Chapter 8

Summary
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The main focus of this thesis was to study the interactions between visual processing streams and, more specifically, covert and overt visual processing via these streams. Section 1 of this thesis provided an overview of the brain structures involved in visual processing. In section 2, rehabilitation methods for homonymous hemianopia and unilateral neglect were reviewed. Section 3 consisted of three experimental studies in which covert and overt processing of faces, emotional facial expressions and conditioned faces were studied. In this chapter, the main findings of the previous chapters will be summarized.

In chapter 2, three parallel visual processing streams were described: a dorsal, occipitoparietal stream for processing visual information related to movement, location and motor action; a ventral, occipitotemporal stream for processing information related to specialized recognition of objects and faces; and a subcortical, cortico-amygdalar and thalamo-amygdalar pathway for processing of emotion-related information.

Impaired visual perception may occur as a result of brain damage. Different types of impaired visual perception were described, that could be related to damage of a distinct stage of visual processing or a distinct visual processing stream. Damage to the lateral geniculate nucleus, the optic radiation or the extrastriate cortex leads to homonymous field defects. Unilateral neglect and Bálint syndrome were described as examples of perceptual disorders after damage to the dorsal stream. Damage to the ventral stream may lead to agnosias. Two specific agnosias were described in the introduction: pure alexia and prosopagnosia. Damage to the amygdala, which is a crucial brain structure for visual processing of emotion-related information, may lead to impaired recognition of negative emotional facial expressions, such as fear.

Although each stream is primarily dedicated to a specific category of visual information, this does not mean that this category is processed exclusively by a single stream. First, many interactions exist between the streams to allow purposeful behaviour, such as visuomotor actions or complex social behaviour. Second, the visual processing streams are capable of modulating each other, either in a top-down or in a bottom-up fashion. Third, impaired processing of a specific category of visual information may in some cases be overcome by processing via another stream, which is not the primary designated stream for that specific type of information. Fourth, visual processing via a not-primarily designated stream may in some cases lead to so-
called ‘covert’ processing – as opposed to ‘overt’ processing via the primarily designated visual processing route.

In section 2, rehabilitation methods for two common visual impairments after acquired brain damage were reviewed. Chapter 3 consisted of a systematic review of the two main rehabilitation methods for patients with homonymous visual field defects (HVFDs): vision restoration therapy (VRT) and scanning compensatory therapy (SCT).

In general, the effect of VRT was only evaluated in terms of the increase of visual field size. Since the basic assumption of VRT is that this increase of the visual field size will help patients with HVFDs to improve functions related to reading and mobility (e.g. better reading performance and less bumping into objects), tasks related to these functions should have been included in the outcome measures. While the evidence for the effect of VRT leans heavily on a change of visual field size, which is also called ‘border shift’, the very techniques aiming to reliably assess this border shift have been questioned. It was therefore concluded that the effects of VRT remain unclear until general consensus is reached which methods of perimetry should be used to measure the exact size of the visual field and the alleged improvements in the transition zone. The recommended treatment for patients with HVFDs is SCT. However, the current body of evidence for SCT should be further substantiated by randomized controlled trials.

Chapter 4 consisted of a review of rehabilitation methods aiming to improve unilateral neglect. In many respects, patients suffering from the neglect syndrome form a heterogeneous group and this complicates the decision which rehabilitation method should be generally recommended. First of all, neglect symptoms cannot be linked to a single, discrete anatomical structure. In most patients, neglect appears to be caused by right hemisphere lesions including the temporoparietal-occipital junction. However, other regions, such as the thalamus, the middle temporal lobe, and the superior temporal lobe may also cause neglect. Also, the symptoms of neglect may vary from patient to patient. For instance, some patients may be more impaired at motor tasks, while others may be more impaired at sensory tasks. Neglect patients may have non-lateralized attentional deficits, such as impaired arousal and impaired sustained attention, which also interact with the neglect symptoms.
Whatever the origin and nature, the neglect syndrome can be regarded as a disorder of impaired dorsal processing. While some rehabilitation methods aim at learning patients to overcome their deficits by applying compensation strategies, as is the case in visual scanning therapy, other interventions aim to use intact networks to modulate or even restore the impaired network. It was concluded that the effects of intensive compensatory training appear to mainly limited to the tasks that are trained. The effects of some of the interventions that aim to overcome the underlying deficits, for example caloric stimulation by pouring iced water in the left ear canal, appear to be compelling. Nevertheless, their effects are also very short-lived.

