Where emotion meets cognition
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General discussion
One characteristic feature of Obsessive-Compulsive Disorder is a persistent urge to perform compulsive actions over and over again. The experiments described in this thesis addressed the question whether these symptoms are related to impaired decision making in an emotional context. This final chapter discusses the results of these experiments in the context of the literature and ends up with some suggestions for future research.

Recapitulation of the findings

With the literature review presented in chapter 1, we attempted to gain insight in the brain dysfunctions that underlie obsessive-compulsive behaviour. Although OCD is accompanied by various cognitive impairments, their precise relationship with the symptoms is not quite clear. Functional brain imaging studies have identified involvement of the orbitofrontal circuit in OCD, which is associated with reinforcement learning and decision-making. Theories on cognitive functions of this specific neural network may not only help to integrate cognitive and neurobiological accounts of OCD, but can also guide the design of new behavioural investigations in OCD.

Before looking at decision-making ability in OCD, we first performed a study on the nature of executive function in OCD (chapter 3). Although executive impairments have been reported in the literature, their role in the pathogenesis of the disorder is far from clear. Our data reveal that OCD patients displayed impairments in planning ability, spatial memory and motor speed that persisted after clinical improvement. The enduring nature of the impairments indicate that they form a trait feature of OCD, which means that they are already present before OCD symptoms become manifest. The character of the impairments refers to a subtle, but yet chronic dysfunction of a neural network involving dorsolateral frontal and parietal regions and subcortical structures.

In the subsequent chapters, we examined different hypotheses about the nature of one particular executive function, namely decision making. More specifically, we questioned to what extent disordered decision processes account for the repetitive nature of compulsive actions. The studies in this dissertation have used different approaches to study decision making behaviour of OCD patients.

Current theories on human decision making ascribe a prominent role to preattentively induced emotional changes in the body, which are in the position to affect subsequent cognitive processing. These bodily responses, or ‘somatic markers’, act as a warning signal by indicating the appetitive value of a candidate response option (Damasio, 1994). A dysfunction in the somatic marker system
would lead to inadaptive decision making, especially in uncertain situations when there are many competing response alternatives. Indeed, patients with damage to the ventromedial prefrontal cortex (which is the part of the brain that would contain cortical representations of somatic markers) do not generate autonomic responses when confronted with aversive stimuli. In addition, these patients show excessive risk taking behaviour, both on laboratory gambling tasks as well as in daily life. On the other hand, in fear-related disorders such as phobia, bodily responses to phobic objects would be extremely strong and therefore interfere with the cognitive appraisal of the object. Patients suffering from these disorders would therefore be predisposed to evaluate such a stimulus as being dangerous or threatening.

In chapter 4, we examined the role of bodily arousal responses in compulsive washing by comparing skin conductance responses (SCRs) of OCD washers to masked washer-relevant and control pictures. We found no evidence that washers produced stronger SCRs to the masked washer-relevant pictures, and it was therefore concluded that automatically elicited fear responses do not play a vital role in compulsive washing behaviour. However, there was some evidence that the patients did not habituate to the masked OCD pictures, whereas they did to the other pictures, suggesting that OCD washers may process disgust-related material in an abnormal way.

A second reason why OCD patients could develop compulsive rituals is because of a failure to interpret the outcome of their own actions. We hypothesized that these patients may be particularly compromised in the use of the motivational significance of feedback. Such a failure may explain why many OCD patients do not ‘experience conviction and a sense of completion’ (Reed, 1983, p. 173) after having performed their compulsions.

However, this hypothesis was not confirmed by our data on the Iowa gambling task (chapter 5). The normal task performance in the OCD group demonstrates that these patients are able to use ‘somatically marked’ emotional experiences for implicit risk learning. We also found that the level of risk adjustment was independently modulated by both the severity of anxiety and obsessive-compulsive symptoms. High anxiety could promote risk taking by interfering with cognitive control functions associated with the frontal lobe. In addition, the presence of increased risk taking behaviour in patients with severe obsessive-compulsive complaints could reflect a difficulty to handle short and long term reward in daily life.

We subsequently tested whether OCD patients can use the emotional significance of feedback to learn certain stimulus-response associations. In the experi-
ment described in chapter 6, OCD patients performed a visuomotor associative learning task in which feedback was used to reinforce certain stimulus-response combinations at the expense of others. Our data not only reveal that OCD patients recalled fewer visuomotor associations, but also needed more time to select a particular stimulus-response combination. Unlike the data of chapter 5, these data show that OCD patients have a profound impairment in processing response feedback. Interestingly, our prediction that discriminative learning was modulated by feedback valence was only confirmed for patients with checking compulsions. This indicates that negative emotions interfere with the encoding of feedback, which could explain why checking compulsions often increase when patients feel responsible for the consequences of their own actions.

