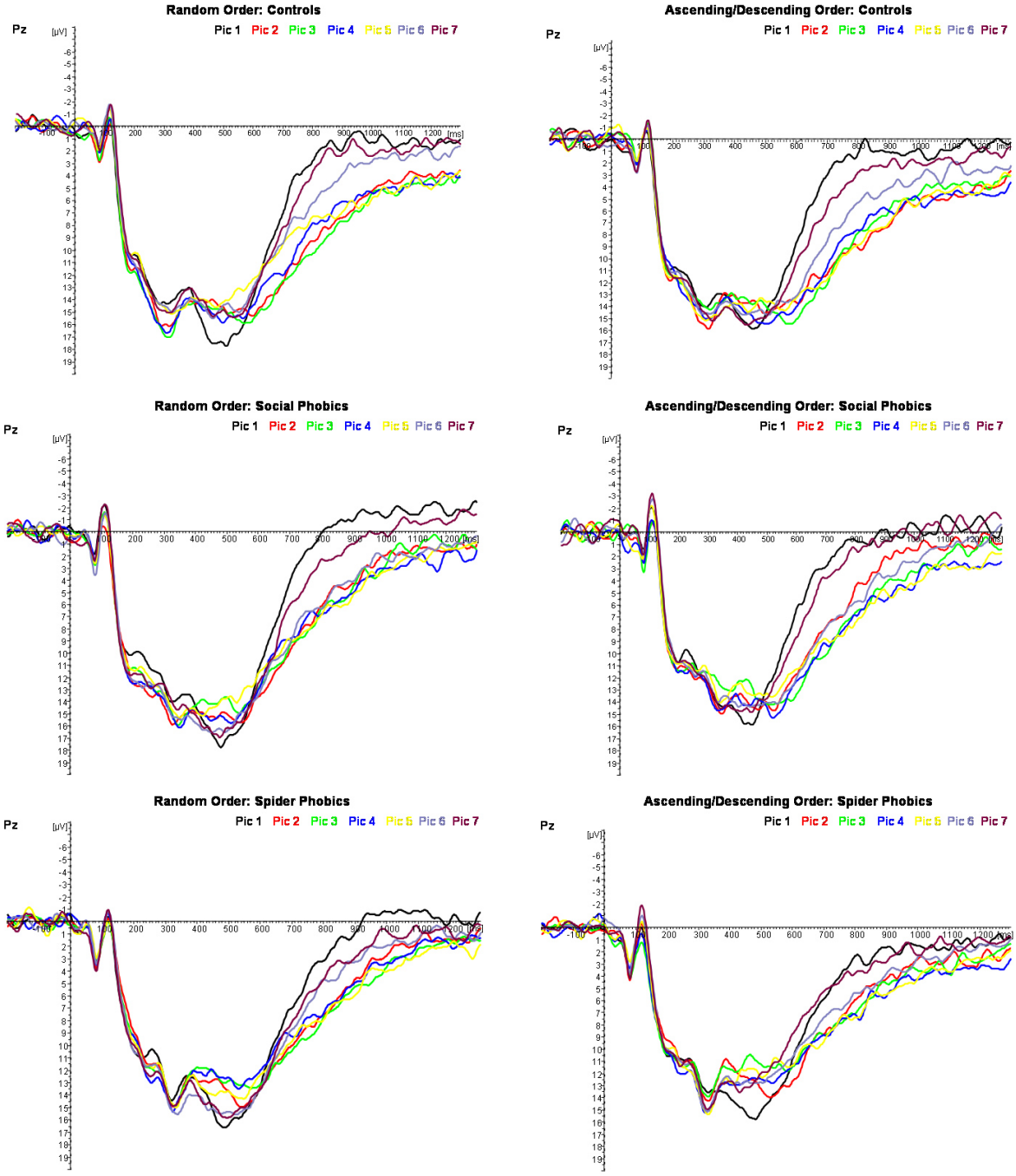


Figure 4.15.: ERPs on electrode P_z in response to each picture in the random (left) and ascending/descending order paradigm (right) for controls (top row), social phobics (central row), and spider phobics (bottom row)

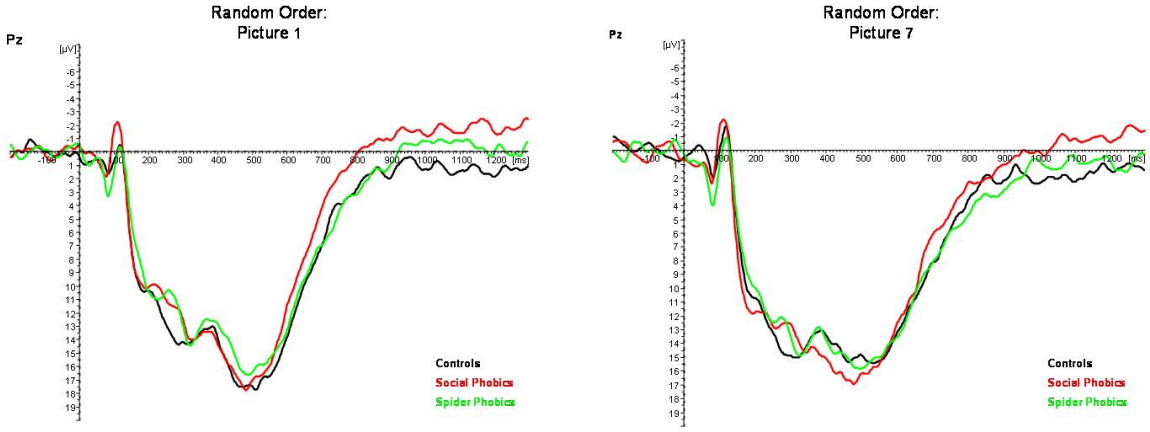


Figure 4.16.: ERPs on electrode P_z for the flower anchor (left) and the spider anchor (right)

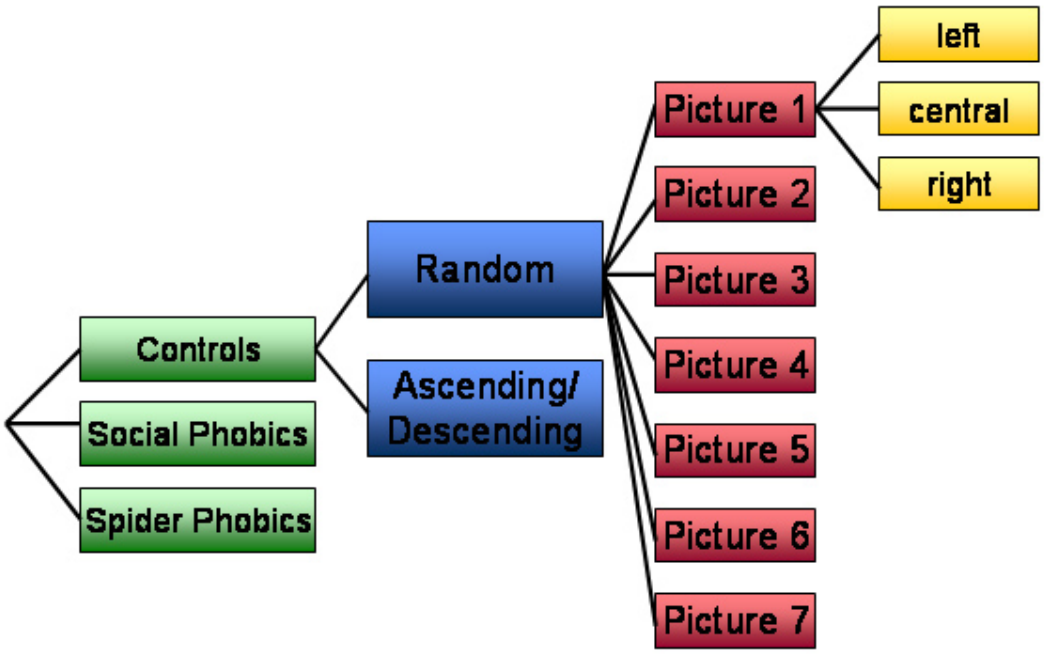


Figure 4.17.: ANOVA design for the analysis of ERPs on electrodes P_3, P_z and P_4 in the time interval of $[400\,\text{ms}, 600\text{ms}]$

Mean Amplitudes in the Time Interval [400 ms; 600 ms]

A 3×2×7×3 ANOVA with between factor *Group* and repeated measures factors *Order*, *Picture* and *Laterality* was calculated. The ANOVA design is depicted in Figure 4.17.

There were main effects of Order ($F_{(1,41)} = 15.88$; $p = 0.0005$), Picture ($F_{(6,246)} = 4.49$; $p = 0.0005$; $\varepsilon = 0.57$), and Laterality ($F_{(2,82)} = 40.76$; $p = 0.0005$; $\varepsilon = 0.84$). Furthermore, there were significant interactions of Order × Picture ($F_{(6,246)} = 2.9$; $p = 0.015$; $\varepsilon = 0.83$) and of Picture × Laterality ($F_{(12,429)} = 4.22$; $p = 0.001$; $\varepsilon = 0.43$).

The main effect of Order indicated that mean amplitudes were larger in the random than in the ascending/descending paradigm. However, there was an additional interaction of Order × Picture. The flower anchor (picture 1) and the spider pictures (6 and 7) led to significantly larger mean amplitudes in the random than in the ascending/descending paradigm (all p-values ≤ 0.0005). Mean amplitudes for pictures 2 to 5 were generally larger in the random than the ascending/descending paradigm, but this difference was not significant or narrowly failed to be significant.

Since the factor Order had a main influence on results, further analyses were calculated separately for both paradigms.

Random Order Paradigm The ANOVA revealed main effects of Picture ($F_{(6,246)} = 6.91$; $p = 0.0005$; $\varepsilon = 0.74$) and Laterality ($F_{(2,82)} = 37.14$; $p = 0.0005$; $\varepsilon = 0.82$) as well as a significant interaction of Picture × Laterality ($F_{(12,492)} = 4.33$; $p = 0.0005$; $\varepsilon = 0.54$), but no group differences.

Mean amplitudes in the time interval [400 ms; 600 ms] were significantly larger at midline than over the left and right hemisphere (both comparisons $p = 0.0005$).

