

MOTIVATED EXECUTIVE ATTENTION - INCENTIVES AND THE NOISE-COMPATIBILITY EFFECT

Jan Seifert^{1*}, Ewald Naumann¹, Johannes Hewig², Dirk Hagemann¹, Dieter Bartussek¹

¹Universität Trier, FB-I Psychologie
Universitätsring 15
54296 Trier, Germany

²Friedrich-Schiller-Universität, Institut für Psychologie
Am Steiger 3 - Haus 1
07743 Jena, Germany

* Correspondence should be addressed to Jan Seifert, Universität Trier, FB-I Psychologie, Universitätsring 15, 54296 Trier, Germany; eMail: seif1301@uni-trier.de; Phone: +49 651 201 2896; Fax: +49 651 201-3956

The present study investigates the effects of reward and punishment on performance in a noise-compatibility-task (B. A. Eriksen & Eriksen, 1974). Flanking distractors indicated a response, which was identical, undefined, or opposite to the appropriate response indicated by the central target. At the beginning of each trial a cue specified positive, negative or no reinforcement in order to elicit three different motivational states: approach, avoidance and a non-reinforced neutral state. Fifty-three subjects (aged 20-27 yrs) participated. Incompatibility effects on reaction times and percentage errors were analysed as a function of motivational state, as were the effects on two ERPs, the lateralised readiness potential (LRP) and the N2. Error and LRP data showed effects of reinforcement only when incompatible distractors were present, which indicates that controlled processing depends on the motivational context. In contrast to previous findings, the N2 was not found to depend on response conflict.

Keywords: noise-compatibility-task; Eriksen-Flanker-task; Monetary incentive; Motivation; Motivated attention; LRP; N2

INTRODUCTION

This research was supported by a grant from the Deutsche Forschungsgemeinschaft (HA 3044/2-1).

Portions of this work were presented at the 29. Arbeitstagung Psychophysiologische Methodik (APM), Würzburg 2003 and the meeting of the Society for Psychophysiological Research (SPR), Chicago 2003.

The authors are very grateful to Eco de Geus and an anonymous reviewer for their helpful comments on earlier drafts of this paper. We also would like to thank Patrick Britz, Sven Haarscheidt, Melanie Hahn, Henning Holle, Alexander Hug, Christoph Kinzig, Pascal Klingmann, Astrid Kronbergs, Sonja Römer, Mirjam Rupp, Olaf Schweisthal.

An a-priori power analysis has been done.

Several years ago Peter Lang emphasized that “attention is determined by primarily motivation” (Lang, Bradley, & Cuthbert, 1997, p. 97). Recent research has shown increasing interest in the conjoint observation of attentional and motivational processes (e.g. Bradley et al., 2003; Derryberry & Tucker, 1994).

The present study will investigate the relation between motivation and attention in a noise-compatibility-task, which was invented by B. A. Eriksen and Eriksen (1974) (see also C. W. Eriksen, 1995 for a more detailed overview) and is also known as Eriksen- or Flanker-task. To provide the relevant background to this task, we will first introduce the paradigm and the theoretical concepts that explain the observable effects. Afterwards we discuss a possible relation between different systems of motivation and processes of attention (in the noise-compatibility-task) based on theoretical

approaches and empirical data. Finally, the rationale for the design of the current experiment will be given.

The noise-compatibility-task and its theoretical background

Contemporary attention research distinguishes between *executive/controlled* and *automatic* processes (Norman & Shallice, 1986; Posner & DiGirolamo, 1998). Automatic processes are quite rapid, parallel and lead to fast response times, but they are also error-prone, especially when dealing with difficult tasks. The crucial automatic process involved in the noise-compatibility-task is described in the continuous flow model by C. W. Eriksen and Schultz (1979). They proposed that fragmented information about a stimulus is immediately transmitted from the perceptual systems to the response systems as soon as the analyses have begun. Response preparation starts unintentionally when the first information fragments arrive. If those fragments carry conflicting information about the response they compete with each other for response capacities. The resulting interference makes the selection of the correct response more difficult.

In order to resolve those conflicts controlled processes are necessary (Casey et al., 2000; Gratton, Coles, & Donchin, 1992; Kopp, Rist, & Mattler, 1996; Iwaki, Miyatani, & Toshima, 2003). Controlled processes are described as flexible and adaptive, but also as rather slow. Control helps avoiding errors but increases response times. There is consensus that control does comprise several different functions, such as: detecting conflicts between cognitive representations, switching between different tasks, sustaining information in short term memory, or inhibiting inappropriate representations (Stuss, Shallice, Alexander, & Picton, 1995). The controlled processes that are crucial in the noise-compatibility-task involve the detection of conflicts between responses, error detection and response inhibition (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Gratton et al., 1992; Kopp et al., 1996; Van't Ent, 2002).

Motivated attention

Incentive stimuli may be hedonically pleasing or discomforting. Accordingly, several researchers hypothesised two separate motivation systems that are triggered by positive and negative incentive stimuli, respectively (e.g. Cacioppo & Gardner, 1999; Davidson, 2000; Carver, 2001). Positive incentive stimuli are associated with appetitive motivation, they promote positive feelings, and induce an action tendency of approach. Unpleasant stimuli activate a defensive motivation system, they come along with unpleasant feelings, and therefore make an organism escape from the situation or avoid it (Davidson, 2000). We will now discuss several contrasting predictions about how states of appetitive or defensive motivation may influence performance in a noise-compatibility-task.

Appetitive motivation. Some authors argue that approach motivation (inducing positive feelings) is likely to improve

performance in controlled processing tasks. The theory proposed by Ashby, Isen, and Turken (1999) provides a neuropsychological approach. Positive mood states result in increased dopamine levels in the brain, particularly in the prefrontal cortex (PFC) and the anterior cingulate (ACC). These structures are known to be involved in several cognitive tasks that demand controlled processing, for example the Stroop-task (e.g. Steel et al., 2001), negative priming (e.g. Metzler & Parkin, 2000) and the noise-compatibility-task (e.g. Botvinick et al., 1999; Casey et al., 2000; Hazeltine, Bunge, Scanlon, & Gabrieli, 2003). According to Ashby et al. (1999) increased dopamine levels lead to better performance in tasks that involve these structures (similar arguments are employed by Servan-Schreiber, Bruno, Carter, & Cohen, 1998). Servan-Schreiber, Carter, Bruno, and Cohen (1998) provided first evidence for the dopamine hypothesis of controlled processing, they found that a dopamine agonist improved reaction times and accuracy only in the incompatible condition of a noise-compatibility-task. Taken together, these arguments suggest a positive influence of approach motivation on the capabilities of the cognitive system to resolve response conflicts.

