

Affective Modulation of Executive Functions: Does it Happen?

Dissertation

zur Erlangung des akademischen Grades

doctor philosophiae (Dr. phil.)

vorgelegt dem Rat der Fakultät für Sozial- und Verhaltenswissenschaften
der Friedrich-Schiller-Universität Jena
von Diplom-Psychologin Jutta Eber
geboren am 5. November 1977 in Kirchheim/Teck

Gutachter

1. Prof. Dr. Klaus Rothermund, Friedrich-Schiller-Universität Jena
2. Prof. Dr. Iring Koch, RWTH Aachen

Tag der mündlichen Prüfung: 26. Februar 2010

Danksagung

Über Monate und Jahre schreibt man als Doktorandin an der Dissertation, von der Eingrenzung eines Forschungsthemas bis zum Einreichen der fertigen Arbeit. Und am Ende steht ein eigenständiges Werk, das die Forschung im jeweiligen Fachgebiet im Idealfall bereichert und vorantreibt. Ohne die Hilfe und Unterstützung zahlreicher Menschen wäre das jedoch nicht möglich.

Mein Dank gilt in erster Linie Klaus Rothermund, der es mir möglich machte an seinem Lehrstuhl diese Arbeit zu schreiben. Sein Interesse und seine Fähigkeiten sich immer wieder aufs Neue mit meinem Thema auseinander zu setzen, sich rein zudenken, wichtige Schlüsse zu ziehen, Tipps und Hinweise zu geben und den Überblick zu behalten haben mich immer wieder überrascht, mir mehr als einmal weitergeholfen und neue Blickwinkel eröffnet.

Danken möchte ich auch Iring Koch für die Bereitschaft die Zweitgutachterrolle für meine Arbeit zu übernehmen, obwohl er wusste, dass meine Experimente nicht die erhofften Ergebnisse zeigen können. Seine Arbeiten waren schon lange bevor er sich bereit erklärte mein Zweitgutachter zu sein eine wichtige Inspiration und Informationsquelle.

Für die „inoffizielle“ Unterstützung gilt es vielen Menschen zu danken. Sie sind diejenigen, die einen auffrichten, wenn es mal schlecht läuft, die sich anhören, wenn man Probleme hat mit dem Schreiben, mit Experimenten, mit Auswertungen und Analysen, mit nicht existenten Effekten... Viele Freunde haben mich durch Gespräche, Tipps, Kaffeetrinkpausen, Besuche, Einladungen, Feste und Partys, Kino- und Kneipenbesuche, gemeinsame Essen, Grillfeste, Unternehmungen und vieles mehr unterstützen, was im Einzelnen vielleicht als nicht sehr bedeutend erscheinen mag, im Ganzen aber mehr ist als die Summe seiner Teilchen.

Zuletzt möchte ich meiner Familie danken, meinen Geschwistern und besonders meinen Eltern für ihre Unterstützung und Hilfe in allen Bereichen, ihren Rat, ihre Klugheit, ihr Interesse, ihre Geduld, ihren Humor und dafür, dass sie mir Rückhalt gewähren in allem was ich tue.

Table of Contents

Table of Figures	VI
List of Tables.....	VIII
1. Introduction	1
1.1 Executive Functions	4
1.1.1 Definitions and discrimination	4
1.1.2 Task switching paradigm	5
1.1.3 Assumed processes underlying switch costs	7
1.1.4 Backward inhibition effect	14
1.1.5 Summary	19
1.2 Cognition, Mood, and Affect	19
1.2.1 Discrimination	20
1.2.2 Mood and affect in models of executive functions	21
1.2.3 A brief review of mood-cognition models and influences of mood.....	22
1.2.4 Affect.....	23
1.2.5 Summary	24
2. Two Models and Hypotheses	25
2.1 Kuhl's PSI Theory.....	25
2.1.1 Supporting findings	28
2.2 The Dopaminergic Theory	30
2.2.1 Supporting findings	31
2.3 Review of the two Presented Models	34
2.4 The Current Experiments, Hypotheses and Expectations	35

3. Method.....	40
3.1 General Information	40
3.2 Experiments and Results	42
3.2.1 Experiment 1	42
3.2.2 Experiment 2: Additional task.....	53
3.2.3 Experiment 3: Valent cues	61
3.2.4 Experiment 3.1: Valent cues 2	69
3.2.5 Experiment 4: Valent feedback	74
3.2.6 Experiment 5: Valent feedback 2	83
3.2.7 Experiment 5.1: No valence	94
3.2.8 Experiment 6.1: Prearranged quadruples, backward inhibition effects.....	98
3.2.9 Experiment 6.2: Prearranged quadruples, switch costs.....	103
4. General Discussion	108
4.1 Main Effects	108
4.1.1 Backward inhibition effects.....	108
4.1.2 Switch costs.....	109
4.1.3 Valence.....	110
4.1.4 Summary	110
4.2 Backward Inhibition Effects and Affect.....	111
4.2.1 Significant interactions.....	111
4.2.2 Descriptive patterns.....	113
4.3 Switch Costs and Affect	115
4.3.1 Significant interactions.....	115
4.3.2 Descriptive patterns.....	117
4.4 Possible Causes for the Observed Result Patterns	118
4.4.1 Technical restrictions	118
4.4.2 Theoretical considerations.....	122
4.5 Synopsis and Outlook.....	125
5. References	126
6. Summary	137
7. Zusammenfassung.....	140

Table of Figures

Figure 1: Simplified schematic illustration of the PSI theory by Kuhl (1996, 2000, 2001).....	26
Figure 2: Schematic display of sequences with feedback and pictures and the notation of positions.....	41
Figure 3: Tasks and response options.....	43
Figure 4: Trial procedure in experiment 1.....	44
Figure 5: Backward inhibition effects for reaction times (in milliseconds) with positive, neutral, and negative valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.....	48
Figure 6: Backward inhibition effects for error rates (in percent) with positive, neutral, and negative valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.....	49
Figure 7: Reaction times (in milliseconds) for non-switch and switch trials after a positive, neutral, or negative picture at position lag-0, respectively. Error bars refer to standard errors.....	51
Figure 8: Backward inhibition effects for reaction times (in milliseconds) with positive, neutral, and negative valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.....	57
Figure 9: Reaction times (in milliseconds) for non-switch and switch trials after a positive, neutral, or negative picture at position lag-0, respectively. Error bars refer to standard errors.....	59
Figure 10: Backward inhibition effects for reaction times (in milliseconds) with positive, neutral, and negative valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.....	65
Figure 11: Reaction times (in milliseconds) for non-switch and switch trials after a positive, neutral, or negative picture at position lag-0, respectively. Error bars refer to standard errors.....	67
Figure 12: Backward inhibition effects for reaction times (in milliseconds) with positive and neutral valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.....	72
Figure 13: Examples of feedback faces that were used in experiments 4, 5, 6.1, and 6.2.....	75
Figure 14: Trial procedure in experiment 4.....	76
Figure 15: Backward inhibition effects for reaction times (in milliseconds) with positive, neutral, and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.....	79
Figure 16: Backward inhibition effects for error rates (in percent) with positive, neutral, and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.....	79
Figure 17: Reaction times (in milliseconds) for non-switch and switch trials after positive, neutral, or negative feedback at position lag-1, respectively. Error bars refer to standard errors.....	82
Figure 18: Error rates (in percent) for non-switch and switch trials after positive, neutral, or negative feedback at position lag-1, respectively. Error bars refer to standard errors.....	82
Figure 19: Random and real feedback - Backward inhibition effects for reaction times (in milliseconds) with positive and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.....	87
Figure 20: Random and real feedback - Backward inhibition effects for error rates (in percent) with positive and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.....	88
Figure 21: Random and real feedback - Reaction times (in milliseconds) for non-switch and switch trials after positive or negative feedback at position lag-1, respectively. Error bars refer to standard errors.....	91

- Figure 22: Backward inhibition effects for reaction times (in milliseconds) with artificial valences positive, neutral, and negative at position lag-2, respectively. Error bars refer to standard errors. 96
- Figure 23: Random and real feedback - Backward inhibition effects for reaction times (in milliseconds) with positive and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors. 102
- Figure 24: Random and real feedback - Reaction times (in milliseconds) for non-switch and switch trials after positive or negative feedback at position lag-1, respectively. Error bars refer to standard errors..... 106

List of Tables

Table 1: Means of valence and arousal for the 48 prime pictures that were used. Listed are the values from the IAPS (Lang et al., 2005) and the present sample's evaluation.	44
Table 2: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.	47
Table 3: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.	48
Table 4: Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.	50
Table 5: Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.	50
Table 6: Means of valence and arousal for the 50 prime pictures that were used. Listed are the values from the IAPS (Lang et al., 2005) and the present sample's evaluation.	54
Table 7: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.	56
Table 8: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.	56
Table 9: Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.	58
Table 10: Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.	58
Table 11: Means of valence and arousal for the nine pictures used as task cues. Listed are the values from the IAPS (Lang et al., 2005) and the present sample's evaluation.	61
Table 12: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.	64
Table 13: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.	64
Table 14: Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.	66
Table 15: Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.	67
Table 16: Means of valence and arousal for the three positive and the three neutral pictures used as task cues, as well as for the three additionally evaluated negative pictures. Listed are the values from the IAPS (Lang et al., 2005) and the present sample's evaluation.	70
Table 17: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the two valences at the two positions, respectively.	71
Table 18: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the two valences at the two positions, respectively.	71

Table 19: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.	78
Table 20: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.	78
Table 21: Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.	81
Table 22: Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.	81
Table 23: Random feedback - Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the two valences at the two positions, respectively.	86
Table 24: Real feedback - Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.	86
Table 25: Random feedback - Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the two valences at the two positions, respectively.	86
Table 26: Real feedback - Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.	87
Table 27: Random feedback - Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.	89
Table 28: Real feedback - Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.	89
Table 29: Random feedback - Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.	90
Table 30: Real feedback - Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.	90
Table 31: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for the three artificial valences at position lag-2, respectively.	95
Table 32: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for the three artificial valences at position lag-2, respectively.	96
Table 33: Random feedback - Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.	101
Table 34: Real feedback - Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.	101
Table 35: Random feedback – Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.	101
Table 36: Real feedback – Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.	102
Table 37: Random feedback - Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.	105

Table 38: Real feedback - Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.	105
Table 39: Random feedback - Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.	105
Table 40: Real feedback - Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.	106

“Man is said to be a reasoning animal. I do not know why he has not been defined as an affective or feeling animal. Perhaps that which differentiates him from other animals is feeling rather than reason. More often I have seen a cat reason than laugh or weep. Perhaps it weeps or laughs inwardly - but then perhaps, also inwardly, the crab resolves equations of the second degree.”