Figure 4.18 depicts mean amplitudes and standard deviations in response to each picture for each group. It can be seen that mean amplitudes for this time interval were largest in response to the flower and the spider anchor pictures. Pairwise comparisons revealed that there was a significant decrease in mean amplitudes from picture 1 to picture 2 ($p = 0.001$), i.e. with the first opening of the petals of the flower, mean amplitudes decreased significantly. Furthermore, there was a non-significant trend towards even smaller mean amplitudes in response to picture 3 (comparison picture '2–3': $p = 0.07$). On the other hand, there was a significant increase in mean amplitudes from the ambiguous picture 5 to the unequivocal spider pictures 6 ($p = 0.003$) and 7 ($p = 0.004$). Finally, the flower anchor picture led to significantly larger ampli-

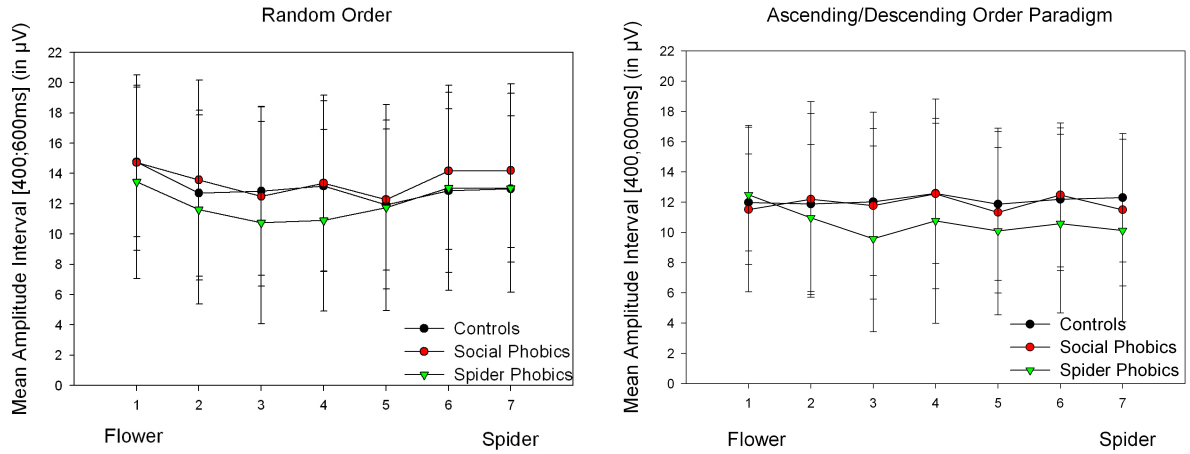


Figure 4.18.: Mean amplitudes and SDs for each picture for the time interval [400 ms; 600 ms] for the random (left) and ascending/descending order paradigm (right)

tudes than picture 6 ($p = 0.04$), while the amplitude for the flower anchor only showed a tendency to be larger than for picture 7 ($p = 0.07$).

Ascending/Descending Order Paradigm For the ascending/descending order paradigm there was a main effect of Laterality ($F_{(2,82)} = 42.47$; $p = 0.0005$; $\varepsilon = 0.87$) and a significant interaction of Picture × Laterality ($F_{(12,492)} = 2.46$; $p = 0.03$; $\varepsilon = 0.47$), but no main effect of Picture nor an interaction of Group × Picture.

Mean amplitudes in the interval [400 ms; 600 ms] were larger centrally as compared to the right and left hemisphere (both comparisons $p = 0.0005$). The interaction Picture × Laterality resulted from slightly higher mean amplitudes over the right compared to the left hemisphere for pictures 1 and 2. However, pairwise comparisons showed that this difference was not significant.

Mean Amplitudes in the Time Interval [600 ms; 1000 ms]

For this late time interval a 3 × 2 × 4 × 7 × 3 ANOVA with between factor *Group* and repeated measures factors *Order* (random, ascending/descending), *Time* (the intervals [600 ms; 700 ms], [700 ms; 800 ms], [800 ms; 900 ms], [900 ms; 1000 ms]), *Picture* (Pictures 1 to 7), and *Laterality* (left, central, right) was calculated. The ANOVA design is depicted in Figure 4.19.

There were main effects of Order ($F_{(1,41)} = 8.26$; $p = 0.006$), Time ($F_{(3,123)} = 178.82$; $p = 0.0005$, $\varepsilon = 0.41$), Laterality ($F_{(2,82)} = 12.35$; $p = 0.0005$, $\varepsilon = 0.76$), and Picture

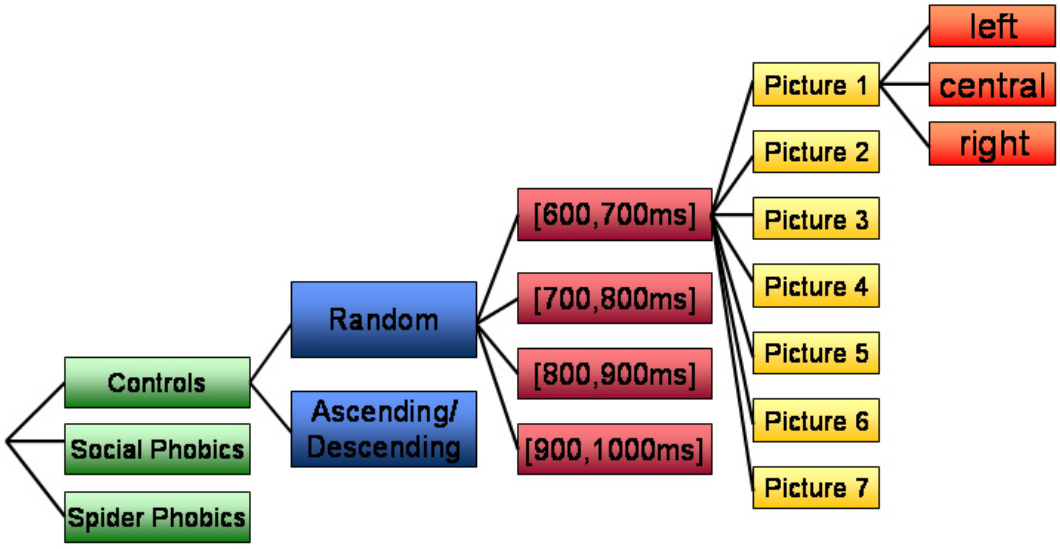


Figure 4.19.: ANOVA design for the analysis of event-related potentials in the time interval of [600 ms; 1000 ms]

($F_{(6,246)} = 27.73$; $p = 0.0005$, $\varepsilon = 0.51$). Among various other interactions there were significant interactions of Order × Picture ($F_{(6,246)} = 2.24$; $p = 0.05$, $\varepsilon = 0.82$) and of Order × Picture × Time ($F_{(18,738)} = 10.24$; $p = 0.0005$, $\varepsilon = 0.49$).

A more detailed analysis of the interactions Order × Picture and Order × Picture × Time revealed that the anchor pictures led to significantly larger mean amplitudes in the random than in the ascending/descending paradigm in the first time interval [600 ms; 700 ms]. A consistent difference in all time intervals between both paradigms was that pictures 2 and 3, the slightly opened petals of the flower, led to a slower return to baseline in the random than in the ascending/descending stimulus presentation.

Random Order Paradigm The ANOVA calculated with the data of the random order paradigm only revealed main effects of Time ($F_{(3,123)} = 184.14$; $p = 0.0005$; $\varepsilon = 0.4$), of Laterality ($F_{(2,82)} = 7.52$; $p = 0.003$; $\varepsilon = 0.72$), and of Picture ($F_{(6,246)} = 19.38$; $p = 0.0005$; $\varepsilon = 0.55$). Furthermore, the interactions Time × Picture ($F_{(18,738)} = 12.74$; $p = 0.0005$; $\varepsilon = 0.39$) and Picture × Laterality ($F_{(12,492)} = 8.97$; $p = 0.0005$; $\varepsilon = 0.58$) were highly significant. However, there were no significant interactions of Group × Picture or Group × Time × Picture.

A more detailed analysis of the main effects of Time and of Laterality showed that mean amplitudes were smaller the more time progressed, and they were in general significantly larger at midline than over the right or left hemisphere (comparisons 'central–right': $p = 0.0005$, 'central–left': $p = 0.0005$).

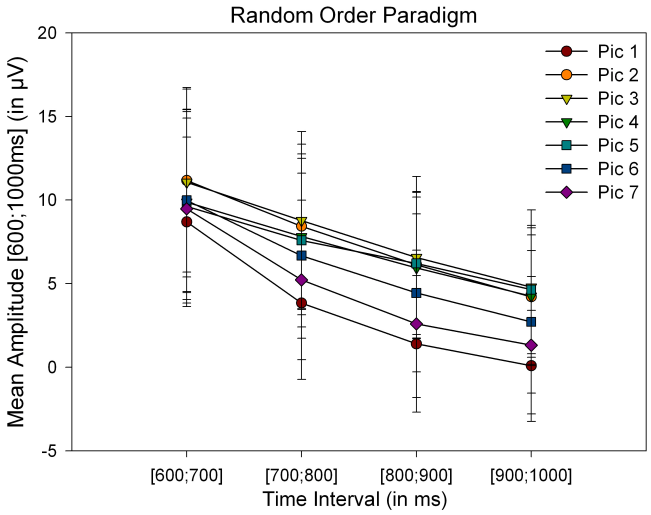


Figure 4.20.: Mean Amplitudes and SDs in each time interval, for each picture in the random order paradigm

Figure 4.21 depicts mean amplitudes for each picture of the series. Ambiguous pictures led to higher mean amplitudes than unequivocal pictures. There was a significant increase in mean amplitudes from picture 1 to picture 2 ($p = 0.0005$) and a significant decrease from picture 5 to picture 6 ($p = 0.03$) and from picture 6 to picture 7 ($p = 0.0005$). In addition, the comparison of the spider with the flower anchor picture showed that spiders led to significantly larger mean amplitudes in this very late time interval than flowers ($p = 0.01$).