Finally, the study described in chapter 7 examined whether the repetitive nature of compulsions is related to memory impairments. In particular, OCD patients may fail to encode the circumstances under which the action took place, especially when they are dealing with threatening information. As a consequence, their memories may not provide sufficient contextual information to decide whether an action was really performed or only imagined. Another possibility is that negative emotions have an effect on the criteria that OCD patients use to evaluate their memory. For instance, it is possible that OCD patients require that the memory of the action is very vivid before they are able to say that the action was performed and not imagined. This would manifest itself in a conservative response bias, that is, the tendency to choose for ‘imagined’ rather than ‘performed’ when being insecure about performing an action. In this study, OCD patients (split in ‘washers’ and ‘checkers’) were presented with both neutral and emotionally salient words either auditorily or visually. In the former case, they were required to imagine their visual form. In the subsequent test phase, subjects first performed an old/new decision on the studied words and then a source memory task in which they indicated whether they had heard the word or seen it. Using signal detection analysis, there was no evidence that encoding of OCD checkers was aversively influenced by checker-related words. However, it appeared that checkers were significantly more inclined to attribute threatening words to the visual modality than neutral words, while this effect was absent in washers and normal controls. It was concluded that poor memory confidence might be due to the fact that checkers change their response bias when judging emotional memories. Quite a different picture emerged in patients with washing compulsions, who displayed a general reality monitoring impairment but no biased decision making for washer-related words. Although tentative, this pattern
may reflect the interfering effects of high anxiety on frontally mediated memory processes.

**Decision making and emotions in OCD**

Clinical observations reveal that OCD patients have profound difficulties to regulate their behaviour when being in an obsessional state. We hypothesized that these behavioural impairments are the result of altered decision-making in an emotional context, and tested this by examining several aspects of decision making in OCD.

According to some theorists, responses generated by the peripheral nervous system play a crucial role in decision-making (Damasio 1994; Ohman, 1998). In particular, anticipatory arousal responses can guide decision-making even before the subject becomes aware of the danger of the situation (Critchley et al., 2001). However, we found no evidence that pre-attentively processed washer-related stimuli elicited extreme arousal responses in compulsive washers (*chapter 4*). This suggests that the difficulty of OCD washers to evaluate the ‘cleanness’ of an object does not result from interference of excessive arousal responses with high level cognitive processing. At the neural level, the normal elementary processing of threatening material refers to intact functioning of the amygdala in OCD. Interestingly, neuroimaging studies in OCD point to abnormal neural functioning of the orbitofrontal network (Swedo et al., 1989; Baxter et al., 1992; Perani et al., 1995; Adler et al., 2000). This network is increasingly associated with the subjective experience of emotion or ‘feelings’, while the amygdala would support the processing of primary emotions (Damasio, 1999; Dolan, 2002). This fits with our suggestion (*chapter 4*) that it is the *interpretation* of emotion-induced changes in the body, rather than elementary emotional processing, that is deficient in OCD.

Ironically, we have seen that this faulty appraisal of emotional information may also partially account for the lack of enhanced *scrs* to unmasked OCD pictures (*chapter 4*). For instance, several OCD patients reported after the experiment that they made inferences about the threat value of a certain picture, due to which a neutral picture representing flowers could come to elicit anxiety (‘a dog may have urinated on these flowers’) while the threat value of some OCD pictures was diminished (‘it is only a picture and not real dirt’). Consequently, it seems incorrect to consider the scrs to unmasked pictures as a genuine control for those elicited by the masked pictures. The advantage of including a masked condition is that it allows for the investigation of emotional processes that are not confounded by (distorted) cognitive processes. These data demonstrate that OCD
washers do not generate excessive fear responses to disgust pictures. However, we should nevertheless be cautious in drawing definite conclusions about the nature of automatic emotional processing in OCD from these data. Perceptual masking is a very delicate experimental technique, and its effects seem to vary strongly with the individual perceptual threshold and the novelty of the target stimulus (see for a full discussion: Mayer, 2000). Furthermore, the stimuli used in our study could have been perceptually more complex as compared to the angry faces or spiders that are usually used in these paradigms, which could mean that could not be processed by the pre-attentive system (LeDoux, 1986). Together with the methodological limitations of the backward masking procedure already mentioned in chapter 4, this paradigm does not seem the best possible method to study automatic emotional processes in OCD.