On the other hand, some authors argue that a state of approach motivation may impair controlled processes, especially when paradigms similar to the noise-compatibility-task are considered. The theoretical outline in Bush, Luu, and Posner (2000) proposes an inhibiting relation between cognitive and affective subdivisions of the ACC. This suggests a reduction of control processes, when executive processing is accompanied by affective processing. Two studies used mood induction to investigate the effect of positive affect on the Stroop-task. Phillips, Bull, Adams, and Fraser (2002) report larger Stroop effects in subjects after induction of positive mood. However, this contrasts with results from Kuhl and Kazen (1999). They found reduced Stroop interference after a positive cue, but only in the second of two consecutive trials.

Data from personality research suggest that appetitive motivation improves automatic processing at the expense of control. Impulsivity is considered to be caused by an increased trait activation of an appetitive motivation system. According to findings from Avila and Parcet (1997) impulsive subjects show less inhibition in a negative priming task. Furthermore, impulsive women show a greater noise-compatibility-effect than non-impulsive women. This suggests that impulsivity comes along with less effective inhibition and increased automatic processing (because automaticity strengthens the noise-compatibility-effect; Gratton et al., 1992). Similar results were evident in the study of Visser, Das Smaal, and Kwakman (1996) in a sample of children. But they found an influence of impulsivity only on negative priming, but not on the Stroop-task.

To summarize these arguments, there is considerable evidence that suggests a relation between processes of controlled conflict resolution and appetitive motivation, but its direction is quite unclear, yet.

Defensive motivation. As Norman and Shallice (1986) have outlined, *dangerous* situations (among several others) trigger controlled processing. Does that mean that more controlled attentional processing takes place, when subjects are threatened with punishment and consequently a defensive motivation system is activated?

Fox (1994) formulated the hypothesis that high anxious subjects suffer from a general deficit to inhibit distracting information. The evidence concerning this hypothesis is contradictory. Fox (1993) did not show an increased Stroop interference in high anxious compared to low anxious subjects. The data did show that high anxious subjects showed stroop-like interference even when the colour patches were spatially separated from the colour words. This was not the case in low anxious subjects. Concerning the negative priming paradigm, Fox (1994) provides further evidence that support the defective inhibition hypothesis. These data were replicated by Kindt and Brosschot (1998). However, the data by Fox (1994) show inconsistent results concerning interference.

In sum, evidence that may provide a hint about the relation between defensive motivation and attentional inhibition is rather sparse and contradictory.

The Present Study

For the purpose of this study the noise-compatibility-task was encapsulated into a motivational setting. A cue stimulus at the beginning of each trial indicated the type of reinforcement. On one third of the presented trials the subjects had the chance to win some money. This was supposed to activate an appetitive motivation system. On another third of the trials punishment followed a slow or incorrect response, which might activate a defensive system. The remaining trials served as control condition. Neither a reward nor punishment followed, regardless of the subject's performance. Thus, the cue stimulus was associated with positive, negative or neutral incentive value.

LRPs were successfully employed by Gratton and colleagues to investigate switching between automatic and controlled processing. The LRP reflects the preparation of moving one hand contrary to the other (for a more detailed description, see Coles, 1989). Negative potentials indicate greater activation of the correct response hand, whereas positive deflections indicate a preferential activation of the wrong hand. Such positive deflections are usually observed in LRPs for a short period of time when incompatible distractors are present in the stimulus display. In Gratton et al. (1992, exp. 2) LRPs indicated a greater activation of the appropriate response (i.e. contralateral to the correct response hand) for compatible than for incompatible trials. The LRPs also indicated a greater activation of the incorrect response when subjects expected compatible distractors and consequently had the tendency to rely on automatic processing. These findings suggest that the positive deflection of the LRP can be a useful tool to measure the degree of automatic processing in the noise-compatibility-task. The more subjects rely on automaticity the greater is the positive LRP.

Just as the positive dip in the LRPs reflects automatic processing, the N2 is supposed to reflect controlled processing in the noise-compatibility-task. The N2 is a negative peak at about 200 ms after stimulus presentation with a fronto-central scalp distribution. Recently, it has been proposed by several groups that this N2 component is the electrocortical correlate of a process which resolves conflict by inhibiting the distractors (Kopp et al., 1996; Heil, Osman, Wiegelmann, Rolke, & Hennighausen, 2000; Iwaki et al., 2003, see also Van't Ent, 2002). Despite these promising results, the precise interpretation of the noise-compatibility-N2 is still a matter of debate. Other hypotheses attribute processes of conflict monitoring to the N2 (van Veen & Carter, 2002) or error detection (also suggested by Kopp et al., 1996). In any case, it is generally recognized that the N2 component reflects some type of controlled/executive processing.

METHODS

Subjects

The sample of the present study was drawn from the student population of the Universität Trier, Germany. All participants took part in a longitudinal study (which will be reported elsewhere). On one of four occasions the participants were asked to perform the task that is reported here.

A total of 53 participants were scheduled for data acquisition. They were recruited via email advertising. The sample of the present study consisted of 29 males (mean age 24.1 years, SD=2.89 years, range 20-27 years) and 24 females (mean age 22.7 years, SD=1.85 years, range 23-24 years). All participants received their payment after their last session. They received 75 EUR plus an extra amount of money (10 to 30 EUR) which they could win in two reaction time tasks.

The participants gave written consent and were informed that they could leave the experiment at any time. All subjects were right-handed and all had normal or corrected-to-normal vision.

Stimuli

Stimuli were presented on a standard PC-CRT (Windows 98) using E-Prime, version 1.0 (Psychology Software Tools, Inc.) in a quasi-randomized order.