Finally, the interactions Picture × Laterality and Time × Picture were analyzed in more detail. The laterality effect was most pronounced for pictures 2 to 5, i.e. the ambiguous pictures, and was not or less significant for the more unequivocal pictures 1, 6, and 7. Regarding the interaction Time × Picture, it can be seen in Figures 4.15 and 4.20 that ERPs returned more slowly to baseline for ambiguous pictures (2–5) than for unambiguous pictures (1,6,7). The differences in mean amplitudes in response to ambiguous and more unequivocal pictures were more pronounced for the late time intervals ([700 ms; 800 ms], [800 ms; 900 ms], [900 ms; 1000 ms]) than for the earlier time interval [600 ms; 700 ms].

Ascending/Descending Order Paradigm Similar effects were found for the ascending/descending order paradigm. There were main effects of Time ($F_{(3,123)} = 132.66$; $p = 0.0005$; $\varepsilon = 0.43$), Laterality ($F_{(2,82)} = 17.6$; $p = 0.0005$; $\varepsilon = 0.81$), and Picture ($F_{(6,246)} = 23.61$; $p = 0.0005$; $\varepsilon = 0.65$). Furthermore, there were significant interactions of Time × Picture ($F_{(18,738)} = 3.6$; $p = 0.0005$; $\varepsilon = 0.36$), Laterality

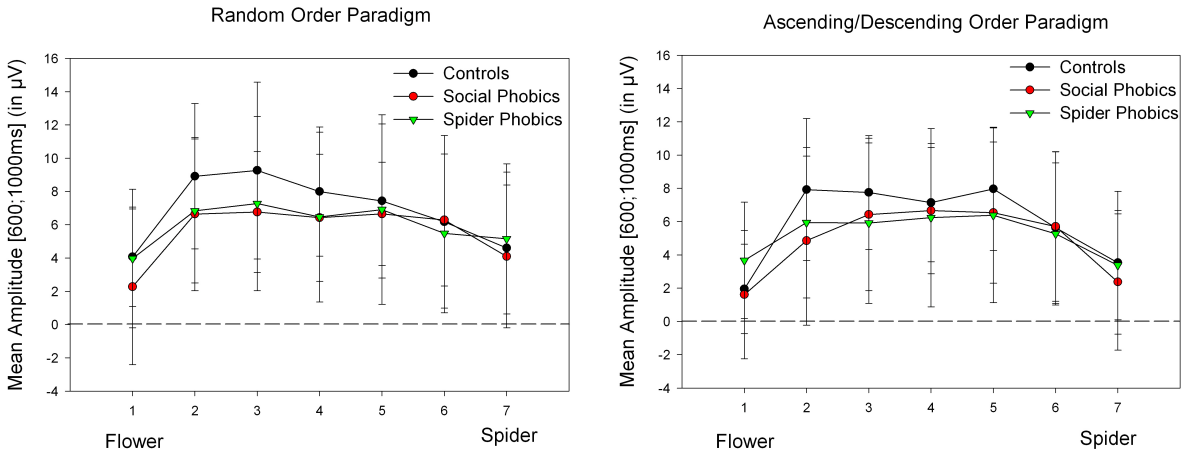


Figure 4.21.: Mean amplitudes and SDs for each picture for the time interval [600 ms; 1000 ms] for the random (left) and ascending/descending order paradigm (right)

× Picture ($F_{(12,492)} = 4.92$; $p = 0.0005$; $\varepsilon = 0.57$), and Time × Laterality × Picture ($F_{(36,1476)} = 2.07$; $p = 0.03$; $\varepsilon = 0.27$). However, there was no significant interaction of Group × Picture.

The main effect of Time indicated that mean amplitudes decreased significantly with each time interval, i.e. the activation returned to baseline. Subsequent analyses of the main effect of Laterality showed that mean amplitudes were largest over midline (comparisons 'central–left': $p = 0.0005$; 'central–right': $p = 0.0005$). However, this effect has to be interpreted together with the significant interaction of Picture × Laterality. Subsequent analyses showed that the central enhancement was most pronounced for the ambiguous pictures, followed by pictures 6 and 7, but not for picture 1. Here, only the comparison 'left–central' was significant ($p = 0.0005$).

Further analyses of the main effect of Picture showed that ambiguous stimuli (pictures 2 to 5) led to significantly larger mean amplitudes in this time interval than unequivocal pictures (pictures 1, 6, and 7). Figure 4.21 depicts mean amplitudes for each picture and for each group in the time interval [600 ms; 1000 ms]. There was a significant increase in mean amplitude beginning with the first opening of the petals of the flower anchor picture (comparison picture 1 vs. 2: $p = 0.0005$) and a significant decrease in mean amplitudes from picture 5 to picture 6 ($p = 0.005$) and from picture 6 to picture 7 ($p = 0.0005$). In contrast to the random paradigm, the spider anchor did not lead to significantly larger mean amplitudes in this time interval than the flower anchor ($p = 0.1$).

For each picture the course of activation was very similar in all time intervals. Once

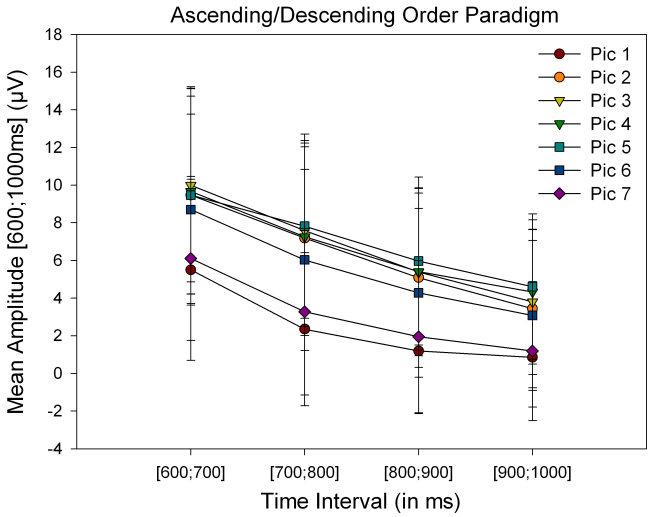


Figure 4.22.: Mean Amplitudes and SDs in each time interval for each picture in the ascending/descending paradigm

again, ERPs returned more slowly to baseline for ambiguous pictures than for unambiguous anchor pictures (cf. Figures 4.15 and 4.22). The interaction of Time × Picture was analyzed in further detail by calculating separate ANOVAs for each time interval. The differences in mean amplitudes between pictures 5 and 6 were not as pronounced in the time interval [600 ms; 700 ms] as in the later time intervals ([700 ms; 800 ms], [800 ms; 900 ms], [900 ms; 1000 ms]). However, this effect seems of minor importance.

4.4. Discussion

4.4.1. Summary of Results

Valence and Arousal Ratings Results showed that with the first opening of the petals of the flower anchor, spider phobics rated the pictures as significantly more unpleasant and arousing than controls and social phobics. This difference increased the more pictures became similar to spiders. Spider phobics rated the last pictures in the series (pictures 6 and 7) as most aversive (unpleasant and arousing).

However, controls did not differentiate in their valence and arousal ratings between the different pictures in the series. At the most, there was a tendency to rate the flower anchor as more pleasant and less arousing. In contrast, social phobics rated the flower anchor as significantly more pleasant and less arousing than all other pictures. They also did not differentiate in their ratings between pictures 2 to 7.

Reaction Times Results in the random and the ascending/descending paradigm were similar. In the non-spider-fearful groups reaction times depended on the ambiguity of the picture, i.e. the more unequivocal, the faster the response. Correspondingly, reaction times were fastest for the unambiguous flower and the spider anchor pictures. In spider phobics, on the other hand, reaction times also increased from the unequivocal flower picture 1 to picture 2 and then decreased the more pictures became spider-like. In addition, spider phobics responded significantly faster to the spider than the flower anchor, while social phobics and controls did not show such an additional facilitation effect for the unequivocal spider anchor.

Subjects responded significantly faster in the ascending/descending than in the random order paradigm. Additionally, reaction times were on average longer for pictures 2 and 3, the first opening of the outlines of the petals of the flower, when presented randomized than when presented ascending/descending. This was probably due to expectancy effects and the continuation of response tendencies.

Classification Frequencies Neither in the random nor in the ascending/descending order paradigm did controls and social phobics differ in their tendency to classify a stimulus as a "spider". In contrast, spider phobics showed a significantly stronger tendency, i.e. a latent trait, to see a "spider" in a stimulus than controls. This effect was present in both paradigms but was even more pronounced in the ascending/descending stimulus presentation. The differences in classification frequencies between spider phobics and controls were due to the tendency of spider phobics to see in ambiguous pictures, which controls rated more often as similar to a flower or "neither/nor", a "spider-like" stimulus.

Event-Related Potentials: [400 ms; 600 ms] In the random order paradigm, ERPs reflected a major influence of equivocation: mean amplitudes in the latency range [400 ms; 600 ms] were larger the more unequivocal the pictures. Furthermore, the comparison of the unequivocal flower and spider pictures (pictures 1, 6, and 7) showed that the flower anchor (picture 1) led to significantly larger mean amplitudes than picture 6 and to non-significantly larger amplitudes than picture 7, which can be interpreted as a tendency. This effects hints at a main effect of Gestalt: presumably, because of the closed form of the flower anchor in contrast to the more open form of pictures 2 to 7, this picture might have stood out, leading to a Gestalt oddball effect.

In the ascending/descending paradigm in the interval [400 ms; 600 ms] no differences in mean amplitudes between the different groups or the different pictures were found.

The conflicting findings on mean amplitudes in this time range in the two different paradigms suggest that the experimental design has a crucial influence on results. For instance, the influence of equivocation, i.e. incomplete information transmission, was less pronounced in the ascending/descending than in the randomized stimulus presentation.

Event-Related Potentials: [600 ms; 1000 ms] The analysis of the late latency range [600 ms; 1000 ms] showed that ambiguity influenced the return of ERPs to baseline: more ambiguous pictures led to prolonged positivities. This applied to both the random and the ascending/descending paradigm. In both paradigms, the flower and spider anchor pictures returned fastest to baseline. In the random paradigm, the flower anchor even returned significantly faster to baseline than the spider anchor. This effect narrowly failed to be significant in the ascending/descending paradigm.