In chapters 5 and 6, we tested the hypothesis that OCD patients develop compulsions because of a failure to interpret the emotional outcome of their own actions. This hypothesis was not supported by the data of chapter 5, which indicate that OCD patients have a normal ability to use previously experienced emotions for adaptive decision making. This conclusion is challenged, though, by recent findings of excessive risk taking of OCD patients on this very same gambling task (Cavedini et al., 2002). One factor that may account for these different findings is the affective state at the time of testing (Manes et al., 2002). For instance, decision-making impairments have been demonstrated as state effects in patients with mania and depression (Murphy et al., 2001). Our own data suggest that high anxiety encouraged risk taking in OCD, possibly because stress ‘takes prefrontal function off-line’ due to which more automatic responses patterns (i.e. choosing for immediate reward) come to control behaviour (Arnsten 1997; Perlstein et al., 2001). A second explanation for these varying results is that the validity of this gambling task may be hampered by the particular ‘coping style’ of OCD patients under study. In our experiment, some OCD patients reported that they had tried to deal with the ambiguity of the task by taking an even amount of cards from safe and risky decks, resulting in an average level of risk taking. In principle, these patients did not meet the task requirements, as they did not develop an implicit preference for the safe decks. Unfortunately, the methods for behavioural analysis of this task are not suited to detect such subtle abnormalities. Taken together, these factors suggest that one should be careful in using performance on this gambling task to draw definite conclusions about decision making ability in OCD.

With the results of the visuomotor associative learning task (chapter 6), we obtained a more comprehensive picture of decision making in OCD. Characteris-
tically, the rate at which visuomotor associations are learned is a direct estimate of the ability to use feedback. Our results confirmed the hypothesis that OCD patients have a profound impairment in encoding the outcome of their actions. One interesting observation was the obvious delay in visuomotor learning of the patients. It has been proposed that specifically the rapid acquisition of visuomotor associations is facilitated by a system that generates expectations about which future events will lead to reward. Without these predictions, associative learning is still possible but will be markedly slowed down (Bussey et al., 2001). Current neural network theories stress the importance of reward prediction signals in learning to adapt to the environment (Schultz & Dickinson, 2000; Dehaene & Changeux, 2000). These theories state that learning occurs when the actual outcome differs from the predicted outcome, which results in a prediction error. These prediction errors can subsequently be used for changing predictions or behavioural reactions until the prediction error disappears (Schultz & Dickinson, 2000). Having a reward prediction system has the important advantage that there is an internal reference against which current outcomes can be evaluated. Furthermore, it provides humans with the ability to mentally ‘test’ different courses of action without the risk of trying them out in the external world (Dehaene & Changeux, 2000). Although speculative, the obvious delay in visuomotor associative learning of OCD patients could refer to a decreased functionality of the internal reward prediction system. As a consequence, patients are less able to differentiate the relative reward value of the one response option from the other, explaining their impaired learning and slowed response latencies. A failure to use reward predictions to guide behaviour is consistent with the postulated deficit in the ‘comparator system’ (Pitman, 1987, see chapter 1) and the abnormally strong error-related brain activity after making errors on speeded reaction time tasks (Gehring et al., 2000; Ursu et al., 2001; Hajcak et al., 2002). It should be noted, though, that different types of neuronal error signals have been described in both the dorsolateral (Niki & Watanabe, 1979), the anterior cingulate (Gemba et al., 1986; Carter et al., 1998) and orbitofrontal cortex (Thorpe et al., 1983; Nobre et al., 1999). Future studies should try to specify the nature of the failure in the reward prediction system in OCD, which in turn may shed light on the role of different cortical regions in the pathogenesis of the disorder.

Finally, we predicted that decision making of OCD patients would be aversively affected by the presence of negative emotions. The data presented in chapters 5, 6 and 7 do not confirm this hypothesis, at least not for the whole OCD sample. A closer look at the data (chapter 6 & 7) reveals that decision making of patients with checking symptoms was indeed differently affected by negative emotional
states, while this seemed not to be the case for washers. This dissociation between cognitive function and emotion in washers and checkers will be elaborated in the next section.

In conclusion, our data demonstrate that OCD patients have circumscribed deficits in decision-making. These deficits do not seem to follow from abnormalities in basic emotional processing. Rather, OCD patients seem to have a fundamental impairment in evaluating the reward value of different response options. It is only in checkers that decision processes appear to be significantly affected by negative emotional states.

Cognitive differentiation of washers and checkers

Washing and checking are the most frequently occurring subtypes of OCD (Rachman, 2002). As there was no a priori reason to expect cognitive differences between these subtypes, most studies used samples comprising of both checkers and washers. However, our experiments (chapter 6 & 7) indicate that the cognitive profile of checkers and washers is qualitatively different.