(Miguel de Unamuno y Jugo)

1. Introduction

In a long tradition that even goes back into ancient times (see for example the Greek philosopher Plato and the compound soul) emotion (passion) has been separated from cognition (reason) and motivation (will or volition). Emotions were the primitive branch of personhood, always disturbing and getting in the way of the strived for good qualities like thought and rationality. Nowadays it is common knowledge that it is difficult to think calmly and clearly while experiencing an extreme emotion. In German legislation it is even differentiated between for example murder and murder in the heat of the moment (“Mord im Affekt”). Emotions are often said to have an irrational nature and that they disrupt rationality and optimal functioning (Ben-Ze’ev, 2000). Expressions like “she was beside herself with rage” or “he was out of his mind with grief” are frequently used terms.

This view can also be recovered in psychological research. For example the cognitive oriented psychological disciplines which are interested in action control, attention, inhibition, problem-solving, decision making, goal pursuit etc. were rarely interested in the modulation of these processes through emotion, affect, or feelings. On the contrary, they often considered emotion or affect as disturbing influences for their research goals in the field of cognition (Oatley & Johnson-Laird, 1987, 1996).

However, this view changes and the idea of cognition and emotion as highly intertwined becomes ever more popular. Nowadays it is more common to examine emotions and cognition not separately but their interrelation. Emotions are discovered as being the centre of human mental and social life. They are declared to be essential and to serve important functions in everyday life. Only emotions and their often evaluative character allow appropriate responses and behaviour in many situations.

One of the most interesting parts of cognition is executive functions. These functions describe basic human processes that make it possible to strive for and to achieve certain goals (Baddeley, 1992, 2000; Luria, 1973; Norman & Shallice, 1986). They organise the coexistence of two contradicting abilities: to guarantee stable and flexible processing within

the cognitive system at the same time. As top-down control processes executive functions enable a person to strive for once set goals and to create actions, intentions and behaviour that allow the realisation of those goals. This requires a certain kind of stability that allows maintenance of intentions and goals over a period of time, that shields them against distraction of any kind from the inside or outside and inhibits and suppresses behaviour and actions that do not serve the current goal. However, at the same time the organism should not be too rigid and be able to flexibly respond to significant changes. Opportunities and changes have to be noticed in order to adjust goals and adapt behaviour whenever it is necessary. Flexibility and stability are controlled in a top-down manner meaning not stimuli in the environment trigger actions but intrinsic processes. This can be described as the will to do this or that even against all odds. The special interest of the current study is whether executive functions can be modulated by affect. It can be imagined that short affective stimuli might be able to disturb the flexibility-stability balance. The selection of the appropriate goals, actions, and behaviour or the ability to ignore distracting information might be influenced by affect. Emmons and Kaiser (1996) state that affect plays an important role in determining one's commitment to goals. These authors think that affect energizes goal directed behaviour and that it can, for example as feedback, provide a basis to inform about the status of a goal. Affective stimulation might be the switch between flexibility and stability. However, models that allow generating concrete hypotheses about modulating influences of affect on executive functions are rare. The classic models of executive functions like the working memory model by Baddeley (1986, 2007) or Norman and Shallice's Supervisory Attentional System (SAS) (1986) do hardly include elements that allow deducing ideas about affective influences on executive functions.

On the other side there is vast research concerning influences of mood on cognition in general. It has been discovered that mood can influence such complex abilities like memory, making judgments, processing of information, or creativity (Clore, Wyer, Dienes, Gasper, Gohm, & Isbell, 2001; see Isen 1999, 2000, and Levine & Pizarro, 2004 for reviews). Quite often it is assumed that positive mood facilitates processing. Further, these mood effects are often explained with different processing styles caused by the different moods (Fiedler, 1988; Isen, 2000; Kuhl, 1983; Schwarz, 1990), or with the help of associative networks (Bower, 1981; Isen, Shalcker, Clark, & Karp, 1978), or the idea of feelings as information (Schwarz, 1990; Schwarz & Clore, 1983, 2003). Some of those ideas are quite elaborate and are good models to explain various mood effects, but they are hardly useful to generate ideas about how short lived affects may influence executive functions like flexibility, stability, planning

and organising, inhibition of inappropriate responses and regulation of impulse control and maintenance of relevant task elements.

Nevertheless there are two models with quite different origins that allow generating more appropriate hypotheses about the assumed influences. The PSI model (Theory of Personality Systems Interaction) by Julius Kuhl (1996, 2000, 2001) is a model that integrates personality, emotional, and action control theories. A second relevant model is the dopaminergic theory by Ashby, Isen, and Turken (1999) that was adapted to executive functions by Dreisbach and Goschke (2004). From both theories assumptions can be deduced concerning influences of affect on flexibility, distractibility, inhibition, perseveration, maintenance capability, automatic and controlled processing. The dopaminergic theory assumes that already mild positive affect increases dopamine release in certain brain areas which influences performance on cognitive tasks. This theory predicts higher flexibility with positive affect whereas Kuhl predicts something similar, reduced flexibility without positive affect, flexibility is suppressed by negative affect. What also results from the dopaminergic theory by Dreisbach and Goschke (2004) is that whereas more dopamine enhances flexibility, stability processes in terms of maintenance capabilities and perseveration suffer. A further special assumption concerning inhibition is made by Kuhl and Kazén (1999) based on PSI theory. They expect that once formed inhibition to control intentions can be overcome more easily with positive affect. These different influences on different elements of executive functions make clear that a common statement like positive affect improves or impairs executive functions cannot be made. This is also due to the vast amount of different functions that are subsumed under the term executive functions.

The hypotheses generated from the two models were tested with a popular paradigm, the task switching paradigm. Switch costs and backward inhibition effects were calculated and used as indicators for executive control functions. Switch costs are a well established measure to represent executive control functions (Jersild, 1927; Meiran, 1996; Rogers & Monsell, 1995; Spector & Biedermann, 1976). To deal with repeatedly switching tasks requires high flexibility and attention, inhibition of inappropriate responses and task sets, maintenance of different task sets, and shielding against distracting influences. The backward inhibition effect introduced for the first time by Mayr and Keele (2000) with a paradigm that consists of three different tasks allows examining separately the ability to use inhibition, especially inhibition linked to abandoned task sets. For affective stimulation positive, negative, and neutral pictures (from the International Affective Picture System, "IAPS" by Lang, Bradley, & Cuthbert,

2005) as well as feedback were embedded into the paradigm. This allowed examining whether affective stimulation influences executive functions.

Before introducing and presenting the two models that allow generating useful hypotheses, Kuhl's PSI theory and the dopaminergic theory, a brief introduction will be made concerning executive functions and the two measures that were used in this study, switch costs and the backward inhibition effect. Furthermore a short overview is given about how affect is defined and distinguished from mood.

1.1 Executive Functions

At first, definitions concerning executive functions are presented briefly. The task switching paradigm is introduced that allows calculating switch costs and backward inhibition effects which both seem to be good indicators for executive control functions. Besides representing executive functions switch costs are in particular also often caused partly by exogenous, non executive processes. This has to be taken into account when working with task switching and switch costs and is therefore discussed in more detail.

1.1.1 Definitions and discrimination

Although it seems that the concept of executive functions is not very old but having its origins in the modern psychology, parts of the processes connected to it can be tracked down to much older ideas. Kuhl (2001) for example emphasised the affinity of modern research concerning executive functions and cognitive control to the older concept of volition. He describes volition that was already examined at the beginning of the last century by Narziß Ach (1910) within the so called famous "Würzburger Schule" as an important part of action control.

Cognitive control or executive functions are normally described as the regulation and organisation of behaviour (Baddeley, 1986; Norman & Shallice, 1986). More precisely these are functions that coordinate perceptual, cognitive, and motor processes in a way that allows a flexible adaptation to current task demands (Baddeley, 1992, 2000; Luria, 1973; Smith & Jonides, 1999). Many different processes have been connected with executive functions because these functions are said to be responsible for adjusting an organism into a present

environment. Flexible and at the same time stable processing is necessary. Attention has to be controlled and when necessary switched to and focused on relevant information and objects (Baddeley, 1992; Kuhl, 1984, 2000; Smith & Jonides, 1999). Information has to be organised and coordinated to make it possible to plan the appropriate actions (Baddeley, 1986, 2007; Bayliss & Roodenrys, 2000; Garner, 2009; Smith & Jonides, 1999; Tranel, Anderson, & Benton, 1994). An adequate response to intrinsic and extrinsic demands always has to take into account personal goals and plans and environmental constraints. Behaviour in general should always be goal directed (Barkley, 1997, 2001; Kuhl, 2000). To allow selected actions to take place the organism also has to inhibit inappropriate responses and regulate impulse control (Bayliss & Roodenrys, 2000; Bjorklund & Harnishfeger, 1995; Garner, 2009; Gruber & Goschke, 2004; Kuhl, 2001). Taken together, all mentioned factors result in action control and action selection (Baddeley, 1986, 2007; Kuhl, 1984, 2000; Smith & Jonides, 1999; Tranel et al., 1994) which make self-regulation (Bayliss & Roodenrys, 2000; Garner, 2009; Kuhl, 2000) and motor control (Barkley, 1997) possible and define executive functions as top-down controlled processes (Bobrow & Norman, 1975; Kluwe, 1995, 1997).

To carry out executive functions many processes are working together to allow an appropriate task management: focusing and switching attention, coding representations, inhibiting irrelevant processes, planning an action sequence to accomplish a goal, monitoring and checking ongoing processes etc. External but also internal stimuli serve as input for the system. Output losses and abnormal behaviour can be the consequences of a damaged or impaired control system.