Furthermore, pictures 2 and 3, the slightly opened petals of the flower, led to larger mean amplitudes in this time range as well as a slower return to baseline in the random than in the ascending/descending paradigm. This finding fits well with the longer reaction times observed for both pictures in the random as compared to the ascending/descending paradigm. Presumably subjects respond faster to these stimuli if they are presented in an ascending/descending order because of continuing response tendencies in the latter paradigm, and this is also reflected in ERPs.

4.4.2. Original Hypotheses and Results

Valence and Arousal Ratings

- It could not be confirmed that all subjects rate schematic spiders as significantly more aversive than flowers. The valence and arousal ratings of controls did not differ at all for the different pictures, and social phobics rated only the flower anchors as significantly more pleasant and less arousing than all the other pictures.
- On the other hand, it could be confirmed that spider phobics rate the spider anchor picture as more unpleasant and more arousing than controls and social phobics.

- There was evidence for a stimulus generalization or an interpretive bias effect in spider phobics: beginning with the first opening of the petals of the flowers, spider phobics rated stimuli as significantly more unpleasant and arousing than controls and social phobics.

The finding that controls did not rate schematic spiders as more unpleasant and more arousing than schematic flowers is in contrast to Experiment II, where it was found that controls also rated schematic spider pictures as significantly more aversive than flowers. In addition, social phobics rated only the flower anchor as more pleasant and less arousing than all other pictures in Experiment III and did not differentiate between the other pictures in the series. Thus, it seems possible that the context in which stimuli are presented influences valence and arousal ratings.

Reaction Times

- It could not be confirmed that all subjects responded faster to spiders than to flowers, as found in Experiment II.
- This pattern only applied to spider phobics: they responded significantly faster to the spider than to the flower anchor. Thus, a specific facilitation effect in spider phobics could be confirmed.
- Consistent with our hypotheses, reaction times increased with increasing ambiguity of stimuli and were fastest for the unequivocal anchor pictures. Surprisingly, this effect was more pronounced in controls and social phobics than in spider phobics.
- Although the reaction times in spider phobics slightly increased with the first opening of the petals of the flower, i.e. when stimuli became more ambiguous, reaction times rapidly decreased the more stimuli became spider-like. Surprisingly, the faster responses of spider phobics were already present for picture 3 (the widely opened petals of the flower) which controls and social phobics rarely judged to be similar to a spider but spider phobics rated in about 37% to 41% of trials (ascending/descending and random order paradigm, respectively) to be "spider-like". These findings support a stimulus generalization or interpretive bias effect, which also finds its expression in faster reaction times even for ambiguous pictures spider phobics judged to be "spider-like".

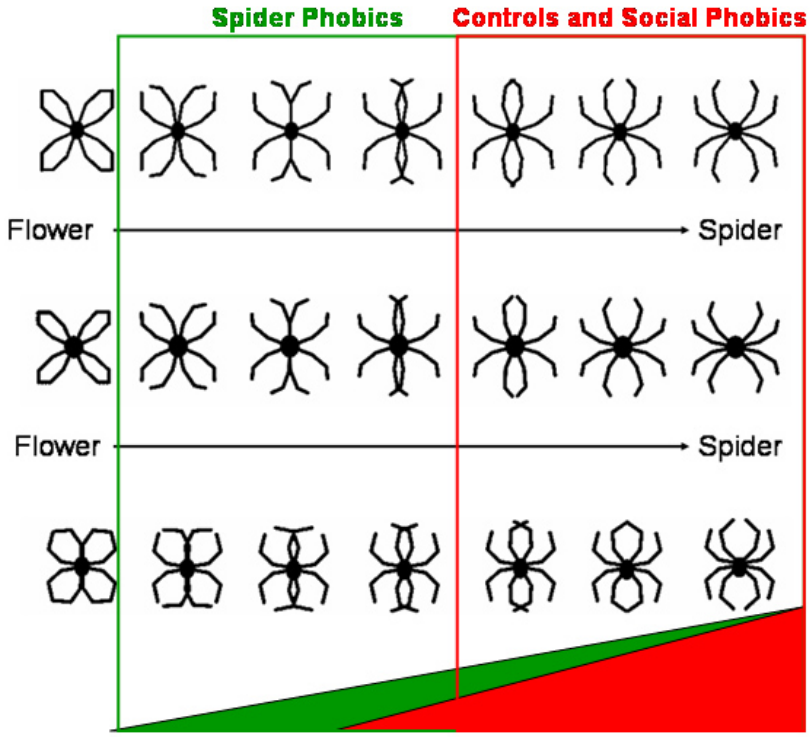


Figure 4.23.: A first answer to the question as to which properties are essential for the perception of a spider: the red border surrounds the stimuli which were classified in most trials as "spiders" by all subjects. The green border outlines the stimuli which were rated in a large proportion of trials as "spider-like" by spider phobics. The tendency to see a spider in a stimulus increased from left to right, which is expressed by the increasing slope of the green and red triangles below the pictures

Classification Frequencies

- The analysis of classification frequencies confirmed that stimuli were rated more often as "spider-like" or "flower-like" the closer their position in the flower/spider series to the corresponding anchor picture was.
- It was confirmed that pictures in mid-positions were largely classified as belonging to the category "neither/nor". In controls and social phobics, "neither/nor" classifications were observed most frequently for picture 4 (the most ambiguous picture), but also frequently for pictures 3 and 5. However, spider phobics deviated from this pattern in that their proportion of "neither/nor" classifications for these mid-position pictures was smaller than their proportion of classifications as "spider-like" stimuli.
- A clear threshold in the series beyond which stimuli were perceived as "spiders" was not obvious. Classifications changed in a rather continuous man-

ner. Picture 5 was the first picture in the series which was classified as a "flower" in only a negligible number of trials and as a "spider" in more than half of all trials in the random order paradigm. Figure 4.23 depicts all pictures of the flower/spider series and shows which pictures were rated in a large proportion of trials by controls and social phobics as "spider-like" (red border).

- In the mixed nonlinear Rasch model, it was found that spider phobics showed a stronger latent trait to classify a picture as a "spider" than controls. This is expressed by their rating ambiguous pictures to a larger proportion as being "spider-like" than controls.

Figure 4.23 shows which stimuli were rated to a large proportion as "spiders" by spider phobics and by social phobics and controls. As detailed above, a case can be made for dividing the stimuli into three sets: picture 1 was classified as a "flower" by all subjects; pictures 2–4 (outlined in green) were rated "spider-like" by spider phobics in a large number of trials, but only rarely by social phobics and controls; and pictures 5–7 (outlined in red) were classified as "spiders" both by spider phobics in most trials and by social phobics and controls in a large number of trials.

Concerning the problem which properties are essential to the perception of a stimulus as a spider, the question thus arises which configurational properties differentiate pictures 2–4 from pictures 5–7. A first explanation might come from the laws of Gestalt psychology: open shapes make the individual perceive a visual pattern as incomplete, and our minds tend to close small gaps and complete unfinished forms. This is known as the Gestalt *law of closure* (Helson, 1933). Possibly, subjects connected the open outlines in pictures 2–4 to form petals and thus flowers. What is common to pictures 5, 6 and 7 is that the outlines of the flower's petals are clearly separate. Thus, the law of closure should not apply any more to these stimuli, and connecting the outlines in such a way as to form petals might not be possible any more. Instead, in pictures 5–7, in each quadrant around the spider body two lines bend in similar directions. Up to picture 7, these two lines form two spider legs in each quadrant.

Thus, the common features of the pictures within the red border in Figure 4.23 provide first clues for an answer to the question as to which properties make a spider fear-relevant. It has to be noted, however, that the present study aimed to be exploratory and that the above suggestions are only a first approach to

answering the above question in a more descriptive way. Obviously, much more research is necessary to arrive at conclusions.

However, one clear result of the present study is that there is evidence to suggest that spider phobics show a stimulus generalization or an interpretive bias effect, since they exhibited a stronger tendency (latent trait) to classify ambiguous stimuli as being spider-like than controls, evaluated them more negatively, and also showed faster responses to these stimuli than controls. Whether the present findings in spider phobics are due to a stimulus generalization effect or a more cognitive interpretive bias remains open, but this question should be pursued by future studies.

Event-Related Potentials

- The hypothesis of larger LPP amplitudes in response to spider anchors compared to flower anchors failed to be confirmed. No significant difference was found in the ascending/descending order paradigm, and in the random order paradigm, there was even a tendency for LPPs to be higher in response to the flower anchor than to the spider anchor.
- As in Experiment II, no specific spider phobia-related enhancements of LPPs in response to spider anchors were found.
- In spite of behavioral evidence for stimulus generalization or interpretive bias effects in spider phobics, no electrocortical correlates of this effect in the form of larger LPPs in response to ambiguous pictures spider phobics judged to be spider-like were found.
- However, the results supported that information transmission had a major influence on LPPs: the unequivocal pictures 1, 6 and 7 led to larger LPPs than the ambiguous pictures 2–5 in the random order paradigm in the interval [400 ms; 600 ms].

  In addition, all pictures presented in the random paradigm led to larger LPPs than in the ascending/descending order paradigm. This is consistent with transmission of less new information in the ascending/descending order paradigm, when subjects could predict what stimulus came next, than in the random order paradigm.

Thus, the results of ERPs fit very well with the model by Johnson (1986) in that *information transmission* strongly influences amplitudes in the P3 latency range.

Johnson's model assumes that unequivocal pictures lead to larger LPPs than more ambiguous pictures. This could be completely confirmed in this experiment.

Johnson also postulates an influence of stimulus *probability* on P3 amplitude. In this study, probability enters the picture in two ways:

- On the one hand, subjective probability was higher in the ascending/descending paradigm than in the random one, since subjects knew what stimulus to expect next. This should cause higher amplitudes in the random paradigm, as we in fact found. This effect overlaps with the influence of information transmission and therefore already appeared above.
- On the other hand, the stimuli used in this paradigm contained only 3 pictures with a closed Gestalt, the flower anchor pictures, while all other pictures had an open Gestalt. Thus, it is possible that subjects classified the stimuli as "open/closed" and exhibited an oddball effect, i.e. a higher amplitude for the flower anchor.