There were three different types of stimuli presented on each trial: a motivational cue stimulus, an imperative stimulus array and a feedback stimulus. Cue and feedback stimuli are shown in figure 1. The following stimuli could appear as *cue stimulus*, their frequencies of occurrence were equal:

- reward: When a green "+" appeared the subjects could win 20 Eurocent, if they made a *correct and fast* response.
- punishment: When the red "-" appeared they could lose 20 Eurocent, if they made an *incorrect or slow* response.
- non-reinforcement: The white "0" told the subjects that their account would not change regardless of their performance.

As *imperative stimuli* R (right-hand response) and L (left-hand response) were used. The imperative stimulus was flanked by two identical letters on each side (R, L or X). This results in $(2 \cdot 3 =)$ 6 stimulus arrays. The whole stimulus array consisted of five letters horizontally subtending 2.4° . Each stimulus array occurred equiprobable.

The *feedback stimuli* depended (partially) on the performance of the subjects (see below). There were 6 different stimuli, one for good and one for bad performance in each cued condition (reward, punishment, non-reinforcement). The colours of the feedback stimulus matched the colour of the previous cue stimulus.

- A green “smiley” with a superimposed coin appeared to feedback the gain of 20 Eurocent. This implies that this trial had been cued with “+” and that the response of the subject was correct and fast.

- A green “frowny” informed the subjects about the failure to gain 20 Eurocent.

- A red smiley informed the subjects that they had avoided the loss of 20 Eurocent. This implies that this trial had been cued with “-” and that the response of the subject was correct and fast.

- A red frowny with a superimposed coin appeared to feedback the loss of 20 Eurocent.

- When a white smiley appeared, subjects had made a correct and fast response, but there was neither gain nor loss possible in this trial. This implies that this trial had been cued with “0” and that the response of the subject was correct and fast.

- A white frowny informed the subjects about an incorrect or slow response.

Procedure

Subjects were seated in an electrically shielded and sound attenuated EEG cabin. They filled in several questionnaires, electrodes were applied for the measurement of EOG and EEG and a resting EEG was recorded. The questionnaire and resting EEG data were part of a different study and will be reported elsewhere.

After recording a resting EEG the subjects received written instructions for the reaction time task. The experiment started with a practice session (27 trials) which was repeated once when a subject made more than two errors. Each subject was tested on 9 blocks of 54 trials each, resulting in 486 trials.

At the beginning of the experiment participants received an account of 5 Euro. Wins and losses were placed to this account. At the end of each block the subjects were informed about their actual balance. Each trial started with the motivational cue stimulus that was presented for 494 ms. After an inter-stimulus-interval (duration: 1294 ms; irregular intervals are due to the CRT refresh rate) four distractor letters appeared, which were joined 106 ms later by the imperative stimulus. The whole array disappeared after 247 ms (so that the duration of the flanker stimulus was 350 ms). Subjects were instructed to react as quickly as possible when they perceived the target letter. Another inter-stimulus-interval (du-

ration: 1530 ms) followed and after that the feedback stimulus appeared, which remained on the screen for 1800 ms and finished the trial. 1000 ms later the next trial started with the cue stimulus.

Several electrocortical phenomena with similar latency and topography are discussed by Pritchard, Shappell, and Brandt (1991) as “N2” components. To prevent confusion between different negativities of similar latency and topography, we adopted a strategy from Kopp et al. (1996). Instead of a more common simultaneous presentation of flanking distractor and target stimuli, the distractors were presented 100 ms prior to the target stimulus. This procedure does not only enlarge the noise-compatibility-effect (Flowers, 1990; C. W. Eriksen & Schultz, 1979), but also separates two negativities that may otherwise overlap (Kopp et al., 1996).

Overt Responses

Reaction times were acquired with a Meilhaus ME-1400 timer card. If a reaction lasted longer than 1500 ms it was considered to be missing. The participants were instructed to respond as fast as possible but not at cost of accuracy. Incorrect and slow reactions were not rewarded. The classification of a reaction as fast or slow was determined by two moving thresholds, in order to reduce the impact of individual differences in subjects’ abilities. They were determined by splitting the reaction times of the previous blocks into terciles. Reaction times in the lower tercile were regarded as fast, reaction times in the upper tercile always as too slow. Since slow (fast) responses are more likely due to controlled (automatic) processes, automatic processing may lead to reward more often than controlled processing. In order to reduce these odds feedback was randomly given in the medium tercile.

Psychophysiological Recording

EEG was recorded with the Easy-Cap electrode system (Falk Minow Services) from 61 sites of an equidistant electrode system including the earlobes (A1, A2). All sites were referenced to vertex (Cz). A bipolar horizontal electrooculogram (EOG) was recorded from the epicanthus of each eye, and a bipolar vertical EOG was recorded from supra- and infra-orbital positions of the right eye. The EEG and the EOG were recorded with Ag/AgCl electrodes. Prior to the placement of electrodes, the expected electrode sites on the participant’s scalp and face were cleaned with alcohol and gently abraded. All impedances of the EEG electrodes were below 5 k Ω , and the differences in impedance between homologous sites were below 1 k Ω . EEG and EOG were amplified with two 32-channel SynAmps Model 5083 amplifiers (input impedance: 10 M Ω ; Neuroscan, Inc.) in AC mode. The pass-band was set to 0.05-30 Hz; the signals were digitised at 200 Hz and stored to hard disk for later analysis.

Data analysis

After data acquisition was accomplished, each combined EOG and EEG record was subjected to an off-line artefact

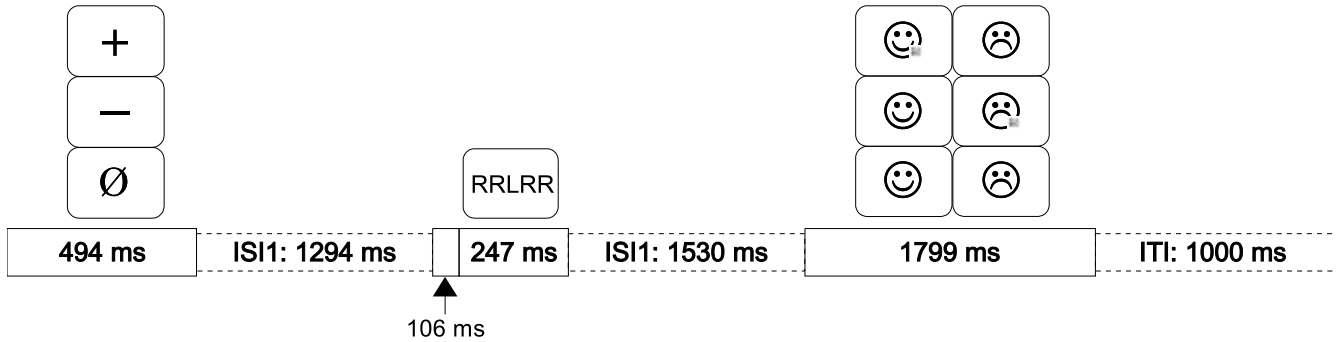


Figure 1. : The trial procedure and the used stimuli. Each trial had a duration of 6470 ms. The stimuli in the experiment were coloured (see text).