1.1.2 Task switching paradigm

Among the many existing methods to measure executive functions the task switching paradigm is picked out and explained further. This paradigm is said to be able to measure executive control functions (De Jong, 2000; Logan, 1985; Sohn & Anderson, 2001). The purpose of executive functions is the adaptation of human behaviour to external and internal demands. However, the core of those functions is that they can work independently from external stimulation if necessary. That requires flexibility and stability at the same time to make an appropriate and adequate action regulation and self-regulation possible. The switching between at least two different tasks requires high flexibility. Both task sets have to

be maintained simultaneously, goals have to be adjusted according to the current task and activation of the relevant task set has to take place as well as suppressing of the irrelevant one. Jersild (1927) introduced the task switching paradigm by comparing reaction times in blocks that consisted of only one task (A-A-A... or B-B-B...) with reaction times in blocks with alternating task sequences (A-B-A-B-A...). The homogeneous list of tasks in the single blocks normally produces faster reaction times compared to the heterogeneous lists of the mixed blocks. So called “switch costs” can be calculated, referred to as “shift loss” by Jersild in his original work. Those costs are supposed to represent the additional cognitive demand to execute two alternating tasks. This additional cognitive demand can be described in terms of different executive processes. What is needed in addition to work through the heterogeneous lists is maintaining two task sets at the same time, switching task sets, shifting attention, inhibiting previously used task sets, and suppressing activation of the abandoned task that might be triggered by ambiguous target stimuli. These processes have to be actively used as top-down controlled processes to be able to execute the requested task sequence. An adequate measure for executive functions is provided in terms of switch costs with the task switching paradigm. Gruber and Goschke (2004) explicitly stated that the abilities to maintain task set information, execute conflict monitoring, inhibit prepotent responses, and switch task sets are part of executive functions.

Rogers and Monsell (1995) observed two problems with Jersild’s paradigm and his way of calculating switch costs. First, the mixed blocks contain two processes that until then were not separable with the common method of data collection. To work through the mixed blocks participants need to maintain two tasks simultaneously and also to switch between the two tasks. Secondly, the authors assumed that the two different block forms, single and mixed require different amounts of attention, effort and strategy use. Rogers and Monsell (1995) changed the paradigm in a way that switch costs could be calculated within the mixed blocks. In heterogeneous lists tasks did not alternate from trial to trial but only every second time (A-A-B-B-A-A-B...). A difference can be calculated comparing the switch trials A-B (or B-A) with the non-switch trials A-A (or B-B). With these changes in task sequences two different measures based on reaction times or error rates can be calculated: general switch costs, representing the difference between single and mixed blocks and specific switch costs, representing the difference between switch and non-switch trials (Kray & Lindenberger, 2000). The two measures represent slightly different executive processes. The specific switch costs show the greater amount of time that is necessary to simply switch between two different tasks. That of course includes various processes like shifting attention, switching

task sets and retrieving the associated goals, activating task sets, and inhibiting distracting information. General switch costs describe how much more time is needed to maintain two tasks *and* switch between them simultaneously compared to maintaining and working on only one task. Switch costs have been investigated through the last 80 years and they have proved to be a reliable measure that is well established and documented nowadays (Allport, Styles, & Hsieh, 1994; Goschke, 2000; Jersild, 1927; Meiran, 1996; Rogers & Monsell, 1995; Spector & Biederman, 1976; Wong & Leboe, 2009; for a short review about task switching see Monsell, 2003).

Although switch costs are used as a measure for executive functions researchers always knew that the costs also include other processes that are not executive control processes (Mayr & Kliegl, 2003; Rogers & Monsell, 1995; Rubinstein, Meyer, & Evans, 2001; Sohn & Anderson, 2001). Some researchers even tried to explain switch costs without any involvement of executive control functions like Allport and colleagues (1994) or hardly any involvement like Waszak, Hommel, and Allport (2003). Besides the fact that switch costs seem to be a fairly good measure to represent executive control functions the question about what causes switch costs, what kind of processes are involved and how they interact is still controversial and will be covered in the next paragraph.

1.1.3 Assumed processes underlying switch costs

Several processes have been named that are involved in producing switch costs. The most frequent explanation is that of exogenous and endogenous reconfiguration processes being responsible (Mayr & Kliegl, 2003; Rogers & Monsell, 1995; Rubinstein et al., 2001). Sometimes different and sometimes quite similar reconfiguration processes are listed by various researchers: Monsell (2003) specifies shifting attention, retrieval of goals and action rules, activating response sets, and inhibiting irrelevant task elements being part of reconfiguration processes; De Jong, Berendsen, and Cools (1999) propose configuration of relevant processing modules and setting task goals that trigger retrieval of representations of the associated task set; and Sohn and Anderson (2001) list encoding, identifying, categorisation, and retrieval of information, rule translation and application and response selection. Further processes that have been named as being a cause for switch costs are for example S-R-event bindings (Waszak et al., 2003; see also Koch & Allport, 2006) and interference from previous tasks (Allport et al., 1994). The latter is closely connected to

passive dissipating of previous activation (Meiran, Chorev, & Sapir, 2000; Sohn & Anderson 2001). Of those five processes (exogenous and endogenous reconfiguration, S-R bindings, interference, dissipating) only endogenous reconfigurations can be identified as being genuine executive control processes. All other processes are stimulus driven bottom-up processes. Most frequently a combination of exogenous and endogenous reconfiguration processes are used as an explanation for switch costs. Therefore reconfiguration processes are going to be discussed together. The three remaining explanations for switch costs, interference, dissipating of activation, and S-R bindings are also outlined together further below as explanations that have no relation to executive functions.

Exogenous and endogenous reconfiguration processes

Rogers and Monsell (1995) declared that part of the task set reconfiguration is endogenously driven meaning that task sets can be adopted and prepared in advance of a target whereas other parts can only be completed by exogenous processes after target onset. The authors link both processes to Norman and Shallice's (1986) model with the endogenous processes being represented in the SAS and the exogenous processes in the contention scheduling. Rogers and Monsell (1995) showed that preparation effects rely on a genuine executive control process. The use of cues within the task switching paradigm, that announce tasks before target onset allow control over the cue target interval (CTI) and the response cue interval (RCI) independently. Switch costs could not be reduced by increased preparation intervals when they were changed randomly. However, presenting the different preparation intervals in a blocked form resulted in significantly reduced switch costs with increasing preparation intervals. Thus, only when participants can count on long preparation intervals the additional time can be used with the help of control processes to prepare a task in advance. The task is not prepared in an automatic way whenever long intervals would allow it. A maximal reduction of costs emerged with preparation intervals up to 600ms, longer intervals (up to 1200ms) could not further reduce the costs and residual costs remained (Rogers & Monsell, 1995). Meiran and colleagues (2000) found the same effects concerning CTIs and called it the preparatory component of switch costs that reflects reconfiguration of a stimulus task set before target onset. A second component in their model called the residual component is caused mainly by the delayed reconfiguration of the response task set (Meiran, 2000). Sohn and Anderson (2001) also identify an endogenous process that is goal-directed, intentional, and voluntary and which produces switch costs in case of an inadequate preparation for a task switch compared to a task repetition. Like Rogers and Monsell (1995), Sohn and Anderson

(2001) declare that executive functions are not represented in residual switch costs any more. Rogers and Monsell's describe endogenous components of task set reconfiguration being able to be carried out during preparation intervals but completion of the reconfiguration process has to await triggering by a task relevant stimulus. Therefore exogenous components can only be completed after stimulus onset. The duration of those exogenous processes results in residual switch costs. Sohn and Anderson (2001) showed in two experiments that in residual costs only the automatic control (= priming of the information of the previous trial) is reflected.

Mayr and Kliegl (2003) put a slightly different focus on reconfiguration processes but confirmed Rogers and Monsell's (1995) fragmentation into exogenous and endogenous reconfiguration processes. In their opinion, cue switches that are part of every cued task switch are mainly responsible for switch costs. They identified two processing stages. The retrieval stage is triggered by internal or external signals and contains cue driven retrieval of rules whereas the application stage is closely linked to the stimulus, with task rules being applied automatically. As a consequence, ordinary switch costs can be divided into a cue switch (= retrieval stage) and a task switch component (= application stage). On application stage only one task set can be maintained in working memory at a time. On retrieval stage task rules of the upcoming task have to be retrieved from long term memory. With the use of two cues per task Mayr and Kliegl (2003) could confirm their model in several experiments. A substantial component of switch costs is caused by cue switches. Cue switch costs (=retrieval stage) interacted with practice and preparation whereas the assumed automatic processes of the application stage in terms of task switch costs are not or hardly influenced by preparation and practice. Therefore processes of the application stage might be called exogenous and processes of the retrieval stage endogenous. This fragmentation into cue switch and task switch costs allows speculating about the generally calculated switch costs as being an appropriate measure for executive functions. Mayr and Kliegl's (2003) findings seem to demonstrate, that cue switch costs could be the more pure and exact measure for executive control functions.

Rubinstein and colleagues (2001) also declared that exogenous and endogenous processes are responsible for switch costs but they focused on the importance of rule activation for task switching. Rules of the previous task need to be disabled whereas the rules of the current task need to be enabled. Those authors classified two separable sets of stages, executive control processes and task processes. The latter ones are suggested to consist of stimulus identification, response selection, and movement production. Tasks performed repetitively

allow an immediate response selection after stimulus identification. Between the end of stimulus identification and the beginning of response selection processing stops in case of a task switch. This delay is used to execute control processes that enable the subsequent response selection stage to proceed correctly. Those executive control processes include two stages, goal shifting and rule activation. Task cuing allows goal shifting and rule activation to take place in advance and reduce switch costs whereas rule complexity affects rule activation in a negative way and increases switch costs. Hence, based on Rubinstein and colleagues' model (2001) increased switch costs are caused by an increased use of executive functions.

A more special form of interplay between exogenous and endogenous processes is presented by De Jong (2000). Although this author also sees exogenous processes being involved in task set reconfiguration like Rogers and Monsell (1995), his main idea is that occasional failures of endogenous processes cause the lion's share of switch costs. De Jong and colleagues (1999) asked whether interference effects like Stroop or switch costs do reflect real limitations in inhibitory capabilities or whether they are only due to occasional failures to fully apply such capabilities. Instead of assuming that parts of the reconfiguration process can only start with stimulus onset, De Jong (2000) presents his "failure-to-engage" (FTE) hypothesis. This hypothesis states that advance preparation is useful and optional and takes place but that residual costs are due to occasional failures to engage in such a preparation. Hence, the cause for residual costs is not the inability to produce a complete reconfiguration in advance but that sometimes reconfiguration processes cannot be executed and accomplished beforehand. The cause for these failures in adequate preparation is seen in goal neglect that causes interference (De Jong, 2000; De Jong et al., 1999). Subjects always attempt task set reconfiguration before stimulus onset. When they succeed, a task switch can be performed without any reaction time loss but in some trials they fail and therefore switch costs emerge. Task set reconfiguration is defined as an all-or-none process, retrieval attempts of task goals and task rules either fail or succeed.