  In fact, this could explain the tendency for higher amplitudes in response to flowers compared to unequivocal spider pictures in the random order paradigm. This effect is contrary to the original hypothesis and the results found in Experiment II. One plausible explanation is that such a Gestalt oddball effect was larger than the influence of stimulus arousal.

  For spider phobics, an affective oddball effect may have had an influence in addition to the above Gestalt oddball effect. They may have classified the stimuli in negative "spider-like" and neutral "non-spider-like" stimuli (the flower anchors), with the latter occurring less frequently, i.e. as oddball stimuli. Such an effect might have caused higher LPPs in response to flower anchors, which might have compensated the larger LPPs for spider-like pictures in spider phobics. This might account for the absence of spider phobia-specific effects on ERPs.

  These effects could not be completely investigated with the paradigms used in this study. However, they may form possible starting points for further research.

Finally, Johnson's model also assumes that stimulus *meaning* influences P3 amplitude and related components in the latency range [400 ms; 600 ms]. Since spider phobics rated stimuli as significantly more unpleasant and arousing, one would have expected corresponding variations in LPPs. Yet, no group differences be-

tween spider-fearful and non-fearful subjects could be found for the processing of spiders and spider-like stimuli. On the contrary, in the random order paradigm there was even a tendency for larger amplitudes in the 400 ms to 600 ms latency range for flowers than for spiders.

To summarize, it seems that the influence of information transmission was most dominant, while the influence of probability is unclear. An influence of arousal (meaning) could surprisingly not be found. Possibly, the factors probability and meaning had opposite influences on LPPs and canceled each other out.

A question that remains to be solved is why reaction times and classification frequencies showed a differential effect for spider phobics, i.e. faster responses the more spider-like pictures became, while ERPs showed no complementary findings. Thus, there was a dissociation between the behavioral findings and the electrophysiological findings which requires an explanation. Three influencing factors may account for this phenomenon: first, the Gestalt oddball effect discussed above, i.e. a larger amplitude to the flower anchor stimuli because of the rare occurrence of a closed Gestalt. Second, an additional affective oddball effect in spider phobics, i.e. spider phobics might have divided the pictures of the flower/spider series in spider-like and non-spider-like stimuli, with the latter occurring subjectively for spider phobics more rarely than the former, because of their stronger latent trait to interpret ambiguous stimuli as being spider-like. Third, there might have been an overall dominant influence of stimulus meaning on P3 amplitude in the present paradigm, which did not allow the investigation of stimulus meaning or emotional content of stimuli on P3 amplitudes and related components.

Summing It All Up

In conclusion, this study confirmed that spider phobics also rate schematic stimuli of spiders as highly unpleasant and aversive. It found that even ambiguous spider-like stimuli were rated as more unpleasant and arousing and that the ratings increased the more the stimuli became similar to the prototype of a spider. In accordance with the valence and arousal ratings, spider phobics showed faster reaction times the more stimuli became spider-like. Furthermore, spider phobics revealed a stronger tendency to classify ambiguous stimuli as being spider-like compared to controls. The described effects could be due to stimulus generalization or to an interpretive bias; however, future studies will have to further explore this phenomenon.

Furthermore, no evidence for a clear threshold in the flower/spider series could be found beyond which stimuli were perceived as spiders. Instead, the classifications changed in a rather continuous manner with spider phobics starting earlier to see spiders in the pictures of the flower/spider series.

The interpretation of ERP data turns out to be difficult because it seems that there were various additional influences on ERPs in the P3 latency range, i.e. information transmission and/or Gestalt oddball effects, and eventually in spider phobics additional affective oddball effects. Future studies will have to find solutions to control for such influences.

A consistent finding of this study is the effect of stimulus ambiguity or equivocation on the amplitude of LPPs and on the return of amplitudes to baseline. Unequivocal stimuli led to larger LPPs which return more rapidly to baseline while ambiguous stimuli led to smaller and more prolonged positivities.

Suggestions For Future Studies

In the present study the responses to the individual stimuli in the flower/spider series were averaged and analyzed independently of how subjects actually categorized stimuli in the individual trials. However, one could also analyze the responses to the pictures depending on each subject's categorization, i.e. their perception in the individual trials, neglecting which picture of the flower/spider series they actually saw. This would lead to three categories which would have to be analyzed, i.e. trials in which subjects perceived a "spider", a "flower", or "neither/nor". It is possible that such an analysis would show differences in LPPs between spider phobics and control groups for those trials in which subjects indicated that they had perceived the stimulus to be a spider.

Continuing from this analysis, one could also analyze induced gamma band activity depending on the category perceived. It has been suggested that induced gamma band activity is a signature of bottom-up and top-down feature processing and is furthermore linked to affective perception (Keil, Gruber, & Müller, 2001). For example, Keil et al. (2001) recorded ERPs while subjects viewed pleasant, neutral, and unpleasant stimuli taken from the IAPS. They were able to show that early mid gamma band activity (30–45 Hz) at 80 ms post-stimulus was enhanced in response to aversive stimuli only. However, the higher gamma band activity (46–65 Hz) at 500 ms showed an enhancement for arousing compared to neutral pictures. Thus, in future studies one could investigate

whether there are similar modulations in gamma band activity in spider phobics when perceiving a spider in an ambiguous schematic stimulus.

5. Summary and Integration of Results

In this final chapter, first the findings of Experiments I, II and III are summarized. Afterwards, an integration and comprehensive interpretation is given, and finally, an outlook on possible future studies is provided.

Experiment I investigated reaction times, heart rates, and event-related potentials in a pictorial emotional Stroop paradigm with spider phobics and non-spider-fearful subjects (controls and social phobics). Subjects either had to identify the color of red or blue spiders, birds and flowers (structural task), or they had to identify the object itself (emotion-focused task) by pressing one of different buttons.

Spider phobics did not show emotional interference, i.e. longer reaction times, when identifying the color of spiders than when identifying the color of birds or flowers. However, they identified spiders generally faster compared to birds or flowers and were faster to identify spiders than controls and social phobics. Furthermore, spider phobics were generally faster than social phobics and – as a tendency – faster than controls in the object identification task.

Heart rate data was difficult to interpret because of high variances. Some evidence for specific changes in heart rates in spider phobics when viewing pictures of spiders was found. However, gender seemed to be a crucial influencing variable: while male spider phobics showed a defense reaction, female phobics exhibited a pronounced orienting response.

ERPs showed larger P3 and P4 amplitudes in spider phobics who viewed their feared object. This effect was independent of task and was interpreted as due to the more arousing character of these pictures for the spider phobic group.

A frontal positivity occurring 500–700 ms post-stimulus was present in all subjects in the emotion-focused task as well as in spider phobics when the task was to identify the color of spiders.

Experiment II attempted to replicate the results of Experiment I using schematic stimuli. Spider phobics, social phobics and controls saw schematic pictures of spiders and flowers, colored either red or blue. The stimuli consisted of identical visual elements, making them ideal control stimuli for each other. Subjects' task was to identify either the color of the stimulus or the object itself by pressing different buttons.

Reaction times showed no emotional Stroop interference in spider phobics when identifying the color of spiders. However, all subjects identified spiders significantly faster than flowers. Spider phobics were generally faster than controls and social phobics in the object identification task.

Heart rates were difficult to interpret, but it seemed that gender had again a strong influence on results: once again, spider phobic females showed a pronounced orienting response to spiders which was not present in male subjects.

The analysis of ERPs revealed that all subjects showed larger late positive potentials (LPPs) in response to spiders compared to flowers, but no additional spider phobia-specific effects were found.

Experiment III was a first approach to explore the question as to which properties make a spider fear-relevant. 3 flower/spider series with 7 pictures each were designed which, starting from the picture of a flower, gradually turned into a spider by shifting the outlines of the petals, turning them into spider legs. Spider phobics, social phobics and controls rated all stimuli for valence and arousal. Stimuli were then presented in random order and in ascending/descending order. Subjects had to decide whether each stimulus was more similar to a "spider", a "flower" or "neither/nor".

With the first opening of the petals of the flower anchor spider phobics rated the pictures as significantly more unpleasant and arousing than controls and social phobics. This difference increased the more pictures became similar to spiders.

In the non-spider-fearful groups reaction times depended on the ambiguity of the picture, i.e. the more unequivocal, the faster the response. In spider phobics reaction times decreased the more pictures became spider-like. Spider phobics showed faster reaction times for the spider than the flower anchor.

Furthermore, spider phobics showed a stronger mean latent trait to interpret a picture as a spider than controls and social phobics. There was no "threshold picture" beyond which subjects started to perceive a spider. Instead, subjects' perceptions changed in a continuous manner with the change in the stimulus configuration.

In the random order paradigm, ERPs reflected a major influence of equivocation: mean amplitudes in the interval [400 ms; 600 ms] were larger the more unequivocal the pictures. Furthermore, contrary to the results of Experiment II, there was a tendency for schematic flowers to lead to larger amplitudes than spiders. In the ascending/descending order paradigm, no differential effects of the different pictures in the series was found.

Finally, in both paradigms ambiguity of stimuli influenced the return of ERPs to baseline: more ambiguous pictures led to prolonged positivities.

Both emotional Stroop paradigms could not find evidence of emotional interference in spider phobics when viewing pictures of their phobic object. This stands in contrast to the studies by Lavy and van den Hout (1993) and Kindt and Brosschot (1997) who found emotional interference in response to pictorial stimuli, although Lavy and van den Hout found less interference for pictorial stimuli than for spider-related words. However, the absence of emotional interference is in accordance with the study by Constantine et al. (2001) which could also find no emotional interference for snake pictures in snake-fearful subjects.

Possibly, the results of linguistic emotional Stroop paradigms in anxiety patients are not replicable with pictorial stimuli, especially when using a manual instead of a verbal response mode. Thus, the question how strongly verbal processing specificities influence the emotional Stroop effect should be discussed. Other possible explanations for the absence of emotional Stroop interference were discussed in Section 2.4.2.