control procedure. The EOG and EEG recordings were visually inspected, and each portion of the EEG data that showed muscular or technical artefacts in any channel was rejected for this channel individually. The data were corrected for ocular movement artefacts with the procedure described by Gratton, Coles, and Donchin (1983). Then the data were re-referenced to linked earlobes and averaged synchronous to the cue stimulus. They were sampled down to 100 Hz, low-pass filtered (6 Hz cut-off) and baseline corrected, with a 200 ms baseline prior to the cue stimulus. LRPs were baseline corrected with a baseline 100 ms prior to the appearance of the distractors.

Two deflections were analysed using averaged amplitudes: a negativity following the imperative stimulus (N2: 2150 – 2200 ms, i.e. 250 ms post-target) and the “positive dip” of the LRP (2000 – 2100 ms, i.e. 100 ms post-target). Their boundaries were determined by visual inspection of the grand average plots. Concerning N2 and LRP analyses, average amplitudes were preferred to peak picking, because it was impossible to determine the peaks in all subjects and conditions.

Statistical analyses of the N2 were restricted to the fronto-central site Fcz. For LRP analyses three electrodes were averaged on each side (C3, Fc3*, Fc5* and F4, Fc2*, Fc4*) to approximate the electrode position which is recommended to analyse readiness potentials and lies 1 cm anterior and 1 cm superior to C3.

Reaction times, errors, N2 amplitudes and LRPs were tested with a two-way repeated measures ANOVA with three levels on each factor (reinforcement: reward, non-reinforcement, punishment; type of noise: compatible, undefined, incompatible). Greenhouse-Geisser correction was used where appropriate. Corrected p-values, (uncorrected) degrees of freedom, effect sizes of partial explained variance (η^2 ; Cohen, 1973) and the Greenhouse-Geisser estimate (ϵ) are reported. Planned comparisons were computed as follow-up tests to break down the omnibus ANOVA effects. Contrasts, that test the experimental factors incentive cue and distractor type, compare each condition to the corresponding control conditions. Any additional post-hoc analyses are

described in the text below.

The artefact screening, re-referencing and averaging was performed with Brain Vision Analyzer 1.04 (Brain Products GmbH), further computations with the program Ekp-Scan (version 1.05.11) developed in our laboratory (Seifert, 2003), the statistical analyses were performed with SPSS for windows (version 11.0; SPSS Inc.).

RESULTS

Reaction Times And Errors

Reaction time means and errors were submitted to a 3×3 (distractor type \times incentive value) repeated measures ANOVA (see tables 1 and 2).

Reaction times. The main effect distractor type was statistically significant ($F[2, 104] = 463.67$; $p < .01$; $\eta^2 = .90$; $\epsilon = .85$). Reaction times were faster in the compatible condition than in the undefined condition (contrast: $F[1, 52] = 459.36$; $p < .01$; $\eta^2 = .90$). Reaction times were slower in the incompatible condition than in the undefined condition (contrast: $F[1, 52] = 262.82$; $p < .01$; $\eta^2 = .85$). This is the pattern typically observed in noise-compatibility-tasks.

The main effect incentive value was statistically significant ($F[2, 104] = 61.02$; $p < .01$; $\eta^2 = .54$; $\epsilon = .73$). Reaction times were faster in the rewarded condition (contrast reward vs. neutral: $F[1, 52] = 80.15$; $p < .01$; $\eta^2 = .61$), and reaction times were faster in the punished condition (punishment vs. neutral: $F[1, 52] = 56.03$; $p < .01$; $\eta^2 = .52$).

The interaction distractor type \times incentive value was not significant ($F[4, 208] = 1.18$; $p > .30$; $\eta^2 = .02$; $\epsilon = .81$).

Error rates. The main effect distractor type was statistically significant ($F[2, 104] = 203.92$; $p < .01$; $\eta^2 = .80$; $\epsilon = .61$). Error rates were lower in the compatible condition (compared to undefined; contrast: $F[1, 52] = 122.75$; $p < .01$; $\eta^2 = .70$). Error rates were higher in the incompatible condition than in the undefined condition (contrast: $F[1, 52] = 192.67$; $p < .01$; $\eta^2 = .64$). This is the pattern typically observed in noise-compatibility-tasks.

Table 1
: Mean reaction times (ms) as a function of noise compatibility and motivational incentive value.

Distractor type	Incentive value			
	+	∅	-	
Incompatible	353.92	378.42	361.89	364.74
Undefined	328.66	351.26	332.64	337.52
Compatible	288.59	310.72	290.00	296.44
	323.72	346.80	328.18	

The main effect incentive value was not significant ($F[2, 104] = 0.15$; $p > .50$; $\eta^2 = .00$; $\epsilon = .65$).

The interaction distractor type \times incentive value was significant ($F[4, 208] = 4.05$; $p < .01$; $\eta^2 = .07$; $\epsilon = .79$). The difference between the incompatible and the undefined condition is greater in rewarded trials compared to neutral trials (contrast incompatible/undefined \times reward/neutral: $F[1, 52] = 6.19$; $p < .02$; $\eta^2 = .11$). All other contrast were not statistically significant (contrast incompatible/undefined \times reward/neutral: $F[1, 52] = 2.27$; $p > .10$; $\eta^2 = .04$; all $p > .05$ and $\eta^2 < .07$). Additional contrasts were computed to compare reward directly with punishment, which did not reveal differences between the incentive conditions (all $p > .60$ and $\eta^2 < .01$).