This single, endogenous process assumption by De Jong (2000) is doubted by Meiran and Chorev (2005). They claim that not the proportion of prepared trials in general is affected but the target related retrieval competition and therefore also residual components of switch costs. Stable task goal representations that are achieved to a greater or lesser extent are the key to the authors idea. Stable representations help to overcome automatic tendencies more easily resulting in better or faster performances and therefore also in reduced switch costs. Especially in switch trials a strong goal representation is needed because with the presentation of the target also the task features of the abandoned task are retrieved. Hence, poor task goal

representation in switch trials increases switch costs. The authors reasoned that alertness might improve goal representation and as a consequence reduce switch costs. Experiments showed that alertness reduced switch costs which confirms Meiran and Chorev's (2005) assumptions.

Explanations that have no relation to executive functions

Allport and colleagues (1994; see also Allport, 1987) seriously doubt whether switch costs are the result of a stagelike control process that precedes S-R task execution. In several experiments the authors showed that expectations derived from that approach were not met. That is, different elements like for example switching more than one task feature, executing more difficult tasks, or switching to non dominant tasks should increase executive control demands, more executive control would be required and therefore also switch costs should increase. That was not the case. Furthermore, the still existent switch costs even after long preparation intervals and with the exact knowledge about the upcoming task were not expected because executive control processes should and could have been carried out in advance to the full extent. Hence, Allport and colleagues (1994) declare that not a stimulus-independent, autonomous control operation is responsible for switch costs but a kind of proactive interference caused by features of the previous task. With proactive interference the authors mainly mean competing S-R mappings persisting from the preceding instruction set and called it task set inertia (TSI). However, also with long reaction stimulus intervals (RSIs) switch costs were still present which makes a passive decay of interference over time very unlikely. It seems more plausible to assume that active disengagement from the previous task set must wait until triggered by the stimulus of the current task. Allport and colleagues (1994) state that features from the previously used instruction set remain active during execution of the current task set what causes interference and in the end the residual costs. Their conclusion is that executive control functions are not responsible for switch costs. Allport and colleagues' (1994) idea clearly supports a stimulus driven explanation for switch costs. In their opinion switch costs are a limitation in people's ability to switch from task to task by fully endogenous means. Costs are due to an inability to inhibit recently adopted, but now irrelevant task sets. Such task sets interfere with the current task and slow down responding. Although Allport and colleagues (1994) deny that endogenous processes in terms of executive control functions carried out before task execution are responsible for switch costs, executive processes might still be involved. The authors themselves open the door to allow such an assumption when they state that costs are due to an inability to inhibit previous task sets.

Inhibition might be used as an endogenous control process to deal with the described interference. Inhibition and suppression of persisting activation or the abandoned task set can reduce interference and be a useful method to facilitate execution of the current task.

The influence of previous tasks on current ones are not only represented in Allport and colleagues' (1994) TSI but also in ideas about what happens with persisting activation. The dissipating of activation has been examined in several studies. Switch costs are reduced with long RCIs. Meiran and colleagues (2000) listed a dissipating component as also responsible for switch costs in addition to the already mentioned preparation and residual components. But compared to reduction by preparation the underlying process for reduction by dissipation is passive and non strategic. This can be assumed because switch costs could be reduced even when RCIs were changed randomly. No control functions were used because whenever longer intervals were present the dissipating took place.

Persisting activation from the previous task set is also mentioned by Sohn and Anderson (2001) as the second source for switch costs besides preparation effects. The authors assume that not the upcoming but the previous task is the problem and cause for switch costs. As a consequence switch costs represent both, control processes (like in preparation effects) and more automatic processes (like in repetition effects). However, as already mentioned Sohn and Anderson (2001) showed that in residual costs only automatic control seems to be reflected.

A further factor that seems to be involved in producing switch costs are S-R-event bindings (Waszak et al., 2003). The idea of such bindings relies on Hommel's so called event files (1998, 2004) which are representations created when a stimulus is presented and an action selected. S-R-event bindings that integrate perceptual and action information and bind for example information about stimuli, response, task, the goal of the action, and task specific processing can be long lasting and later reactivated from memory. The authors claim that stimuli acquire associations with the tasks they occur with. Features of the competing task are also triggered by a stimulus when task activation is weak (e.g. switch trials). Hence, the common procedure of using the same stimulus in different tasks might be the cause for the greatest share in switch costs because especially under switching conditions the retrieval of irrelevant task features leads to increased reaction times. Indeed, experiments showed that switch costs included a massive item specific effect meaning, that stimuli used previously in the other task produced higher reaction times compared to stimuli had not been shown before (Waszak et al., 2003). In the authors opinion this cannot be simple task set inertia (Allport et al., 1994) because this effect was obtained even over long intervals with several other tasks to

execute in between. A stimulus driven priming of higher order task elements is assumed to explain the effect (Waszak et al., 2003).

The assumption that stimulus-based priming affects the task level was later confirmed by Koch and Allport (2006). These authors further examined influences of preparation and decay of activation on that part of switch costs that is caused by such stimulus-task associations. Longer CTIs reduced the effect of stimulus-based priming on switch costs. Hence, Koch and Allport (2006) conclude that stimulus-based effects are probably not responsible for residual costs that are normally still existent after long preparation intervals. However, longer RSIs did not have an impact on stimulus-based effects of switch costs. The authors assume, that stimulus-based priming and preparation effects relate to stimulus set whereas effects of decay relate to response set, with response and stimulus set being components of the task set (Meiran, 2000).

Conclusion

Small or large switch costs do not allow drawing conclusions about how many executive functions were used or how much control was exercised. Normally large switch costs would mean that executive functions have been executed poorly. All functions that can be used to flexible switch between tasks like shifting attention, activating and retrieving task sets, adjusting goals, inhibiting irrelevant elements etc. were applied slowly and not used efficiently. Small costs can be understood as a sign of well applied executive functions that allowed a quick and accurate execution of switch tasks. However, besides being a measure of executive functions also a lot of exogenous, non executive processes are represented within switch costs.

It has further to be considered that a reduction of switch costs not always means that executive functions were applied more efficiently. Exogenous and endogenous processes can be represented separately (see Mayr & Kliegl, 2003) which could result in reduced switch costs. However, this would only mean that normally also measured exogenous processes are not included in the costs anymore. Also the effect of smaller switch costs with long CTIs or RCIs does not mean that executive functions were used more efficiently. Long CTIs only allow completing endogenous processes before reaction time measuring with target onsets starts. The still measured costs are caused by exogenous processes and a statement about the efficiency of applied executive processes is not possible anymore. In case of the effect with longer RCIs this only means that a non executive process, the decay of activation takes place and facilitates the execution of the next task. However, this persisting activation from the

previous task that causes interference (Allport et al., 1994) might also be influenced by an endogenous process. As already mentioned earlier this activation might be handled with the help of inhibition. It can be assumed that inhibition plays an important role in task switching and for the size of switch costs (see Koch, Gade, Schuch, & Philipp, in press, for a detailed review). Thus, inhibition as part of endogenous reconfiguration processes is covered separately in the next paragraph. Especially the calculation of backward inhibition effects allows a more detailed examination of inhibition concerning abandoned task sets.

1.1.4 Backward inhibition effect

It has already been assumed that inhibition is an executive function itself. It is responsible for suppression of impulsive reactions, competing motivational tendencies (Baddeley, 1986; Smith & Jonides, 1999), or inappropriate responses (Bayliss & Roodenrys, 2000; Garner, 2009; Gruber & Goschke, 2004; Kuhl, 2001). Bjorklund and Harnishfeger (1995) state that inhibition mechanisms play an important role for controlling of social behaviour, attention, and cognition and that poor inhibition can cause severe illness like for example obsessive compulsive disorders.

Mayr and Keele (2000) developed a paradigm that allows examining inhibition as a part of switching tasks. For flexible switching especially the disengagement from the previous task set might be a crucial factor which seems to make the involvement of inhibition processes obvious. The inhibition involved is called backward inhibition by Mayr and Keele (2000). To avoid conflicts during task execution a still active task set of the previous trial is inhibited and suppressed to prevent interference and to facilitate performance of the current task. This was examined with three different, comparable tasks. Task sequences like CBA are compared with sequences that include an indirect task repetition like ABA. If inhibition of the previous task set takes place, it must be harder to reactivate a task set that had recently been inhibited like task A (at the first position) in the sequence ABA, producing higher reaction times compared to task A in the sequence CBA that had not recently been inhibited. If however the activation hypothesis would be true, the last task in ABA sequences should produce a faster reaction time than the same one in CBA sequences. That is, because a task set that was recently and maybe is still activated, although other tasks have been executed in the meantime must be executed faster when it is used again (like task A in the sequence ABA). With quite complicated tasks Mayr and Keele (2000) found, that the last tasks in ABA sequences show

slower reaction times than in CBA sequences. These results confirmed the backward inhibition hypothesis. The authors declare backward inhibition to be a genuine executive process being only present and measurable in top-down control situations like when using a cue (see also Hübner, Dreisbach, Haider, & Kluwe, 2003) and not in bottom-up control situations like when stimulus driven tasks are used. Mayr and Keele (2000) concluded that inhibition processes are part of the switching process, that they work on task set level and that they are a top-down control process. As a consequence, the cause for residual costs cannot be seen in a lack of activation of the upcoming task but in the necessity to overcome earlier formed inhibition. It is further assumed that no longer relevant task set representations are inhibited and that this inhibition takes place probably once the next task set is known. Therefore the main function of the backward inhibition is to prevent interference only as soon as the current task set is started. That defines backward inhibition as a purely reactive process. Eliminated as an alternative explanation of backward inhibition was negative priming (Mayr & Keele, 2000), and later also automatic episodic retrieval (Mayr, 2002). The idea whether preventing interference is a cause for using inhibition was later tested by Hübner and colleagues (2003). They showed that elements of the previous task interfered less with the current one resulting in faster reaction times compared to elements of other abandoned tasks. A further finding by Mayr and Keele (2000) was that backward inhibition cannot be reduced with longer intervals of preparation which was confirmed by other researchers (Hübner et al., 2003; Koch, Gade, & Philipp, 2004; Mayr, 2002; Philipp & Koch, 2006). A factor that was also already suggested by Mayr and Keele (2000) is the decay of backward inhibition over time. This was later covered several times in the literature (Koch et al., 2004; Mayr, 2002) and it was examined in detail in an experimental series by Gade and Koch (2005). These authors tested with different RCIs whether decay of inhibition influences the size of the backward inhibition effect or the amount of task conflict that seems to make inhibition necessary in the first place. If decay of inhibition takes place, a long RCI between trial n and $n-1$ should reduce backward inhibition. If decay of activation from the previous task and therefore reduced conflict influences backward inhibition, a long RCI between trial $n-1$ and $n-2$ should decrease backward inhibition effects. The authors found a reduction of backward inhibition for long RCIs after trial $n-2$, but no interaction of long RCIs after trial $n-1$ and backward inhibition. The conclusion was that remaining activation causes interference in the cognitive system which produces a need for inhibition and that this defines the size of backward inhibition whereas decay of inhibition seems hardly to exist.