In Experiments I and II, faster reaction times in spider phobics compared to social phobics and controls were found when subjects had to identify spiders. This is consistent with the findings of Öhman et al. (2001) who reported that spider phobics and snake phobics were particularly fast in detecting their feared stimulus in a matrix of neutral, fear-relevant and feared stimuli. Similar results were observed in social phobics when detecting angry faces in a visual search paradigm (Gilboa-Schectman et al., 1999). Thus, there is evidence for an attentional bias in spider phobics for their feared object.

Furthermore, faster responses to schematic spiders compared to schematic flowers were observed in all subjects. This matches the findings of Öhman et al. (2001) who reported a faster detection of fear-relevant stimuli (snakes and spiders) compared to fear-irrelevant stimuli (flowers and mushrooms) in a group of randomly sampled subjects.

Thus, the reported results provide some evidence for the faster detection of spiders in healthy controls and an even stronger similar effect in spider phobics. One explanation could be that schematic spiders depict fear-relevant features to which feature detectors are tuned in all humans whether phobic or not. However, it remains open why such a general bias for spiders was only found when using schematic spider stimuli and not when using non-schematic spider pictures. A possible cause for this effect might be a better generalization of spider phobics from the real life spider to the spider schematic which would lead to faster reaction times for non-schematic spiders.

Finally, spider phobics responded generally faster than controls and social phobics in the object identification task of Experiment II and to some extent also in Experiment I. This is consistent with a general hypervigilance (Beck et al., 1985; Eysenck, 1991, 1992, 1997) in spider phobics, which would lead to generally faster responses. An analogous effect was not significant in the color identification task, presumably because this task is less complex than the object identification task.

In Experiment I, spider phobics showed larger P3 and P4 amplitudes in response to spiders compared to flowers, and there was also some evidence for larger P3 amplitudes for spiders compared to flowers in controls, and a trend for larger P4 amplitudes in response to spiders compared to flowers in social phobics. In Experiment II, all subjects showed larger LPPs in response to spiders than to flowers. Thus, the present studies found evidence for an influence of affective valence/arousal on LPPs, i.e. more arousing and unpleasant stimuli lead to larger parietal positivities in the P3 latency range. This is consistent with various previous studies using emotional pictures from the IAPS series which were discussed in the introduction 1.5.2.

However, it remains to be explained why this effect was more pronounced in all subjects when using schematic spider stimuli compared to non-schematic spider pictures. Yet, this finding should not be overrated and future studies will have to investigate in more detail the differences between schematic and non-schematic spider stimuli.

Furthermore, Experiment I found significantly larger P3 and P4 amplitudes for spider phobics in response to their feared object as compared to controls. The enhanced LPPs in spider phobics for their feared object are consistent with previous findings

by Gutberlet and Miltner (1999, 2001) and Krieschel (2003) who reported larger P3 amplitudes in animal phobics when viewing pictures of their feared object. However, in Experiment II spider phobics also showed larger LPPs for schematic spiders compared to flowers, but this effect was not specific to spider phobics but also appeared in controls and social phobics. Thus, spider phobics did not differ significantly in their P3 and P4 amplitudes in response to spiders from controls and social phobics. It still requires an explanation for this finding: why did spider phobics not show larger amplitudes to schematic spiders although they rated them as more arousing and unpleasant than controls and social phobics?

An enhanced late frontal positivity in the latency range [500 ms; 700 ms] was found in spider phobics when they identified the color of spiders which was not present in social phobics or controls. Two explanations were proposed for this finding: first, that spider phobics in contrast to the control groups concentrated not only on the color of spider pictures but also processed the picture emotionally. Second, that this late frontal positivity reflects an enhanced attentional dwell-time on the feared object in spider phobics and that a possible origin of this frontal positivity could be the ACC, which has been conjectured to play a role in classical and emotional Stroop paradigms. Yet, an explanation is lacking for the failure to replicate such a component in Experiment II when schematic spider stimuli were used. Possibly, the schematic spider stimuli were not as frightening as the non-schematic spider stimuli and therefore spider phobics did not dwell on them as they did on the more realistic non-schematic spider pictures.

Finally, Experiment III yielded some very interesting new insights into the processing of feared and fear-relevant stimuli. Spider phobics rated spiders and spider-like stimuli as significantly more unpleasant and arousing than controls and social phobics. Surprisingly, this effect started with the first opening of the outlines of the petals of the schematic flower anchor picture. Furthermore, spider phobics also showed a reaction time advantage for spiders and stimuli they judged more frequently to be spider-like. In addition, the analysis of classification frequencies with a modified mixed Rasch model found a significantly stronger latent trait to see a spider in a picture in spider phobics compared to controls and social phobics. All these findings strongly hint at an interpretive bias in spider phobics which is similar to the negative interpretation bias found in social phobics. Like social phobics who are more prone to (mis)interpret ambiguous social situations as more threatening, spider phobics also rated the ambiguous stimuli used in this experiment as more threatening, classified them more often as a spider, and showed on average faster reaction times for these stimuli than controls and social

phobics. Alternatively, the results could also be explained by a well-known effect of learning psychology, namely stimulus generalization. While interpretive covariation biases are well-documented in animal phobia, i.e. spider phobics tend to overestimate the association between between spider pictures and aversive outcomes, this is the first study to report a negative interpretation bias or stimulus generalization effect in animal phobia.

In the light of the consistent findings for affective picture ratings, classifications, and reaction times, it seems the more surprising that no electrophysiological correspondence to the behavioral effects could be found. Instead, ERPs reflected a major influence of equivocation: increased uncertainty in identifying the eliciting event reduces LPPs. This is consistent with Johnson's model of influences on P3 amplitude and with the results of previous studies (Fitzgerald & Picton, 1982; Johnson & Donchin, 1978; Ruchkin & Sutton, 1978). Various reasons for the failure to find an influence of affective valence/arousal of the different stimuli on LPPs in Experiment III were discussed. These were an overall dominant effect of equivocation, and possibly also a Gestalt oddball effect and in spider phobics an additional affective oddball effect.

Finally, Experiment III could not identify a clear threshold in the flower/spider series beyond which stimuli were perceived as spiders. Instead, the classifications changed in a rather continuous manner. Suggestions regarding which configurational properties caused a picture to be perceived as a spider, i.e. fear-relevant, were discussed. While controls and social phobics were rather similar in their classifications of the different stimuli, spider phobics differed significantly from both groups in their latent trait to see a spider in a stimulus. In spider phobics, even the picture with the slightly opened outlines of the petals of the flower anchor was interpreted in nearly a third of all trials as a spider. Thus, for spider phobics the pictures in the series started to look spider-like once the closed configuration of the flower anchor turned into an open Gestalt, and the subjective similarity to a spider increased continuously the more the outlines of the petals opened and turned into spider legs.

The following conclusions can be drawn from the results reported in this thesis:

1. Experiments I and II provided strong evidence for an attentional bias for feared stimuli in spider phobia, but this bias was expressed as a more ready detection of threat rather than – as reported previously in linguistic emotional Stroop paradigms – as an emotional interference effect. Presumably different mechanisms are at work in pictorial and linguistic emotional Stroop paradigms.

2. Furthermore, Experiment II found some evidence for a special relevance of spiders for all subjects, independent of whether they are phobics or not. This supports evolutionary models which assume that specialized neural systems for the processing of fear-related stimuli evolved during evolution since rapid detection of fear-related cues was critical for survival.

3. Experiment III is the first study to report evidence for a negative interpretation bias or stimulus generalization effect in spider phobics.

4. No threshold in the flower/spider series beyond which stimuli were perceived as spiders was found. Instead, classifications changed in a rather continuous manner, although spider phobics started interpreting stimuli as being spider-like earlier than controls and social phobics.

5. However, the results of the present studies strongly depended on the experimental design and the stimuli, e.g. schematic vs. non-schematic stimuli (as in Experiment I and II), or schematic flower and spider anchors only vs. a picture series with transitional pictures in between (as in Experiment II and III).

5.1. Implications for Future Studies

The results of the present experiments show that different results can be obtained with only small variations in experimental conditions. In the study of attentional biases in animal phobia, but also of anxiety disorders in general, an uneven use of a limited number of experimental paradigms can be observed. Regarding the attentional bias in phobia and anxiety disorders, the influence of card vs. computer presentation, blocked vs. single trial presentation, linguistic vs. pictorial stimuli, and oral vs. manual response modes should be investigated. As Wells and Matthews (1994) argue, where consistent results are found using only a limited number of paradigms, there is the possibility that these findings reflect procedural aspects of the tasks used and not more general phenomena. More information on the internal consistency, stability, and comparability of variants of the emotional Stroop task is needed (Egloff & Hock, 2003).

Although it seems an established finding that an attentional bias in anxiety disorders exists, it has been demonstrated with a limited number of paradigms, and the influence of small variations in experimental designs on results is still not well understood. Various suggestions for future studies were given in the discussion of each experiment.

In particular, the transitional stimuli used in Experiment III might help in developing new paradigms to investigate different aspects of attentional bias in spider phobia. It seems promising to study in further detail the phenomenon of stimulus generalization and/or interpretive bias in spider phobia. One interesting question would be, for instance, whether the observed interpretative bias or stimulus generalization effect occurs on a more preattentive level (possibly because feature detectors are tuned differently in spider phobics compared to controls) or whether it is due to a more or less conscious cognitive bias. In the latter case the term "interpretative bias" would be more appropriate while in the former case learning mechanisms on preattentive levels could play a role and the term "stimulus generalization" would be more appropriate. Öhman (1993), for example, explicitly notes that conditioning mechanisms may play a role in the development of phobias by tuning feature detectors to respond preferentially to features of feared objects.

In addition, further characteristic features of fear-relevant stimuli like the sinusoidal shape of a snake should be investigated. Also, whether feature detectors are specifically sensitive to certain movement-related characteristics of feared animals like the wriggling of snakes and the crawling of spiders should be investigated.

While the reported studies mainly focused on P3 and related components, future studies should investigate the variation of additional components, in particular early visual components like the visual N1 or induced gamma activity (cf. Keil et al., 2001), in response to fear-relevant vs. fear-irrelevant stimuli.