Table 2
: Means of errors (relative frequencies in brackets) as a function of noise compatibility and motivational incentive value.

Distractor type	Incentive value			
	+	∅	-	
Incompatible	20.70 (.38)	19.38 (.36)	20.32 (.38)	20.13 (.37)
Undefined	8.51 (.16)	8.98 (.17)	8.58 (.16)	6.62 (.16)
Compatible	2.30 (.04)	3.85 (.07)	2.38 (.04)	4.91 (.05)
	10.50 (.19)	10.74 (.20)	10.43 (.19)	

Event related potentials

Lateralised readiness potential

The average amplitude of the positive dip was submitted to a 3×3 ANOVA (type of distractor \times incentive value) (see figure 2).

There was a statistically significant main effect distractor type ($F[2, 104] = 51.48$; $p < .01$; $\eta^2 = .50$; $\epsilon = .73$). Highest amplitudes could be observed in the incompatible condition (contrast $F[1, 52] = 21.44$; $p < .01$; $\eta^2 = .29$); lowest amplitudes could be observed in the compatible condition (contrast $F[1, 52] = 55.98$; $p < .01$; $\eta^2 = .52$).

The main effect incentive value was not significant ($F[2, 104] = .20$; $p > .50$; $\eta^2 = .00$; $\epsilon = .99$).

The interaction distractor type \times incentive value was significant ($F[4, 208] = 2.79$; $p < .05$; $\eta^2 = .01$; $\epsilon = .90$). The positive difference between incompatible and undefined conditions was bigger in the rewarded condition than in the neutral condition (contrast

incompatible/undefined \times reward/neutral: $F[1, 52] = 4.59$; $p < .04$; $\eta^2 = .08$). The remaining contrast were not significant (contrast incompatible/undefined \times punishment/neutral: $F[1, 52] = 0.90$; $p > .30$; $\eta^2 = .02$; all $p > .58$ and all $\eta^2 < .01$). This pattern was quite similar to the interaction effect of the error rates. Additional contrasts were computed to compare reward directly with punishment, which did not confirm differences between the two incentive conditions (all $p > .17$ and $\eta^2 < .04$).

N2

Figure 3 shows the potentials elicited by the imperative stimulus. Statistical analyses at the Fcz electrode reveal a statistically significant main effect distractor type ($F[2, 104] = 100.47$; $p < .01$; $\eta^2 = .66$; $\epsilon = .96$). The contrasts revealed increased negative amplitudes when incompatible distractors were present ($F[1, 52] = 71.73$; $p < .01$; $\eta^2 = .58$) and decreased negative amplitudes when compatible distractors were present ($F[1, 52] = 36.86$; $p < .01$; $\eta^2 = .42$).

The main effect incentive value was not significant ($F[2, 104] = 2.13$; $p > .10$; $\eta^2 = .04$; $\epsilon = .98$).

The interaction distractor type \times incentive value was statistically significant ($F[4, 208] = 2.97$; $p < .05$; $\eta^2 = .05$; $\epsilon = .90$). None of the examined contrasts was statistically significant (all $p > .09$ and $\eta^2 < .06$).

DISCUSSION

In the present choice reaction task subjects could achieve reward and had to avoid punishment. The experimental design specifically should have activated one of two motivation systems (an appetitive and a defensive system) by presenting an incentive cue at the beginning of each trial. In the subsequent imperative stimulus array a target stimulus was surrounded by distractors that were either identical to the target, by distractors that had the opposite response assignment, or by undefined distractors with no response assignment at all.

Reaction times were faster when reinforcement had been signaled. This finding replicates Sobotka, Davidson, and Senulis (1992), and hence, reaction times can be taken as evidence for a successful motivational manipulation. As regards the verification of the attentional manipulation, the behavioural data replicate the traditional noise-compatibility-effect. Reaction times and errors show the typical pattern between the different noise conditions. The same applies for the positive deflection of the LRP. So far, the data suggest the successful manipulation of motivational and attentional processes.

There was a small interaction between the distractors and the motivational state. Subjects made more errors in rewarded trials. This effect is corroborated by the lateralised readiness potentials. After positive incentive cues the positive dip is more pronounced. This indicates that distractors had more influence on the selection of the response when reward was signaled.

Since the conflict in the noise-compatibility-task requires controlled processing to be resolved, it was to be expected