What is inhibited?

Despite the original and not very exact assumptions of Mayr and Keele (2000) that task set representations are inhibited and that inhibition starts with the processing of the next task set, some researchers have tried to answer this question more precisely. It was attempted to clarify which of the two stages, application or retrieval stage (Mayr & Kliegl, 2003) is affected by inhibition to determine whether cue representation and activation are the crucial factors. Unfortunately experiments did not reveal very clear results. In the end the authors concluded, that inhibition is probably affecting representations associated with task set application, because the assumed automatic processes in the application stage are not or hardly influenced by preparation and practice and backward inhibition is also not influenced by preparation. This was confirmed by Arbuthnott (2005) for verbal cues. Cue factors are supposed to mainly influence the retrieval stage what would mean that different cues should not influence backward inhibition. However, Arbuthnott (2005) found that spatial cues could eliminate backward inhibition effects completely compared to verbal ones. Spatially cued tasks do obviously not receive sequential inhibition. Arbuthnott (2005) explained this finding with less activation of competing tasks by the spatial cues. This seems to reduce interference to an amount that makes inhibition unnecessary. The special processing of spatial cues seems to interact less with the semantic digit stimuli of the chosen tasks than the verbal processing of semantic verbal cues. The author argues that verbal cues possess strong cue-task associations that normally facilitate task retrieval compared to spatial cues. This for example is supposed to be the reason for increased switch costs for spatial cues. That would implicate that on application stage the verbal cues that also activate competing tasks with their strong cue-task associations need lateral inhibition to be able to execute the current task. Contrary to verbal cues spatial cues only activate the relevant task thus producing less interference which makes lateral inhibition unnecessary. This emphasises that competing activation which produces conflict and interference is the relevant factor for inhibition to take place. In line with Schuch and Koch (2003), Arbuthnott (2005) further assumed, that inhibition seems to influence response selection and not the retrieval stage.

The study by Schuch and Koch (2003) generated the hypothesis that response selection processes are crucial for switch costs and the backward inhibition effect and that the two costs are rather caused by competition on the response selection level than on the level of task set reconfiguration. Therefore after no go trials when no response selection is required, switch costs or backward inhibition effects should not be found. Experiments showed that if there was no response selection in trial n-1 switch costs could not be measured (Schuch & Koch,

2003). The same applied for backward inhibition effects. In ABA sequences with a no go trial as task B no backward inhibition effect could be demonstrated. A similar result was obtained by Verbruggen, Liefoghe, Szmalec, and Vandierendonck (2005, 2006). These authors also found no difference between switch and no switch trials when the responses of the previous tasks were not executed. When there is no interference caused by the previous trial, switch costs seem to disappear. Schuch and Koch (2003) additionally showed that the crucial factor for their findings is response selection and not response execution. Hence, it was concluded that inhibition is triggered by conflicts concerning response selection and that inhibition is not happening on task set level but rather on the response selection level (see also Arbuthnott, 2005). This is specifying Mayr and Keele's (2000) original assumptions. Even more precisely the previous category response mappings are supposed to be inhibited by Schuch and Koch (2003). That includes the complete responses of the last executed task. This might happen to support recoding of the meaning of responses especially in overlapping S-R tasks. Gade and Koch (2005) assume that probably S-R rules or stimulus category response rules are inhibited. Additionally Koch and colleagues (2004) also assume a response-related component of task inhibition and found that basic response modes (at least different manual response modes) are probably inhibited.

Backward inhibition: an executive function?

In the end of this paragraph one further issue will be discussed briefly, the question whether after all backward inhibition is an executive function in terms of a high-level control process or not. Already Mayr and Keele (2000) presented some findings that supported and some that contradicted the idea of backward inhibition being an executive function. In favour of the idea are results demonstrating that the effect emerged also in paradigms that included direct task repetitions (experiment 4) and that it is only present in cued paradigms (experiment 3). Two different findings reject the idea: knowing the task sequence in advance did not prevent backward inhibition (experiment 5) and preparation effects were also not found (experiment 1). Already in their original paper Mayr and Keele (2000) responded to that problem with the assumption of backward inhibition in general subserving selection of high-level control settings. However, the authors further suggest that the way backward inhibition is controlled and exerts control is characteristic of a low-level process. Contrary for example to activation that can be flexibly modulated at all times, once triggered inhibition might be insensitive to further changes and modulations. Thus, backward inhibition is seen as a more local control process triggered by the next task set and as a kind of lateral inhibition.

The finding that backward inhibition effects are even measurable when direct task repetitions were included in task sequences (that supported the idea of backward inhibition being an executive control process) was challenged by contradicting findings by Philipp and Koch (2006). Their experiments revealed that the size of backward inhibition effects is influenced by direct task repetitions. A group with direct repetitions showed significantly smaller backward inhibition effects than a group without direct task repetitions. The same reduction of backward inhibition effects was also found when direct task repetitions varied blockwise within participants. On blocks with repetitions backward inhibition effects were significantly smaller compared to blocks without repetitions. The experiments further showed that when participants once had completed a block with repetitions the backward inhibition effect also decreased in following blocks even when they were without repetitions. As an explanation Philipp and Koch (2006) assume activation and inhibition to be partly independent processes but being heavily influenced by each other. The amount of inhibition and activation is supposed to be always adapted to the current situation. For example if activation is more helpful in a situation then inhibition is constrained. That gives the whole process the character of a strategic option that allows optimal adaptation to situational demands. This finding of reduced or eliminated backward inhibition effects in task sequences that include direct task repetitions gives reason to doubt that backward inhibition in general is a part of switch costs. That is, because backward inhibition does not emerge in the typical sequences (with direct repetitions) that are normally used to be able to calculate switch costs.

Summing-up

Backward inhibition is thought to reduce interference from the recently abandoned task set (Arbuthnott, 2005; Hübner et al., 2000) and has been observed in numerous studies (Arbuthnott & Frank, 2000; Dreher, Kohn, & Berman, 2001; Gade & Koch, 2005; Mayr, 2002; Mayr & Keele, 2000; Mayr & Kliegl, 2003; Schuch & Koch, 2003). Backward inhibition is not influenced by preparation and its decay over time is questionable. Although what exactly is inhibited and what triggers inhibition is still controversial, category response mappings and conflicts on response selection level seem to be the most likely answers so far.

1.1.5 Summary

Executive function is a frequently used term that describes many different human abilities. It is a kind of umbrella term for a set of functions also called “higher cognitive processes” that allow an adapted human action regulation resulting in appropriate behaviour. Included are for example such processes as planning, organising of information, working memory, set and attention shifting, inhibition and suppression of distracting information, error detection and correction, selective attention, rule application, inhibitory control of prepotent responses etc. The execution of the appropriate processes at the right time guarantees stable and flexible processing at the same time.

The task switching paradigm (Jersild, 1927; Rogers & Monsell, 1995) is a popular method to examine executive functions. Switch costs that can be calculated with that paradigm offer the opportunity to cover many of the executive functions researchers are interested in. Nevertheless, it has to be noted that also non executive and exogenous processes are represented. With a variation of the task switching paradigm one special supposedly also endogenous executive function, namely inhibition can be examined closer (Mayr & Keele, 2000). In spite of some difficulties with the two presented measures switch costs and backward inhibition effects, they seem fairly good indicators for endogenous executive control functions.

1.2 Cognition, Mood, and Affect

Models resulting from mood research and classical models of executive functions hardly offer any idea or suggestion about how short affective stimuli might influence executive functions. The differences between mood and affect and explanations of mood effects make clear that findings of mood research are hardly transferable to the micro level of short affective stimulation of executive functions. Furthermore, the brief presentation of two classical models of executive functions shows that they can also not offer assumptions about the hypothesised interactions between affect and executive functions. Hence, after discriminating between mood and affect, the presentation of the two models of executive functions and findings, and models of mood research, the concept of affect and some of its attributes are explained in more detail because of the relevance of affect for the current study.

1.2.1 Discrimination

A rough differentiation between mood and affect is useful because they are clearly not the same and it clarifies why findings and assumptions regarding mood research are non-applicable for short affective stimulation.

Moods are affective states (Clore et al., 2001) and they are felt or sensed by a person (Larsen, 2000). They are normally of little cognitive content and object-free (Ben-Zeév, 2000; Russel, 2003), or rather the object has become diffuse and non-specific (Clore et al., 2001). Most of the time, a clear starting point, an exact time of duration, or a level of stability cannot be identified (Larsen, 2000; Russel, 2003). Moods are of low intensity, floating in the background and sometimes lasting for several hours (Ekman, 1992; Forgas, 1994; Larsen, 2000; Oatley & Johnson-Laird, 1987). Often mood can only be classified very broadly as good or bad. Mood and affect do have this aspect in common. Affect is also often only classified roughly as good or bad, pleasant or unpleasant (Larsen, 2000). With the term affect Clore and colleagues (2001) for example describe representations of value, good or bad, positive or negative. When it is used as a term with an own meaning affect is said to be the feeling tone associated with emotion, it is usually evaluative.

The use of the term affect is different in the two languages German and English. In the English speaking world affect is often used as a synonym for emotion or as a superordinate term applying for everything dealing with emotion, feeling, mood etc. (Forgas, 1994; Meyer, Reisenzein, & Schützwohl, 2001; Otto, Euler, & Mandl, 2000). In German emotion is the superordinate term and affect is sometimes used as a synonym for emotion (Otto et al., 2000; Sokolowski, 2002). However, when affect is used as a discrete term it often describes very strong and intensive emotional states (Meyer et al., 2001). These short and intensive emotional experiences sometimes also include strong action tendencies.