A. DSM-IV Criteria

A.1. Specific Phobia

According to **DSM-IV** (American Psychiatric Association, 1994) the essential features of Specific Phobia are:

A: Marked and persistent fear that is excessive or unreasonable, cued by the presence or anticipation of a specific object or situation (e.g. spiders, snakes).

B: Exposure to the phobic stimulus almost invariably provokes an immediate anxiety response, which may take the form of a situationally bound or situationally predisposed Panic Attack. Note: In children, the anxiety may be expressed by crying, tantrums, freezing or clinging.

C: The person recognizes that the fear is excessive or unreasonable. Note: In children, this feature may be absent.

D: The phobic situation(s) is avoided or else is endured with intense anxiety or distress.

E: The avoidance, anxious anticipation, or distress in the feared situation(s) interferes significantly with the person's normal routine, occupational (or academic) functioning, or social activities or relationships, or there is marked distress about having the phobia.

F: In individuals under age 18 years, the duration is at least 6 months.

G: The anxiety, Panic Attacks or phobic avoidance associated with the specific object or situation are not better accounted for by another mental disorder, such as

Obsessive-Compulsive Disorder, Post-traumatic Stress Disorder, Separation Anxiety Disorder, Social Phobia, Panic Disorder with Agoraphobia, or Agoraphobia Without History of Panic Disorder.

A.2. Social Phobia

The essential features of Social Phobia according to **DSM-IV**(American Psychiatric Association, 1994) are:

A: A marked and persistent fear of one or more social or performance situations in which the person is exposed to unfamiliar people or to possible scrutiny by others. The individual fears that he or she will act in a way (or show anxiety symptoms) that will be humiliating or embarrassing.

B: Exposure to the feared social situation almost invariably provokes anxiety, which may take the form of a situationally bound or situationally predisposed Panic Attack.

C: The person recognizes that the fear is excessive or unreasonable.

D: The feared social or performance situations are avoided or else are endured with intense anxiety or distress.

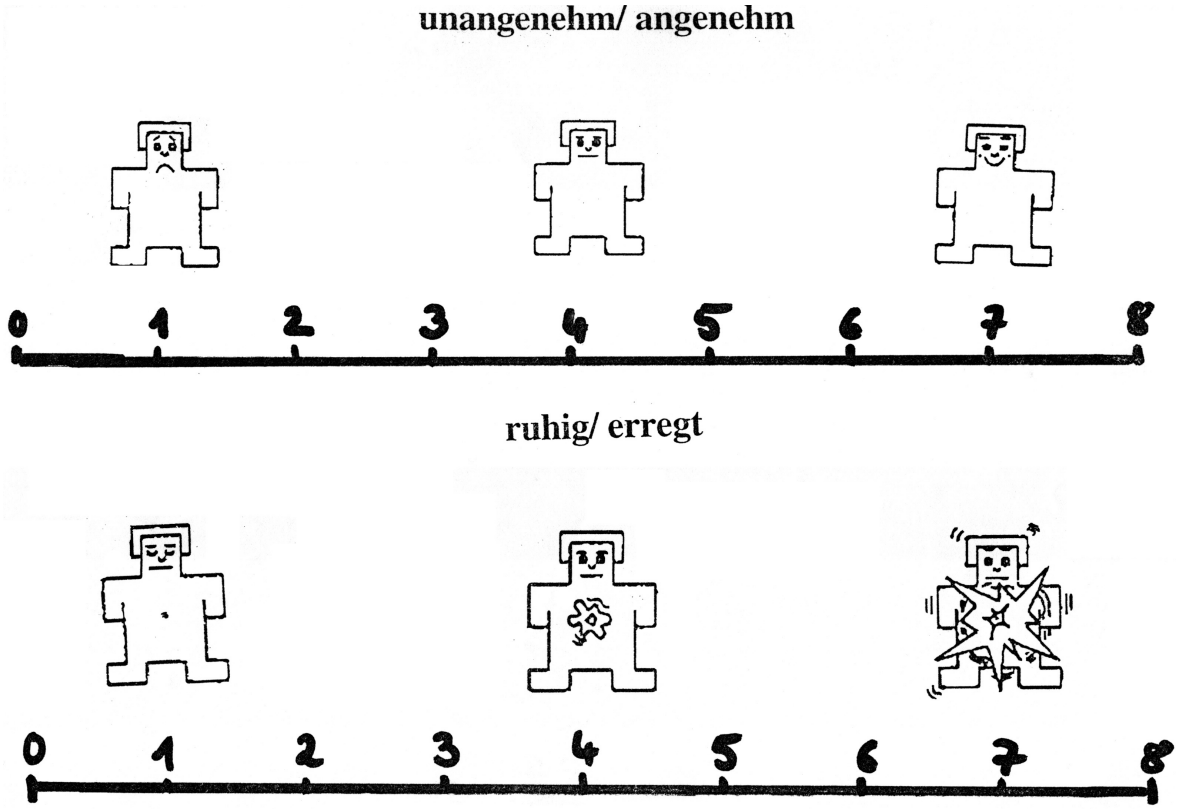
E: The avoidance, anxious anticipation, or distress in the feared situation(s) interferes significantly with the person's normal routine, occupational (academic) functioning, or social activities or relationships, or there is marked distress about having the phobia.

F: In individuals under age 18 years, the duration is at least 6 months.

G: The fear or avoidance is not due to the direct physiological effects of a substance (e.g. a drug of abuse, a medication) or a general medicational condition and is not better accounted for by another mental disorder (e.g. Panic Disorder With or Without Agoraphobia, Separation Anxiety Disorder, Body Dysmorphic Disorder, a Pervasive Developmental Disorder, or Schizoid Personality Disorder).

H: If a general medical condition or another mental disorder is present, the fear in Criterion A is unrelated to it, e.g. the fear is not of Stuttering, trembling in Parkinson's disease, or exhibiting abnormal eating behavior in Anorexia Nervosa or Bulimia Nervosa.

B. Self Assessment Manikin

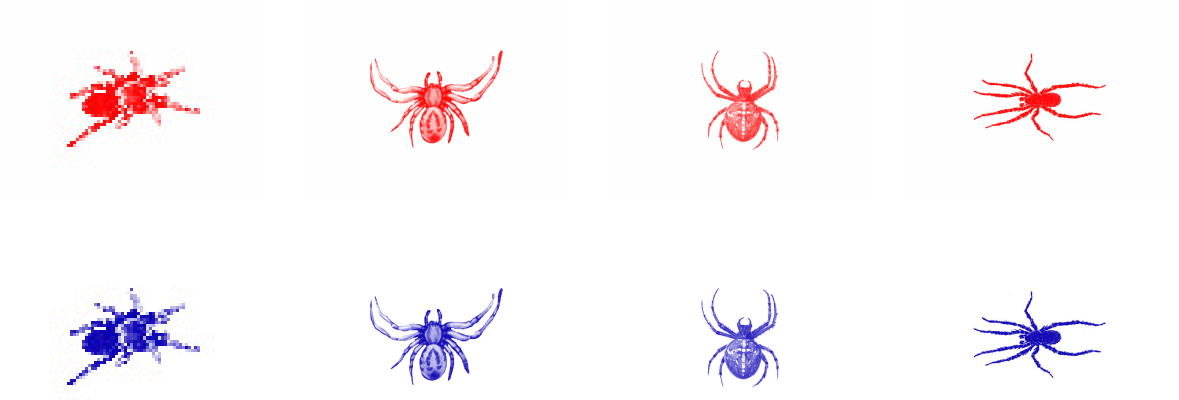


The picture shows a slightly modified version of the SAM scale. Instead of ranging from 1–9 this scale ranges from 0–8. The upper scale assesses emotional valence, e.g. whether the stimuli are rated pleasant or unpleasant (German: "angenehm" vs. "unangenehm"). This dimension is related to behavioral approach or avoidance. The lower scale assesses the intensity of emotional arousal ranging from low to high arousal (German: "ruhig" vs. "erregt").