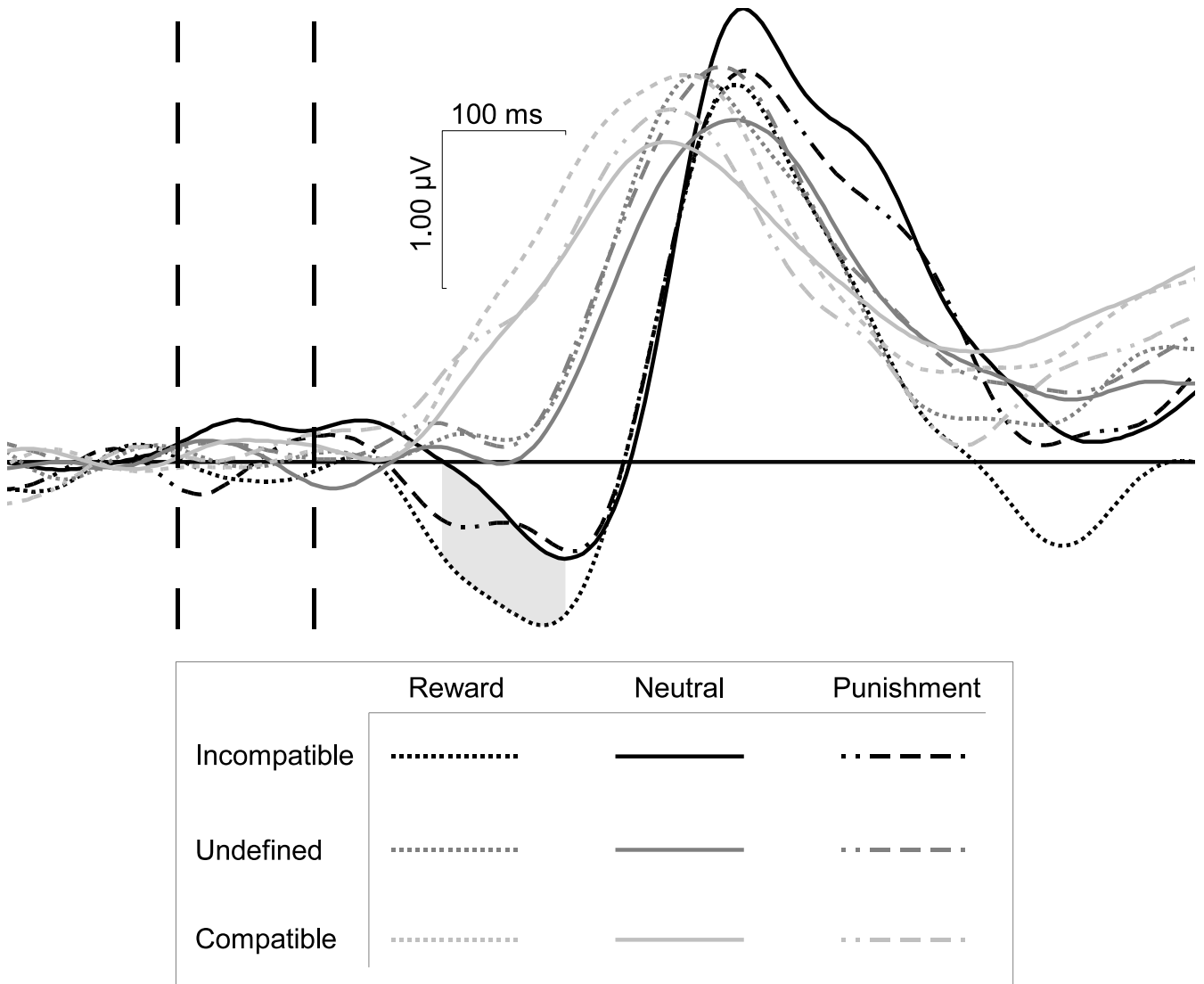


Figure 2. : The lateralised readiness potentials. The first vertical line marks the appearance of the distractors, the second line marks the appearance of the target letter. The grey area marks the significant contrast incompatible/undefined × reward/neutral. Positive is plotted down.

that any influence of motivation would exclusively affect the incompatible condition. There are at least two ways to interpret the decreased performance in rewarded trials. Firstly, subjects may tend to act less cautious, when reward is promised, they rely more on automatic processing than on control. This contrasts Ashby et al. (1999) who predict better performance when positive mood is involved. It favours the conclusion drawn by Servan-Schreiber, Carter, et al. (1998), instead. Having administered a dopamine agonist to their subjects they found increased performance in incompatible trials. Since the mesolimbic dopamine system plays an important role in motivation (especially in reward, e.g. Berridge & Robinson, 1998; Gray & McNaughton, 1996) their effects may have been due to an interaction between dopaminergic processes of motivation and attention. Servan-Schreiber,

Carter, et al. (1998) focus in their model on motoric aspects of dopamine, the present data – however – suggest that motivational aspects of dopamine may influence conflict resolution in the noise-compatibility-task as well. The data also favour the suggestion made by Bush et al. (2000). They proposed an inhibitory relation between processes of approach motivation and those of control. The expectation of reward may have reduced controlled processing.

Secondly, controlled processes may have led to greater avoidance of errors in punishment trials. In this comprehension of the data there is a general trade-off in favour of response speed, and at cost of accuracy after a motivational cue had been presented. After punishment cues, however, subjects act more cautiously and may overcome this trade-off. This interpretation would favour the hypothesis by Norman

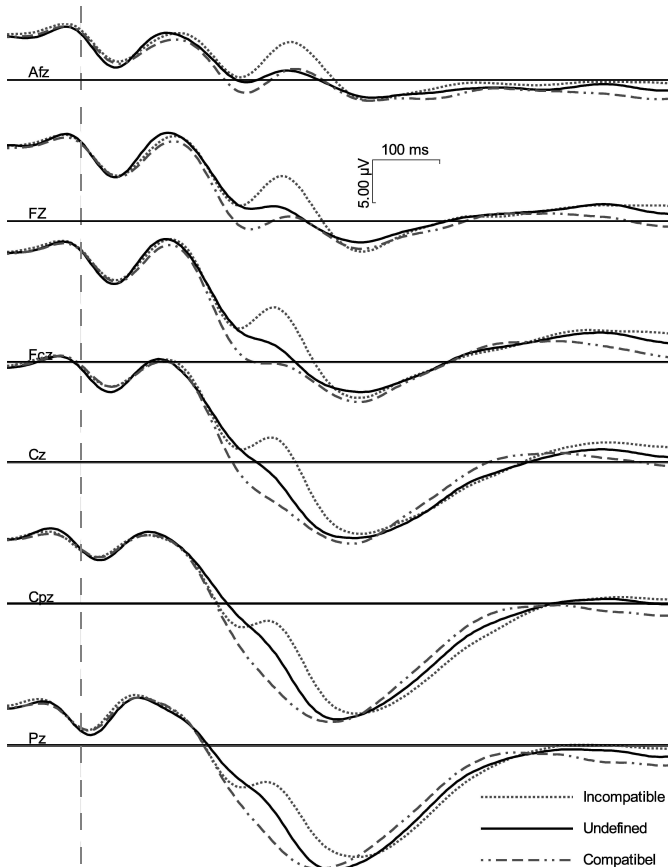


Figure 3. : Potentials elicited by the imperative stimulus. The appearance of the target letter is indicated by the vertical dashed line. The potentials shown here are baseline corrected and filtered with a 6 Hz low-pass. Positive is plotted down.

and Shallice (1986) who stated that subjects utilise executive processes to respond with more caution, when punishment follows an erroneous response. The data can not decide between these two interpretations. Regardless of these, it seems that executive control is capable to affect speed and accuracy to some degree independently.