An evaluative aspect of affect is described in both languages. Affect is supposed to be a short first evaluative classification in terms of good or bad, most of the time the valence of information is observed. Those affective evaluations can be described as being of an automatic nature (Baddeley, 2007; Ekman, 1992; Koole & Kuhl, 2008) and when they appear they are experienced with little awareness or conscious cause (Ekman, 1992; Oatley & Johnson-Laired, 1987, 1996).

1.2.2 Mood and affect in models of executive functions

Two of the most popular models representing executive functions are Baddeley's working memory model (1986, 2007) and Norman and Shallice's Supervisory Attentional System (SAS) (1986). Those models have been useful over the last years to examine executive functions but for the present study they have to be checked regarding their ability to integrate affective modulation of executive functions. Baddeley's original model (1986) for example did not include an affective component. In the renewed version (Baddeley, 2007) some changes were made and now emotional influences are represented as well. However, Baddeley seems only interested in influences of extreme emotions like danger, elation, anxiety, depression, or craving. A new element, the hedonic detector is introduced but it represents emotional influences on working memory only in connection with extreme emotional states like depression or mental disorders. It is hardly capable to help understanding the influence of short affective stimuli on executive functions.

The second extremely popular model of executive functions by Norman and Shallice (1986) is based on an earlier model of central control by Bobrow and Norman (1975). Norman and Shallice's (1986) model describes top-down processing executed with the help of schemata and bottom-up processing that is triggered by input information. It consists of two complementary processes, an automatic one called "contention scheduling", that is a basic mechanism and a controlled one described as the "supervisory system". This supervisory attentional system (SAS) is not controlling every action in detail but it can influence the activation of certain schemata with the help of motivation and attention. An explicit affective or emotional control or modulation of processes apart from those motivational influences on activation is not included in the model.

The brief presentation of those two models clearly demonstrates that the importance of emotions and affect on cognitive processing are often undervalued and disregarded. Oatley and Johnson-Laird (1987, 1996) for example declared that although emotions have important cognitive functions they appear as accompanying and disturbing elements when multiple goals and cognitive representations show inconsistencies. Affective influences are not mentioned or of only minor importance for these models. Hence, they cannot give impulses to generate hypotheses about how affective modulation might influence executive functions.

1.2.3 A brief review of mood-cognition models and influences of mood

Models with a focus on emotion and affect also hardly offer possibilities to deduce ideas about how affect might influence executive functions. Models and ideas often only apply to a more superordinate, general level. Examples are the controversy between Lazarus (1984) and Zajonc (1984) about what comes first, emotion or cognition, Lazarus' later developed "cognitive-motivational-relational theory" (1991), or the action control model by Lanterman (1983) that tried to integrate a cognitive and an emotional control system. Also many models dealing with influences of mood rather focus on social questions and problems (see review by Bless, 1997) than on cognitive functions.

However, on this more general level influences of affective stimulation mainly in terms of mood on cognitive processes have been examined and reported by various researchers. Mood is known to influence a wide range of processes and behaviour (see Isen 1999, 2000; Levine & Pizarro, 2004 for reviews). In more detail it can influence creative problem solving and cognitive organisation (Isen et al., 1978; Isen & Daubman, 1984; Isen, Daubman, & Nowicki, 1987), social judgments (Bodenhausen, Kramer, & Süsser, 1994; Bodenhausen, Sheppard, & Kramer, 1994), decision-making (Adolphs & Damasio, 2001), retrieval and recall processes (Bower, 1981; Bower, Gilligan, & Monteiro, 1981; Isen et al., 1978; Lee & Sternthal, 1999; Snyder & White, 1982), learning (Bower, 1981; Isen et al., 1978; Lee & Sternthal, 1999), and flexibility (Forgas, 1989; Estrada, Isen, & Young, 1997).

Explanations for those findings are most of the time adapted to the special attribute of mood being a long lasting effect. The ideas of different processing styles activated in different moods (Bless, 2001; Fiedler, 1988; Kuhl, 1983; Schwarz, 1990) or of spreading activation in associative networks triggered by moods (Bower, 1981; Isen et al., 1978) heavily depend on long lasting influences and time-consuming general cognitive changes caused by moods. Also the theory by Schwarz and Clore (1983, 2003) and Schwarz (1990) that affective states have an informative function themselves and the affect infusion model (Forgas, 1994, 2001) imply and require a different processing of the affective stimulation. As already mentioned affect and mood differ (see paragraph 1.2.1) which makes it impossible to transfer those explanations and adapt them to the assumed influences of short affective stimulation.

1.2.4 Affect

A more detailed definition of affect seems appropriate. As described earlier, affect differs from mood but also from emotion. Brief affective stimulations cannot include the same complete emotional experience like emotions. What they can activate must be less elaborated and can only include rudimental emotional aspects. Hence, the question is what more precisely characterises affect and those rudimental emotional aspects.

A function of affect is appraisal and evaluation of situations, internal states and their interaction (Sokolowski, 2002). Affect is assumed to play an important role in determining one's commitment to goals and to energize goal directed behaviour (Emmons & Kaiser, 1996). This shows that affect also serves motivational purposes. Motivational states can be elicited by affect and affect is seen as a necessary element for action (Lang, Bradley, & Cuthbert, 1997). Two basic and quite popular dimensions are often used to classify affect: pleasure with the extremities positive and negative and arousal with the extremities high and low (Lang et al., 2005, Pauli & Bierbaumer, 2000; Russel, 2003; Wundt, 1896). Although this seems to allow only a very rough classification, in Davidson's (1992) understanding the translation of positive and negative into approach and withdrawal reflects the motivational aspect of affect. This emphasises that the fundamental decisions an organism will make as a relation to its environment are also described with this labelling and classification.

The patterns of involvement concerning emotional states or emotions and short affective stimulation differ in intensity. On the one end there are reactions to emotional or affective stimuli that only trigger some brain activities in certain areas and on the other end there is full involvement meaning an emotion is subjectively experienced and felt, there are activated brain areas and bodily responses, cognitive and evaluative processing is started and preparation for action takes place etc. In between those extremities are of course different levels and shades of involvement. Support for this view comes from research and literature concerning embodied emotions (Niedenthal, 2007). Different levels of involvement in emotions exist and already only activating concepts and knowledge about emotions which means that emotions are not experienced in a complete way on a subjective level can have an impact (Barsalou, Niedenthal, Barbey, & Ruppert, 2003, Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009; Oosterwijk, Rotteveel, Fischer, & Hess, 2009). Regarding these considerations short affective stimulation must be settled on quite a low level of emotional involvement.

1.2.5 Summary

Affect is a brief, quick and short lived evaluation of internal and external stimuli on the broad dimension of good or bad, positive or negative. A full emotional involvement does not take place. This point marks one of the main differences between affect and emotion. Affect also differs from moods which are weaker, long-lasting and without an object. Due to the fact that they are so long-lasting, moods can fundamentally change cognitive structures and processing which is often the base for explanations of mood effects. Such fundamental changes are not possible with short affective stimulation. Thus, mood models cannot be applied to short affective stimulation. Also models of executive functions do not offer useful ideas regarding influences of affect on executive functions.

2. Two Models and Hypotheses

In the following paragraphs the PSI model by Julius Kuhl (1996, 2000, 2001) and the dopaminergic theory (Ashby et al., 1999; Dreisbach & Goschke, 2004) are presented that allow deduction of hypotheses concerning affective modulation of executive functions. It is assumed that short affective stimuli might influence the flexibility-stability-processes that guarantee adapted human behaviour. Each theory is presented separately accompanied by some major findings that support the respective theory. In the end, the final hypotheses that were tested in the current study are deduced and specified.

2.1 Kuhl's PSI Theory

The PSI model (Theory of Personality Systems Interaction) by Julius Kuhl (1996, 2000, 2001) is a model that integrates personality, emotional, and action control theories and further also assimilates and absorbs motivational aspects. Interactions between emotion and cognition, affect and action control are explicitly stated as being part of the theory. It offers a functional design perspective instead of the traditional emphasis on the role of beliefs and other cognitive contents as explanation for human behaviour especially concerning self-regulation, action control and motivation. The theory provides four different psychological systems. Moods, emotions and affects control the activation of those psychological systems. Emotion regulation allows an effectively working overall system because the right emotions at the right time or the overcoming of obstructive emotions give way for the necessary resources and motivations (see figure 1). The four systems are 1. Intention memory: Includes representations and maintenance of intentions, especially when intentions cannot be executed immediately. When difficulties and drawbacks are recognised while trying to pursue a goal intention memory comes into action to be able to still reach the goal after all problems have been solved. It is supported by analytical processing like reasoning and planning and inhibits the intuitive behavioural control which is responsible for automatic action control. 2. Intuitive behavioural control: It is the antagonist to the intention memory. It controls automated action sequences, routines, and programs that do not need much cognition and complex planning. This is all done intuitively without any conscious control. 3. Extension memory: It is a huge and holistic system that integrates representations of internal states like needs, emotions,

somatic feelings, and values. Within this system, emotions and positive and negative experiences can be found. Most of the stored information is unconscious and more felt than known. It is based upon a network of action options, feelings and experienced situations. Also the self is located within the extension memory because all information concerning the self like fears, needs, preferences, standards, and values are stored in this memory system. This system also has to integrate and conduct different time perspectives and time lines. 4. Object recognition system: It is the antagonist to the extension memory. This system allows a conscious perception of single sensations. Negative moods can activate the system and then mainly novel, and unexpected information is taken into focus as well as errors and information that does not seem to fit with the situation at hand. This system supplies the extension memory with new learned experiences.

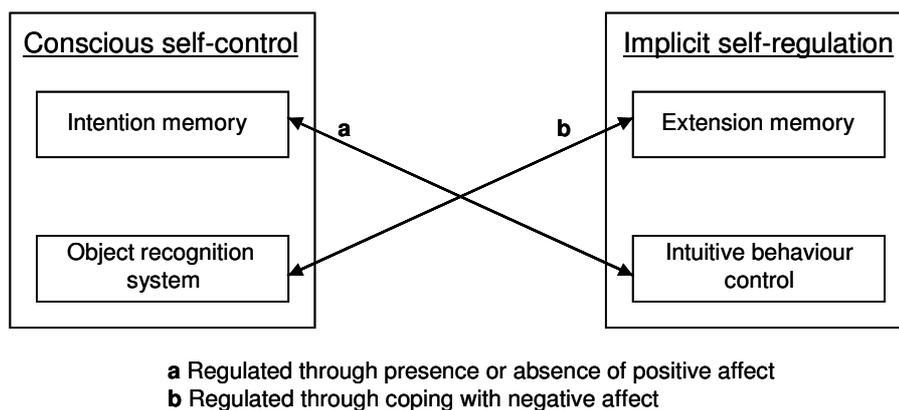


Figure 1: Simplified schematic illustration of the PSI theory by Kuhl (1996, 2000, 2001).