In section 3, three experimental studies were presented that focused on covert and overt processing of faces or emotional facial expressions. In *chapter 5*, a patient (JS) was described, who displayed symptoms of both prosopagnosia and Capgras delusion. JS had impaired recognition of familiar faces, which is the hallmark of prosopagnosia. However, recognition of close family members was far worse than recognition of celebrities. Moreover, JS had delusional attributions about the appearance of people with whom recognition was accompanied by a strong emotional connotation. For instance, JS believed that her grandchildren looked extremely tanned and corpulent. The fact that that recognition of close family members was more impaired than recognition of celebrities, and that recognition of family members was accompanied by a delusional attribution, provides some striking similarities with Capgras delusion. On the other hand, patients suffering from Capgras delusion normally have adequate performance on face recognition tasks.

To explore this phenomenon, different measures of covert and overt face recognition were employed to assess performance on a face recognition tasks. JS’ performance was compared with three control subjects who were matched for age, sex and family size. Whereas control subjects had faster decision times for recognizing photographs of family members compared to celebrities and unfamiliar people, JS showed an opposite pattern, as her decision times for recognition of family member was almost twice as long as for celebrities and unfamiliar people. Strikingly, JS’ had enhanced skin conductance responses (SCRs) to presentation of images of family members, compared to unfamiliar people. This may indicate that, in the absence of overt face recognition, some type of covert face processing is still intact, although it was argued that the enhanced SCRs may be indicative of other mechanisms as well.
A second experimental study, designed to investigate early, pre-attentive visual processing of facial emotional expressions and aversively conditioned faces, was described in chapter 6. In this study, event-related potentials (ERPs) to masked and unmasked photographs of faces were assessed in 32 young adults. Two early ERP components were analysed: P1 and N170. The P1 component is related to extrastriate activity and is usually considered to be the first endogenous ERP component in visual processing, but in some studies P1 has been shown to be sensitive to face processing as well. The N170 is regarded as the first face-specific ERP component and has been linked with the phase of structural encoding, during which facial features are integrated to generate a face representation. In the experiment described in this chapter, face stimuli consisted of a neutral face (N), an unconditioned angry face (CS-) or an aversively conditioned angry face (CS+). Stimuli were presented either masked, to assess visual processing without awareness, or unmasked, to assess conscious processing.

P1 was only sensitive to masked presentation of stimuli. P1 amplitudes to CS- masked faces were higher than those elicited by masked CS+ and N stimuli, while P1 amplitudes to masked CS+ stimuli were lower than masked N stimuli. N170 amplitudes were sensitive to conditioning when stimuli were masked: amplitudes to CS+ were less negative than CS- amplitudes. In the unmasked condition, N170 was only sensitive to facial emotional expression: amplitudes to N stimuli were more negative than CS- amplitudes.

Interestingly, P1 amplitudes in the masked condition interacted with subjects’ experienced anxiety in daily life, as assessed by the State-Trait Anxiety Inventory. Subjects with relatively high trait anxiety had higher P1 amplitudes in general and, more specifically, showed no difference between P1 amplitudes to CS+ and N. Whereas trait anxiety only correlated with P1 amplitudes, state anxiety only correlated with N170 amplitudes. Subjects with low state anxiety had more negative N170 amplitudes than subjects with high state anxiety.

It was concluded that P1 and N170 may reflect distinct neural mechanisms of face processing. P1 may be sensitive to unconscious processing of both facial emotional expression and classical conditioning. N170 may be sensitive to unconscious processing of conditioning and conscious processing of emotional facial expressions. It was argued that the P1 modulation may reflect afferent projections of
the amygdala to the extrastriate cortex. N170 may reflect afferent projections of the amygdala to later stages of cortical processing.

In *chapter 7*, a patient (FZ) was described, who had impaired overt recognition of fear after a lesion of the right lower and middle temporal gyrus and the right amygdala. Employing ERPs in a backward masking design similar to the one described in chapter 6, covert processing of facial emotional expressions and aversively conditioned faces was assessed. Stimuli consisted of faces with a surprised emotional facial expression (S), an unconditioned fearful face (CS-) and an aversively conditioned fearful face (CS+). Two ERP components could be related to the experimental manipulation: a centrofrontal P170 and a frontal Late Negativity. P170 was only sensitive to the effect of aversive conditioning (i.e. the difference between CS- and CS+) when these stimuli were presented in the unmasked condition. However, in the masked condition, N170 was only sensitive to the effect of basic emotional expression (i.e. the difference between S and CS-). The frontal Late Negativity component was sensitive to the effect of aversive conditioning and basic emotional expression in the masked condition, and only sensitive to the effect of basic emotional expression in the unmasked condition.

It was concluded that, although FZ has no explicit recognition of fearful facial expressions, the ERP data in this experiment show that, at least to a certain extent, covert processing of fear is still intact. The fact that an effect of aversive conditioning was only found under circumstances of masked presentation, might be indicative of the involvement of the intact left amygdala in this type of visual processing.