According to Bush et al., 2000 both reward and punishment impair controlled processing. While reward reached the level of statistical significance, punishment did not. This reflects the fact that the interaction effect $\langle \text{reward, neutral} \rangle \times \langle \text{incompatible, undefined} \rangle$ is twice as big as the corresponding contrast involving punishment. The direct comparison between reward and punishment – however – did not reach the significance threshold. This reflects the fact that there was also an increased tendency to errors in incompatible-punishment trials. The data cannot clearly resolve that inconsistency. The data may also support the proposition by Bush et al., 2000 that reward and punishment may have similar effects on controlled processes. Subjects have to perform well in *both* incentive conditions to gain money, furthermore, they only played for small amounts. The symmetry between reward and punishment may be bro-

ken more severely, when clinical subjects are examined or a stronger stimulation is used. Nevertheless, the authors want to point out that the reward effects on errors/LRPs were two/four times bigger than those of punishment. Hence, influences of motivation on controlled processing was stronger when reward was signaled.

Since we made use of effect sizes, we have to pose one question: why are the effects in LRP and error data so small? Gratton et al. (1992) manipulated the tendency to controlled and automatic processing, respectively, by probabilities and by the subjects' expectancies. Their effects sizes lie at about $.16 \leq \eta^2 \leq .48$. The effects reported here are $\eta^2 < .10$. One possible explanation is that 20 Eurocent may be an amount too small to cause large effects. In Sobotka et al. (1992), however, \$0.25 were sufficient to study effects of incentives on performance in a simple reaction time task. Another explanation aims at the speed instructions employed in the current design. Speed and accuracy instructions, respectively, may be considered to be a motivational manipulation per se (e.g. Carrillo-de-la-Pena & Cadaveira, 2000). The effects of the incentive conditions may have been reduced due to the fact that reward and punishment were determined on the basis of a speed criterion. This might be an important issue because several paradigms in attention research are bound to speed instructions. Error effects in the noise-compatibility-effect can only be observed when subjects react fast (Gratton et al., 1992; Gratton, Coles, Sirevaag, Eriksen, & Donchin, 1988). The negative priming effect decreases when speed is stressed in the instructions (Fox, 1995).

The results of the noise-compatibility-N2 can not complement the impression given by errors and lateralised readiness potentials. There was a small interaction, but it did not show any topographical variation, and it is due to the punishment condition, unlike the error and LRP effects, which are due to reward. It seems that the process reflected by the noise-compatibility-N2 is not influenced by incentive conditions. This interpretation stands in contrast to the findings by Kopp et al. (1996) and Iwaki et al. (2003), but in line with Van't Ent (2002). According to our data neither a process of conflict detection nor response inhibition nor error detection can explain the N2 data. The increased LRP dip in rewarded trials suggests that any of those processes should have been amplified. Accordingly, we would have expected increased N2 negativities in rewarded trials. This was not the case.

The results of the N2 are often difficult to interpret, because of substantial component overlaps in the N2 interval. In our data, figures 3 (and additional analyses) indicate that the P300 peaks earliest in the compatible condition, followed by the undefined and the incompatible condition. Because of additional parietal variance, the maximum of the difference wave between incompatible and undefined conditions is flattened, and between the conditions undefined and compatible appears a parietal difference maximum, where no effects were expected. Accordingly, figure 3 shows a more parietal effect. Earlier studies have also reported problems of component overlap (Kopp et al., 1996). Further research is needed to shed some more light on the meaning of the N2 component in the noise-compatibility-task.

In summary, results indicate decreased controlled processing in the noise-compatibility-task when subjects may achieve a reward. More errors were made, and a stronger activation of the incorrect response hand was evident in those trials. Current notions of the functional significance of the N2 would have expected, that the N2 amplitudes rise (get more negative) with greater activation of the incorrect response. The present data cannot confirm this hypothesis. Finally, the motivational context is an important variable in experimental research and may influence the processes of interest.