Each of the described systems is an expert in a special sector. The demands of the situation and the ability of the individual to regulate those systems decide which system is going to be in charge. The most interesting idea about this theory is that factors of modulation are positive and negative affects. Those affects are also acting back on the four psychological systems. Hence, behavioural control depends mainly on how a person can regulate the affective system. In the first assumption of modulation of the theory the intuitive behavioural control is activated through positive affect (see figure 1, the pair-headed arrow marked with the letter 'a'). Positive affect facilitates the access of formed intentions stored in the intention memory to executing systems in the intuitive behaviour control. Positive affect provides a connection

between the two systems. To get stored intentions in the intention memory to be executed a person must be able to motivate him- or herself and generate positive affect whenever this is necessary. Losing positive affect activates the intention memory and helps to keep track of awkward intentions if somebody is able to bear the absence of positive affect over a certain period of time. This high frustration tolerance enables a person to even execute difficult intentions and achieve complex goals. The second assumption of modulation (see figure 1, the double-headed arrow marked with the letter 'b') deals with the two other antagonistic systems. The object recognition system gets activated through negative affect. The holistic view stands back and details are focused. This might be useful when error detection is necessary. Only down regulation of negative affect allows again a more general view and the reconsidering of for example options for actions that are accessible via the extension memory. To function properly a healthy person must be able to carry out those regulations and switches between different affects. Especially with difficult tasks this skill is needed.

Affect regulation

This theory denies the traditional hedonic view of affect regulation (Koole & Kuhl, 2008) and affect has a more diverse function. It is assumed that instead of feeling good people more often want to feel right and this depends of course on social and also on functional constraints. PSI theory offers some explanations and definitions for those functional constraints. For example people are assumed to use positive affect to regulate between deliberation and action. Negative affect on the other hand regulates between cognitive integration and elementary perception. In that context moderate intensity levels seem to be more useful than extreme affective states (Koole & Kuhl, 2008).

In general basic affective operations can be performed automatically and without conscious reflection. Different strategies like suppression, reappraisal, distraction, projection, denial etc. are used to make affect regulation possible that has to be efficient, flexible and context sensitive at the same time. The purpose of affect regulation is the modulation of the cognitive and behavioural system to allow adequate responses to ongoing task demands. In PSI theory so called intuitive affect regulation under the control of extension memory can provide such a control system. Intuitive affect regulation is supposed to improve the efficiency of volitional action control and can appear in terms of inhibition of positive affect or amplification of negative affect. Inhibition for example is especially relevant for the formation and implementation of difficult intentions. In general functions and influences of positive affect are: to foster execution of actions, to support the intuitive behaviour control (which can be

regarded as automatic action control and is therefore very close to Norman and Shallice's (1986) contention scheduling), to help executing once formed intentions that are stored in the intention memory, and to facilitate the release of inhibition that controls planned intentions until they can be executed. Functions and influences of negative affect are: to disable the use of the extension memory with its more holistic processing mode, to activate the object recognition system which constricts flexibility, to support detail oriented processing, and to deactivate a more integrating view which also allows distracting but maybe necessary information to solve a current problem to gain more influence.

2.1.1 Supporting findings

Functions of intention memory as a special kind of working memory are maintenance of an intended action, inhibition of an action until the time is right for execution, and inhibition of the pathway to the output systems. This system is needed when a task is very difficult and requires a separate representation in a higher order or symbolic format. Tasks, that are useful to test this are such ones that need sequencing of action steps and monitoring from a control system. In general intention memory is required for delayed responses and for tasks with difficult and complex intentions. Positive affect is supposed to modulate the interaction between intention memory and the output system by releasing inhibition existing between the two systems. Positive affect presumably serves as an internal signal to start certain actions.

The idea of positive affect facilitating the execution of already formed intentions was tested by Kuhl and Kazén (1999) with the Stroop task. Facilitation is possible because positive affect helps to release the inhibition that is blocking intentions which are stored in the intention memory. Every trial in the experiment consisted of two consecutive Stroop tasks, respectively. The positive affect was presented in terms of words before every trial. It is expected that the positive stimuli function as a kind of go signal and release inhibition inflicted on certain intentions and responses. Thus, positive affect is expected to reduce Stroop costs for the first tasks in the trials only. More specifically, a volitional facilitation and not a generally appearing behavioural facilitation is expected. In a first experiment positive, negative, and neutral prime words were presented for 250ms, 750ms, or 2250ms. Baseline trials (XXXX in different colours) and incongruent trials (different colour words in different inks) were presented randomly in a block. Naming the ink colour was always the task that had to be executed. As a result Stroop costs (for the first task in every trial) were significantly

reduced for positive prime words compared to neutral ones. These reduced costs are caused mainly by faster reaction times in incongruent trials.

According to PSI theory the correct sequencing of the two action steps (task one and two in a trial) that require executive control activate a symbolic representation of an intention. With the two action steps in a row the positive affect helps to release the inhibition of the pathway between intention memory and output systems. In a second experiment it was tested whether the two consecutive tasks are really needed to produce the effect. Hence, trials with one and with two tasks were presented in blocked form but in a within-subject design. The results confirmed the findings of the first experiment. Reduced Stroop costs after a positive prime word were found, but only when two tasks had to be executed per trial. When only one task had to be worked on per trial intention memory is probably not loaded and reduced Stroop costs do not emerge. Kuhl and Kazén (1999) concluded that Stroop interference can be reduced under positive affect. It is assumed that the affect releases inhibition that blocks execution of certain actions but only under the condition that intention memory is loaded. The positive affect allows a kind of shortcut from intention to action. These results were later confirmed in a further study by Kazén and Kuhl (2005).

The assumption that negative affect deactivates the extension memory was confirmed indirectly in a study by Baumann and Kuhl (2005). A deactivated extension memory leads to impaired holistic processing and flexibility, and the opportunity to use action alternatives is suppressed. The idea of the study was that the absence of negative affect causes an increase of flexibility in cognitive processes. This was tested with a target detection paradigm. The higher flexibility was demonstrated with faster responses to non dominant, local features with positive affect whereas at the same time responding to the dominant, global features had to be overcome. Flexibility after negative prime words was impaired, the global focus was kept active.

Results from mood research offer the opportunity to confirm a further assumption of the PSI model. That is, positive affect increases automatic processing because it activates the intuitive behaviour control. Due to the described differences between mood and affect (see paragraph 1.2.1 Discrimination) these studies can only be considered as weak evidence. Hänze (1997) and also Phillips, Bull, Adams, and Fraser (2002) found larger Stroop costs under positive mood compared to neutral mood. Hänze (1997; see also Hänze, 1996 and Storbeck & Clore, 2008) declared that increased use of automatic processing under positive mood causes the effect. The forced automatic processing is a handicap when executing the Stroop task (naming the ink colour of incongruent colour words) because the more automated process is that of

reading the colour words. As a consequence the effect was caused by increased reaction times in Stroop task blocks under positive mood in both studies (Hänze, 1997; Phillips, Bull et al., 2002). These findings are not contradictory to Kuhl and Kazén's (1999) study who found a reduction of Stroop interference under positive affect because intention memory was not involved in the studies by Hänze (1997) and Phillips, Bull and colleagues (2002).

2.2 The Dopaminergic Theory

The second model going to be presented relies more on neuropsychological and –biological ideas and assumptions. The dopaminergic theory of positive affect formulated by Ashby and colleagues (1999) assumes that during periods of mild positive affect a concomitant increased dopamine release in the mesocorticolimbic system and perhaps also in the nigrostriatal system takes place. These elevated dopamine levels influence performance on a variety of cognitive tasks like for example episodic memory or creative problem solving (Ashby et al., 1999). A mild increase is already sufficient. The impact of the neurotransmitter dopamine on frontal brain areas seems to be of special relevance for performance of executive control functions. The importance of the frontal lobes and especially the prefrontal cortex for regulation and control of human activation is emphasised quite often (Luria, 1973; Nelson, 1976; Tranel et al., 1994; Walsh, 1978). Executive control is supposed to be organised in several stages with different processing centres in different frontal brain areas (Koechlin, Ody, & Kouneiher, 2003) and dopaminergic activity in those brain areas seems to modulate cognitive control functions. Kimberg, D'Esposito, and Farah (1997) describe a close connection between dopamine-mediated prefrontal functions and working memory capacity. And Dreisbach, Müller, Goschke, Schulze, Lesch, and Brocke (2005) found that dopaminergic activity, as indicated by spontaneous eyeblink rates which are supposed to be a functional marker of central dopaminergic function, modulates cognitive control. Dopamine seems to be a possible candidate to dynamically regulate cognitive control and therefore to influence stability and flexibility processes and to foster the flexible updating of working memory (Dreisbach, 2006). Dreisbach and Goschke (2004) state that phasic increases of dopamine in the prefrontal cortex serve as gating signal, triggering the updating of working memory and facilitating a switch of cognitive sets.

A connection of these findings with affect exists, because it is supposed that positive affect causes mild increases of dopamine in the prefrontal cortex (Ashby et al., 1999; Cohen,

Braver, & Brown, 2002; Dreisbach et al., 2005). Drugs that enhance the dopaminergic activity also elevate affect (Beatty, 1995) and a flattened affect emerges with dopamine antagonists (Hyman & Nestler, 1993). A further finding of relevance is that pictures with positive or negative valence affected the dopaminergic system the same way as positive and negative feedback: positive affect increased and negative affect decreased the activity of the dopaminergic system (Colzato, van Wouwe, & Hommel, 2007). However, it has to be noted, that dopamine is not supposed to also mediate the positive feelings that are associated with positive affect (Ashby et al., 1999).

Hence, it is hypothesised that moderate increases in positive affect, which are associated with mild dopamine increases in frontal brain areas enhance cognitive flexibility and reduce perseveration. This includes an improvement of the ability to overcome dominant responses as well as selective attenuation of perseverating behaviour. The increase of cognitive flexibility happens at the cost of increased distractibility and impulsivity. Furthermore, the antagonistic processing mode of flexibility, maintenance capability of working memory is weakened and impaired with positive affect (Dreisbach, 2006; Dreisbach & Goschke, 2004). It has to be noted that dopamine is not supposed to enhance switching of cognitive sets in general but higher dopamine levels are assumed to lead to higher cognitive flexibility and at the same time reduce perseveration (Owen, Roberts, Hodges, Summers, Polkey, & Robbins, 1993) what might then also facilitate switching.