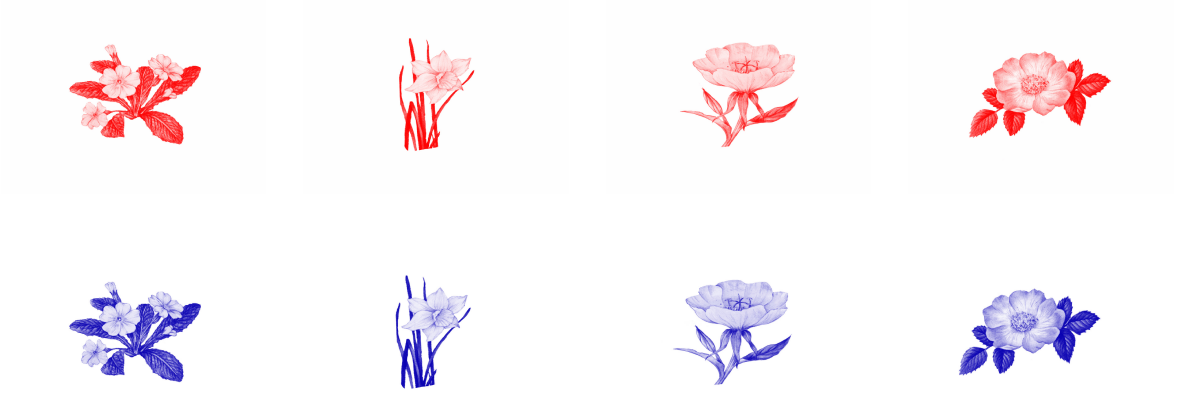
C. Stimuli

C.1. Examples of Stimuli in Experiment I

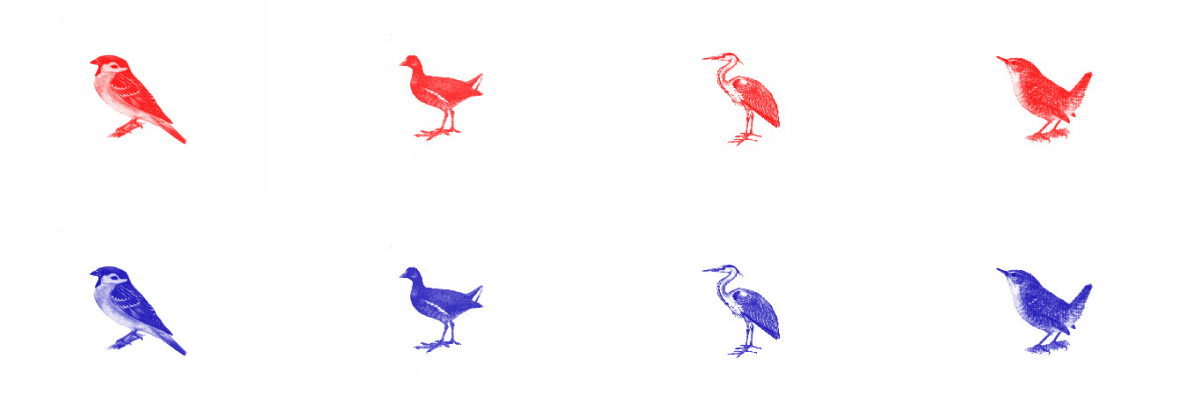
Spider Stimuli



Flower Stimuli

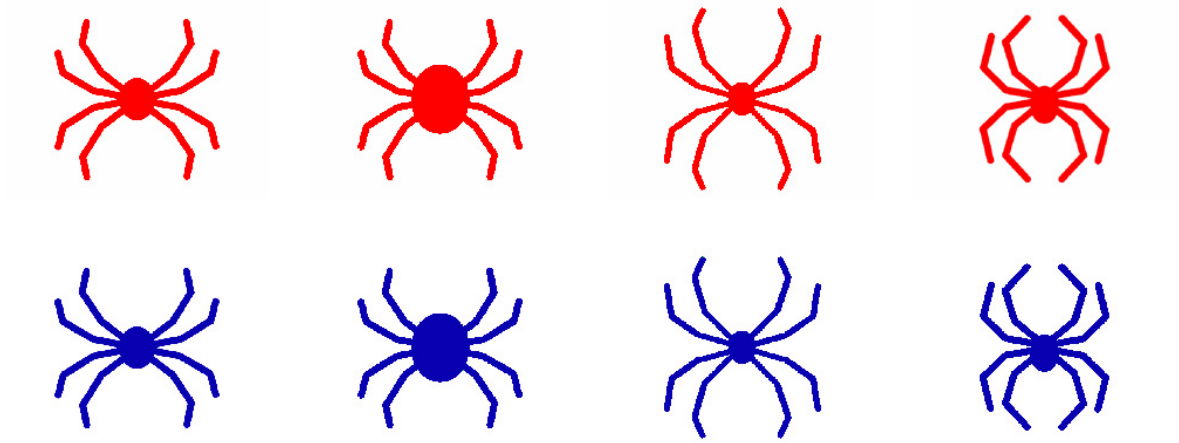


Bird Stimuli

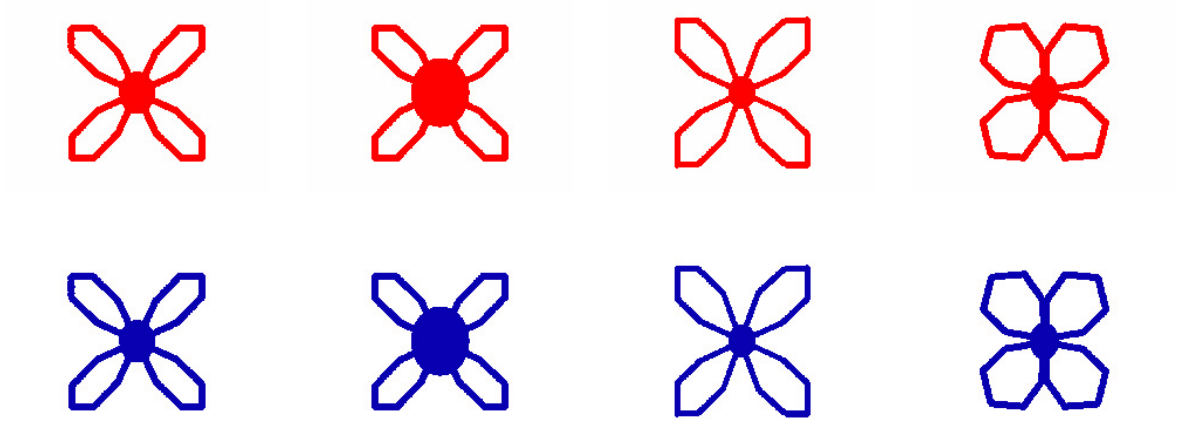


C.2. Schematic Stimuli of Experiment II

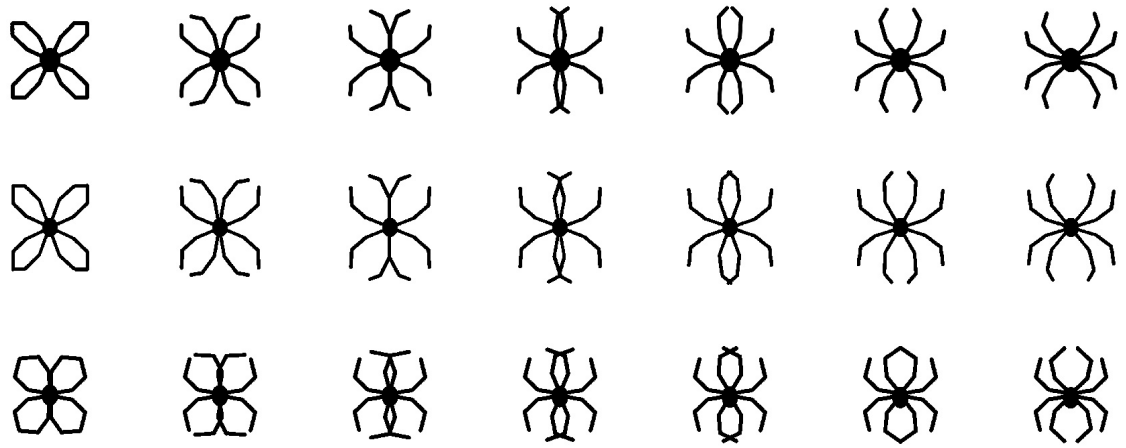
Spider Stimuli



Flower Stimuli



C.3. Transitional Schematic Flower/Spider Stimuli of Experiment III



The stimuli are shown smaller than in Appendix C.2 in order to fit in one line. In the actual experiment they were as large as in Experiment II.

D. A Modified Mixed Rasch Model for the Analysis of Classification Frequencies

A Modified Mixed Rasch Model was used to analyze the classification frequencies of schematic spider pictures.

The "simple" Rasch model can be summarized as follows (Andrich, 1988): consider dichotomous responses r_{jk} of subject j to item k with possible values 0 and 1 (e.g. 1 corresponding to "spider" and 0 to "flower" or "neither-nor"). The response r_{jk} is p_{jk}-Bernoulli distributed, i.e. $P(r_{jk} = 1) = p_{jk}$, where

$$p_{jk} = \frac{\exp(z_{jk})}{1 + \exp(z_{jk})} \quad \text{with} \quad z_{jk} = \theta_j - \delta_k. \tag{D.1}$$

In this formula, θ_j denotes a *latent trait* of subject j (e.g. the ability of subject j to recognize a spider in some picture), and δ_k denotes the *item difficulty* of item k (e.g. the difficulty of recognizing a spider in the k-th picture). Thus, p_{jk} is logistic in θ_j and "negatively" logistic in δ_k.

For our estimations, we will assume normal distributions, i.e. $\theta_j \sim N(0, \beta)$, where β is the standard deviation of the subject component.

For our purposes, we extend the simple Rasch model in two ways: first, we allow multiple answers of the same subject to the same item, since in our experiments, each subject saw every stimulus more than once. Suppose that subject j answers n_{jk} times to item k, and that every single answer is p_{jk}-Bernoulli distributed. Then the sum of all answers, which we again denote by r_{jk}, is a natural number between 0 and n_{jk} and

is (p_{jk}, n_{jk})-binomially distributed:

$$P(r_{jk} = s) = \binom{n_{jk}}{s} p_{jk}^{s} (1 - p_{jk})^{n_{jk}-s}. \tag{D.2}$$

Second, we know that each subject belongs to one of three groups (in this application, spider phobics, social phobics and controls). This additional information can be included in the model by assuming a mean latent trait of 0 for the control group, of some value α_{So} for the social phobics and of some α_{Spi} for the spider phobics. Consider two indicator variables x_j^{Spi} and x_j^{So}, where $x_j^{\text{Spi}} = 1$ if subject j is a spider phobic and $x_j^{\text{Spi}} = 0$ otherwise, and analogously $x_j^{\text{So}} = 1$ if subject j is a social phobic and $x_j^{\text{So}} = 0$ otherwise. Now, the logit z_{jk} in Equation (D.1) is calculated as follows:

$$z_{jk} = \theta_j + \alpha_{\text{Spi}} x_j^{\text{Spi}} + \alpha_{\text{So}} x_j^{\text{So}} - \delta_k, \tag{D.3}$$

where again $\theta_j \sim N(0, \beta)$.

Now the parameters α_{So}, α_{Spi}, $\delta_1, \ldots, \delta_k$ and β can be estimated, e.g. by maximizing an approximation to the likelihood integrated over the random effects, as implemented in the NLMIXED procedure of SAS (Wolfinger, 1999).

List of Tables

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Ehrenwörtliche Erklärung

Hiermit erkläre ich:

Die geltende Promotionsordnung ist mir bekannt.

Ich habe die vorliegende Dissertation selbst angefertigt und dabei die Hilfe eines Promotionsberaters nicht in Anspruch genommen. Alle von mir benutzten Hilfsmittel und Quellen sind angegeben. Keine weiteren Personen haben mich entgeltlich oder unentgeltlich unterstützt und weder unmittelbar noch mittelbar geldwerte Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

Die Dissertation wurde weder in dieser noch in ähnlicher Form als Prüfungsarbeit für eine staatliche oder andere wissenschaftliche Prüfung eingereicht, noch habe ich gegenwärtig oder früher eine Dissertation an einer anderen Hochschule oder Fakultät eingereicht.

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