References

- Ashby, F. G., Isen, A. M., & Turken, A. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review*, *106*(3), 529-550.
- Avila, C., & Parcet, M. A. (1997). Impulsivity and anxiety differences in cognitive inhibition. *Personality and Individual Differences*, *23*(6), 1055-1064.
- Berridge, K. C., & Robinson, T. E. (1998). What is the role of dopamine in reward: Hedonic impact, reward learning, or incentive salience? *Brain Research Reviews*, *28*(3), 309-369.
- Botvinick, M., Nystrom, L. E., Fissell, K., Carter, C. S., & Cohen, J. D. (1999). Conflict monitoring versus selection-for-action in anterior cingulate cortex. *Nature*, *402*(6758), 179-181.
- Bradley, M. M., Sabatinelli, D., Lang, P. J., Fitzsimmons, J. R., King, W., & Desai, P. (2003). Activation of the visual cortex in motivated attention. *Behavioral Neuroscience*, *117*(2), 369-380.
- Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, *4*(6), 215-222.
- Cacioppo, J. T., & Gardner, W. L. (1999). Emotion. *Annual Review of Psychology*, *50*, 191-214.
- Carrillo-de-la-Pena, M. T., & Cadaveira, F. (2000). The effect of motivational instructions on p300 amplitude. *Neurophysiologie Clinique*, *30*(4), 232-239.
- Carver, C. S. (2001). Affect and the functional bases of behavior: On the dimensional structure of affective experience. *Personality and Social Psychology Review*, *5*(4), 345-356.
- Casey, B. J., Thomas, K. M., Welsh, T. F., Badgaiyan, R. D., Eccard, C. H., Jennings, J. R., et al. (2000). Dissociation of response conflict, attentional selection, and expectancy with functional magnetic resonance imaging. *Proceedings of the National Academy of Science of the United States of America*, *97*(15), 8728-8733.
- Cohen, J. (1973). Eta squared and partial eta squared in fixed factor Anova designs. *Educational and psychological measurement*, *33*, 107-112.
- Coles, M. G. (1989). Modern mind-brain reading: Psychophysiology, physiology, and cognition. *Psychophysiology*, *26*(3), 251-269.
- Davidson, R. J. (2000). The functional neuroanatomy of affective style. In R. D. Lane & L. Nadel (Eds.), *Cognitive neuroscience of emotion* (p. 371-388). London: Oxford University Press.
- Derryberry, D., & Tucker, D. M. (1994). Motivating the focus of attention. In P. M. Niedenthal & S. Kitayama (Eds.), *The heart's eye: Emotional influences in perception and attention* (p. 167-196). San Diego, CA, US: Academic Press, Inc.
- Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception and Psychophysics*, *16*(1), 143-149.
- Eriksen, C. W. (1995). The flankers task and response competition: A useful tool for investigating a variety of cognitive problems. In H. Shibuya & C. Bundesen (Eds.), *Visual selective attention* (p. 101-118). Hillsdale: Lawrence Erlbaum Associates, Inc.
- Eriksen, C. W., & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. *Perception and Psychophysics*, *25*(4), 249-263.
- Flowers, J. H. (1990). Priming effects in perceptual classification. *Perception and Psychophysics*, *47*(2), 135-148.
- Fox, E. (1993). Attentional bias in anxiety: Selective or not? *Behaviour Research and Therapy*, *31*(5), 487-93.
- Fox, E. (1994). Attentional bias in anxiety: A defective inhibition hypothesis. *Cognition and Emotion*, *8*(2), 165-195.
- Fox, E. (1995). Negative priming from ignored distractors in visual selection: A review. *Psychonomic Bulletin & Review*, *5*(2), 145-173.
- Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artefacts. *Electroencephalography and Clinical Neurophysiology*, *55*(4), 468-484.
- Gratton, G., Coles, M. G., & Donchin, E. (1992). Optimizing the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General*, *121*(4), 480-506.
- Gratton, G., Coles, M. G., Sirevaag, E. J., Eriksen, C. W., & Donchin, E. (1988). Pre- and poststimulus activation of response channels: A psychophysiological analysis. *Journal of Experimental Psychology: Human Perception and Performance*, *14*(3), 331-344.
- Gray, J. A., & McNaughton, N. (1996). The neuropsychology of anxiety: Reprise. In D. A. Hope (Ed.), *Perspectives on anxiety, panic and fear* (Vol. 43, p. 61-134). Lincoln: University of Nebraska Press.
- Hazeltine, E., Bunge, S. A., Scanlon, M. D., & Gabrieli, J. D. E. (2003). Material-dependent and material-independent selection processes in the frontal and parietal lobes: An event-related fmri investigation of response competition. *Neuropsychologia*, *41*(9), 1208-1217.
- Heil, M., Osman, A., Wiegmann, J., Rolke, B., & Hennighausen, E. (2000). N200 in the eriksen-task: Inhibitory executive process? *Journal of Psychophysiology*, *14*(4), 218-225.
- Iwaki, N., Miyatani, M., & Toshima, T. (2003). A psychophysiological study on the function of the response-stop in the eriksen task. *Japanese Psychological Research*, *45*(2), 100-108.
- Kindt, M., & Brosschot, J. F. (1998). Cognitive inhibition in phobia. *British Journal of Clinical Psychology*, *37*(1), 103-106.
- Kopp, B., Rist, F., & Mattler, U. (1996). N200 in the flanker task as a neurobehavioral tool for investigating executive control. *Psychophysiology*, *33*(3), 282-294.
- Kuhl, J., & Kazen, M. (1999). Volitional facilitation of difficult intentions: Joint activation of intention memory and positive affect removes stroop interference. *Journal of Experimental Psychology: General*, *128*(3), 382-399.
- Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang & R. F. Simons (Eds.), *Attention and orienting: Sensory and motivational processes* (p. 97-135). Mahwah, NJ: Erlbaum.
- Metzler, C., & Parkin, A. J. (2000). Reversed negative priming following frontal lobe lesions. *Neuropsychologia*, *38*(4), 363-79.

- Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation* (p. 1-18). New York: Plenum Press.
- Phillips, L. H., Bull, R., Adams, E., & Fraser, L. (2002). Positive mood and executive function: Evidence from stroop and fluency tasks. *Emotion, 2*(1), 12-22.
- Posner, M. I., & DiGirolamo, G. J. (1998). Executive attention: Conflict, target detection, and cognitive control. In R. Parasuraman (Ed.), *The attentive brain* (pp. 401-423). Cambridge, MA, US: The MIT Press.
- Pritchard, W. S., Shappell, S. A., & Brandt, M. E. (1991). Psychophysiology of N200/N400: A review and classification scheme. In J. R. Jennings & P. K. Ackles (Eds.), *Advances in psychophysiology: A research annual, vol. 4* (p. 43-106). London, England: Jessica Kingsley Publishers, Ltd.
- Seifert, J. (2003). *Ekpscan*. EEG-Labor Universität Trier.
- Servan-Schreiber, D., Bruno, R. M., Carter, C. S., & Cohen, J. D. (1998). Dopamine and the mechanisms of cognition: Part I. a neural network model predicting dopamine effects on selective attention. *Biological Psychiatry, 43*(10), 713-722.
- Servan-Schreiber, D., Carter, C. S., Bruno, R. M., & Cohen, J. D. (1998). Dopamine and the mechanisms of cognition: Part II. d-amphetamine effects in human subjects performing a selective attention task. *Biological Psychiatry, 43*(10), 723-729.
- Sobotka, S. S., Davidson, R. J., & Senulis, J. A. (1992). Anterior brain electrical asymmetries in response to reward and punishment. *Electroencephalography and Clinical Neurophysiology, 83*(4), 236-247.
- Steel, C., Haworth, E. J., Peters, E., Hemsley, D. R., Sharma, T., Gray, J. A., et al. (2001). Neuroimaging correlates of negative priming. *Neuroreport, 12*(16), 3619-3624.
- Stuss, D. T., Shallice, T., Alexander, M. P., & Picton, T. W. (1995). A multidisciplinary approach to anterior attentional functions. In J. Grafman & K. J. Holyoak (Eds.), *Structure and functions of the human prefrontal cortex* (Vol. 769, pp. 191-211). New York, NY, US: New York Academy of Sciences.
- van Veen, V., & Carter, C. S. (2002). The timing of action-monitoring processes in the anterior cingulate cortex. *Journal of Cognitive Neuroscience, 14*(4), 593-602.
- Van't Ent, D. (2002). Perceptual and motor contributions to performance and erp components after incorrect motor activation in a flanker reaction task. *Clinical Neurophysiology, 113*(2), 270-283.
- Visser, M., Das Smaal, E., & Kwakman, H. (1996). Impulsivity and negative priming: Evidence for diminished cognitive inhibition in impulsive children. *British Journal of Psychology, 87*(1), 131-140.