First, although both washers and checkers had impairments in the processing of response feedback, it was only in checkers that performance was significantly affected by the emotional salience of the feedback. In particular, checkers learned worse under conditions of punishment than reward and this effect was most obvious during the early stage of the task. It has been suggested that checkers overestimate the ‘costs’ of a feared event (Rachman, 2002). Taking a lead from this, checkers may have experienced more anxiety in the punishment condition, because the costs of making a mistake in this condition were considerably higher than those of the reward condition. This anxiety may have led to the generation of extremely strong error signals in the brain of checkers. This is supported by findings that subjects with high trait anxiety produced larger error-related negativities (ERNs) when making an error on a task with highly conflicting response options (i.e. a flanker task) (Luu et al., 2000). In contrast, ERNs of subjects who are typically unresponsive to punishment, such a low-trait-socialized individuals, are typically smaller than those of normal controls when errors are penalized (Dikman & Allen, 2000). The presence of punishment thus may have elicited extremely strong error signals in checkers, due to which the functionality of the reward prediction system deteriorated even further. Both psychophysiological and fMRI studies localize the neural source of error related activity in the medial frontal cortex, in particular the anterior cingulate cortex (ACC) (Dehaene et al., 1994; Gehring et al., 1993; Menon et al., 2001). The ACC would be not only crucial
for the monitoring of conflict, but also for the processing of the emotional outcome of a certain decision. This latter information is used to signal other brain regions (cortical areas but also the basal ganglia) that changes are needed in order to avoid future judgment errors (Krawczyk, 2002). Our data suggest that aversive stimulation leads to the excessive activation of the ACC of checkers, and that this is followed by a functional disarrangement of the neural network that subserves adaptive decision-making.

Second, there was evidence that negative emotions also affect the way checkers make decisions about their own memory. Again, this effect was not present in patients with washing compulsions. Traditional accounts of compulsive checking have very much focused on the role of memory (Rachman, 2002). However, there is accumulating evidence that memory function of checkers is spared, and that checking is related to poor memory confidence instead (McNally & Kohlbeck, 1993; Merckelbach & Wessel, 2000; Hermans et al., 2003). Our finding that reality monitoring of checkers was normal, even in the context of negative emotions (chapter 7) confirms that memory impairments are not the primary cause of compulsive checking. Rather, checkers were in case of doubt more inclined to say that words were seen rather than imagined. The nature of the change in response bias suggests that decision making of checkers was disproportionately influenced by the valence of the words (chapter 7), which could be reconciled with the observation that decision making of checkers is modulated by the emotional salience of feedback (chapter 6).

Recently, one interesting hypothesis about the nature of memory doubt in checkers was tested by Van den Hout & Kindt (2003). These authors propose that repeated checking is sufficient to induce poor memory confidence. This is because checking increases the familiarity with the issues checked, but reduces the vividness and detail of the memory. This hypothesis was confirmed in an experiment in which healthy controls performed ‘relevant’ (ie. checking the gas stove) and ‘irrelevant’ (checking virtual light bulbs) checking behaviour. With repetitive checking, memory confidence of the subjects dropped significantly despite the fact that their actual memory performance remained intact. Furthermore, confidence levels decreased disproportionally for the relevant as compared to the irrelevant checking condition. Importantly, these data show that memory doubt of checkers is not pathological for itself, as it can be induced in healthy people as well. Our finding that negative emotions have a disproportionally large influence on decision making of checkers may add to these data, as they may explain why the doubt of checkers often takes such an extreme form.
Washing compulsions, on the other hand, seem to be related to a different profile of cognitive impairment. Our data indicate that neither bodily arousal (chapter 4) nor negative emotional states (chapter 6 & 7) play a significant role in the decision making of OCD washers. This suggests that the judgmental processes, used to determine the adequacy of the washing behaviour, are relatively unaffected by the emotional state of the patient. One alternative explanation for the repetitive nature of compulsive washing could lie in the effects of anxiety on other executive functions than decision making. It was found that washers displayed a general decline in memory for context, while their recognition memory was intact (chapter 7). We tentatively concluded that anxiety, which was induced by confrontation with washer-relevant items, interfered with the more demanding cognitive processes involved in contextual encoding. This is not unlike the notion that stress takes the prefrontal cortex ‘offline’ and ‘shifts control to subcortical regulation of behaviour’ (Arnsten, 1998). As a consequence, behaviour becomes more and more controlled by automatic, habitual responses. Interestingly, a rather similar account has also been used to explain compulsive drug use (Tiffany & Conklin, 2000). Cues of alcohol or drugs are often difficult to resist because they trigger highly automatized behaviours that are largely regulated outside conscious awareness. It is only with considerable cognitive effort that this automatized behaviour can be counteracted successfully (Tiffany & Conklin, 2000). Interestingly, one obvious implication of this hypothesis is that the cognitive processes underlying washing behaviour are more akin to those involved in compulsive drug craving than to those mediating checking behaviour.

Executive function in OCD: the role of the dorsolateral network

This chapter ends up with some remarks on the potential involvement of other fronto-striatal systems in the pathogenesis of obsessive-compulsive behaviour. In chapter 3, we found evidence for executive impairments that refer to a dysfunction of the dorsolateral prefrontal regions. The fact that these impairments persisted after successful treatment indicates that they are not secondary to the symptoms, but instead form a trait feature of the disorder. Previous neuropsychological studies in OCD also found evidence for dysfunction of the dorsolateral network (Head et al., 1989; Veale et al., 1996; Purcell et al., 1998ab; Schmidtke et al., 1998; Barnett et al., 1999), which is remarkable because most neuroimaging studies fail to find abnormal activation of the dorsolateral circuit in OCD (Purcell et al., 1998b). Here, we are confronted with the paradoxical situation that the executive impairments are mediated by a neurocognitive network that does not
seem to play a significant role in OCD (chapter 3). However, it should be noted that there is accumulating evidence that the dorsolateral and orbitofrontal circuit do not function in complete segregation from each other. There has been a strong tendency within cognitive neuroscience to look for double-dissociations between the dorsolateral and orbitofrontal regions of the prefrontal cortex (e.g. Bechara et al., 1998; Rogers et al., 1999), in which the medial and orbital frontal cortex (MOFC) are primarily associated with emotional processes and the dorsolateral prefrontal cortex (DLPFC) with high-level cognitive function. This view may turn out to be artificial (Gray et al., 2002), as emotional and cognitive processes contribute in many cases equally to the control of thought and behaviour (Dolan, 2002; Houdé et al., 2002; Perlstein et al., 2002; Gray et al., 2002). In fact, a recent review paper on the neural basis of human decision making (Krawczyk, 2002) states that the different regions of the prefrontal cortex (orbitofrontal/ventromedial, dorsolateral and ventral/anterior cingulate) all play a role in decision making. The dorsolateral regions are needed for conscious reflection about the different response options that are available (which places a considerable demand on working memory), and are also recruited when decisions are based on previously acquired knowledge or rules (Krawczyk, 2002). This leads to the view that decision-making involves a distributed network of several prefrontal and subcortical regions. The regional involvement of the differing prefrontal structures would depend on the affective and computational demands of the task at hand: the MOFC would be important when subjects are dealing with gains and losses in risky situations, whereas DLPFC regions help to sort out complex, unstructured problems in which conscious thought is needed to make the choice. This view is not unlike the one formulated by Dehaene & Changeux (2000) who propose that there is one unitary neural system that underlies both decision-making and planning behaviour. In both cases, subjects have to formulate sub-goals and tentative actions in order to achieve a desired goal state (which could be either the solution to a planning problem or obtaining a high points score). In addition, subjects must select or reject these tentative actions depending on whether the internal reward system signals that the distance to the goal state has decreased or increased (Dehaene & Changeux, 2000). If this presumption holds, than it is possible that seemingly divergent executive impairments observed in OCD patients originate from an impairment in one single underlying system, that is, the system that uses internal reward signals to select between tentative plans of action.
Suggestions for future research

The results of our studies demonstrate that OCD patients have impairments in several aspects of executive function. It was proposed that part of these impairments are due to a failure in the system that evaluates the relative reward value of competing response options. One important goal of future work in OCD would be to characterize the nature of the dysfunction within this system. These studies need not only to confirm whether there is indeed a failure in this system, but also whether its functionality deteriorates when dealing with aversive information (as was already found in checkers). One way to do this is to combine the feedback task with psychophysiological measures of error processing. This can reveal whether excessive error signals accompany a decreased ability to use feedback for behavioural guidance. Neuroimaging techniques such as fMRI can help to delineate the neural network that codes for the altered decision making in OCD.

Another line for future research could be to characterize the cognitive profile underlying the different subtypes of OCD. Such work could address the differential effects of emotions on decision making, memory and behavioural selection. Of course, there is no need that such a cognitive differentiation remains limited to subtypes of OCD. It can also be used to delineate how OCD dissociates from other OCD spectrum disorders, such as pathological gambling, eating disorders or trichotillomania.