2.2.1 Supporting findings

Based on the dopaminergic theory Dreisbach and Goschke (2004) tested whether positive affect increases flexibility and distractibility and at the same time reduces perseveration. The basic idea was that positive affect might modulate the balance between switching and maintaining intentions. The authors developed a special task that allowed examining those different abilities. It is predicted that positive affect reduces perseveration and therefore facilitates set switching and that at the same time positive affect increases distractibility. In a decision task with letters (vowel or consonant) and digits (odd or even) participants are trained to respond to stimuli in a prespecified target colour and ignore distractor stimuli in a different colour. After 40 trials in blocks of 60 trials participants in a first group had to switch to a completely new target colour whereas the former target colour became the new distractor colour. It is expected that under positive affect increased flexibility facilitates disengagement

from the formerly relevant target colour supported by a bias towards novel stimuli and reduced perseveration. Therefore it should be easier to switch distractor and target colours in the described way compared to neutral affect. In a second group the former distractor colour became the new target colour whereas a new colour was chosen as the new distractor colour. Predictions for this second group were that increased flexibility and the bias towards novel stimuli with positive affect focuses attention on the distractor and therefore more time is needed to complete that kind of target and distractor colour switch compared to neutral affect. As valent stimuli positive and neutral pictures of the IAPS (Lang et al., 2005) were used.

Since Dreisbach and Goschke (2004) called those time (and error rate) differences to execute those switches of target colours “switch costs” it has to be noted that those “switch costs” are different from what is normally understood with that term (see paragraph 1.1.2 Task switching paradigm). Dreisbach and Goschke (2004) only switched once per block and not the task but only the cue (=colour) that signalled which are the relevant task features. A task switch in a traditional task switching paradigm includes a change of cue, task rules, responses, response mappings etc. and is executed repeatedly.

Nonetheless predictions for the two groups were supported and the suspected increase and decrease in reaction times were mainly found for the response incompatible trials. This allowed the authors to assume that positive affect not simply increases reaction times but shows differentiated influences. Positive affect showed its impact only when strategies of inhibition and flexibility are really executed. It is further assumed that affect might influence a more global parameter like activation threshold which then is responsible for the reported effects. Dreisbach and Goschke (2004) concluded that positive affect reduces perseveration and at the same time increases flexibility which is supposed to be expressed in a bias towards novel stimuli.

In a second study Dreisbach (2006) concentrated more on the maintenance factor that is also important in task switching. It was expected that mild positive affect (again IAPS pictures were used) reduces maintenance capability. Reduced maintenance should result in costs when a certain goal has to be executed and in benefits when the goal unexpectedly changes. Different levels of maintenance of tasks and parts of tasks were represented with a continuous performance task. If the letter A (cue) was followed by the letter X (probe) the right response button had to be pressed. Was the X preceded by another letter like B (e.g. B-X), the left response button was the correct reaction as well as for an A not followed by an X (e.g. A-Y). Also the combination of B (not A) as cue and Y (not X) as probe indicated a left button press. A further important component of the experiment was the probability of occurrence of the

letter pairs. Pairs that required a right button press appeared in 70% of all trials, whereas each cue-probe pair with a left button press occurred in 10% of all trials, respectively. That meant that participants were forced to expect an X after an A. It was hypothesised that positive affect weakens maintenance therefore A-Y tasks are expected to be performed faster and with less errors compared to neutral or negative affect. The weak maintenance of the cue A which prepares for a right button press facilitates a left button press when the probe Y unexpectedly appears. The goal unexpectedly changes and the reduced maintenance capability caused by positive affect facilitates the response. B-X tasks were expected to be slower and more erroneous under positive compared to neutral and negative affect. The weakened maintenance of the cue B should impair reactions for the following probe X that requires different responses depending on the cue. Dreisbach (2006) also claimed costs under positive affect for B-Y pairs. This is not very plausible because cue and probe indicate the same response button and whether the cue is maintained well or not should not make any difference. However, what is predicted by Dreisbach (2006) is that under positive affect B-X pairs should produce more costs than B-Y pairs because increased response competition occurs with the probe X that indicates two opposing responses. Maintenance of the cue is necessary to know which response is required. The probe Y does not cause such a response conflict and competition.

In the first experiment the predictions were not well met and there was reason to believe that the obtained results were due to a simple speed-accuracy trade-off. Therefore in a second experiment the general maintenance demands were increased by introducing distractors between cue and probe. The distractors made the effects clearer. Under weak maintenance caused by positive affect A-Y tasks were performed faster whereas B-X tasks were performed slower compared to neutral and negative affect, respectively. In general effects were more pronounced with error rates. Especially the prediction that B-X pairs will show worse performance under positive affect than B-Y pairs was only revealed with error rates. Although the effects of those two experiments were generally weak it can be concluded that positive affect impairs maintenance capability. It is further assumed that results of weakened maintenance capability under positive affect might only be obtained with quite simple tasks.

The already mentioned study by Baumann and Kuhl (2005) further confirms the prediction of the dopaminergic theory that positive affect helps to overcome dominant responses. Short affective stimulation with words facilitated to shift the focus from dominant (global) to non dominant (local) stimulus features. The tendency to respond to the dominant global shapes was interrupted by positive affect.

A further interesting result was revealed by Phillips, Bull and colleagues (2002). As already mentioned these authors found increased Stroop costs under positive mood but they could also obtain higher general switch costs with positive mood. This effect originated in higher reaction times in mixed blocks for participants with a positive mood compared to a neutral mood. As described earlier (see paragraph 1.1.2 The task switching paradigm) general switch costs also include the measuring of maintenance. The costs are calculated by comparing single task blocks that do not require maintenance of the other task with mixed blocks that rely highly on maintenance capabilities. The result of larger general switch costs under positive mood can be considered to reflect weakened maintenance capability and higher distractibility, represented in increased reaction times in mixed blocks.

2.3 Review of the two Presented Models

The complicated interplay between affect and the four systems of the PSI model reveals that a simple answer to the question whether affect influences executive control functions or not and if it does how this influence may look like is not possible. Influences of positive and negative affect can vary greatly depending on what measures are used and what elements of executive functions these measures represent. Nonetheless PSI theory offers opportunities to deduce hypotheses regarding interactions of positive affect with switch costs and backward inhibition effects (see further below). This is possible because the systems that are mainly modulated by positive affect (intuitive behaviour control and in particular intention memory) are connected with volition, action control and action planning, factors that are of relevance for task switching. Furthermore, based on PSI theory Kuhl and Kazén (1999) and Kazén and Kuhl (2005) already examined inhibition, a factor that seems to be of some importance for task switching. A clear advantage is that the model focuses on ideas about influences of affect and not of moods or emotions. However the part of the model that describes systems that are mainly modulated by negative affect (extension memory and object recognition system) clearly show, that it is in general a theory about personality and the development of identity. Those more global issues are hardly useful to deduce hypotheses for the micro processes covered by task switching.

The dopaminergic theory seems to be much more convenient and applicable to task switching and its processes. Dreisbach and Goschke (2004) have to be credited for taking the hypotheses about dopamine and its influences on cognitive tasks from Ashby and colleagues (1999) and

applying them to the processes of set and task switching. However, the relevant processes like for example maintenance were examined separately and with paradigms that are quite different to the task switching paradigm. As described earlier switch costs measure a combination of different processes (see paragraph 1.1.3 Assumed processes underlying switch costs). The fragmented way in which only certain processes or combinations of processes were examined in the studies by Dreisbach (2006) and Dreisbach and Goschke (2004) do not reflect the complex combination of processes being responsible for switch costs. However, the dopaminergic theory focuses on affect and not on emotions or moods what is most useful for the current study.

In the end PSI theory might be too holistic and the dopaminergic theory too fragmented to be adequate models that fit the attempts of the current study to modulate measures of executive control functions like backward inhibition effects and switch costs by affect. Nonetheless the two models were used to deduce hypotheses about influences of brief affective stimulation on switch costs and backward inhibition effects which are presented in the next paragraph.

2.4 The Current Experiments, Hypotheses and Expectations

The aim of this study was to measure affective modulation of executive functions. As measures of executive control functions task switching costs (Rogers & Monsell, 1995) and backward inhibition effects (Mayr & Keele, 2000) were chosen and calculated with the dependent variables reaction times and error rates.

In general results and findings concerning influences of affect on switch costs and backward inhibition effects as measures of executive functions are rare. There are studies that examined executive functions but they used different tasks and measures like for example the Tower of London task (Oaksford, Morris, Grainger, Williams, & Mark, 1996; Phillips, Smith, & Gilhooly, 2002), the Stroop task (Hänze, 1997; Kazén & Kuhl, 2005; Kuhl & Kazén, 1999; Phillips, Bull et al., 2002), fluency tasks (Baker, Frith, & Dolan, 1997; Mohlman, Mangels, & Craske, 2004; Phillips, Bull et al., 2002), the Wisconsin Card Sorting Test (Mohlman et al., 2004) or other tasks (Aycicegi-Dinn, Dinn, & Caldwell-Harris, 2009; Dreisbach, 2006; Dreisbach & Goschke, 2004; Oaksford et al., 1996; Spies, Hesse, & Hummitzsch, 1996; Wang, LaBar, Rosenthal, Dolcos, Lynch, Krishnan, & McCarthy, 2008). Furthermore very often not short lived affect but mood was induced (Baker et al., 1997; Hänze, 1997; Oaksford et al., 1996; Phillips, Bull et al., 2002; Phillips, Smith et al., 2002; Spies et al., 1996; see

Mitchell & Phillips, 2007 for a review), personality traits or even clinical samples with for example affective disorders were tested (Aycicegi-Dinn et al., 2009; Fales, Vanek, & Knowlton, 2006; Mohlman et al., 2004; Moritz, Hübner, & Kluwe, 2004; Uekermann, Channon, Lehmkämer, Abdel-Hamid, Vollmoeller, & Daum, 2008; Wang et al., 2008). Studies that worked with task switching often did not use a pure and classical task switching paradigm (Dreisbach & Goschke, 2004; Phillips, Bull et al., 2002; Wang & Guo, 2008) or affective manipulations were far from being comparable with the brief induction of positive, neutral, or negative affect as intended in the current study (Paulitzki, Risko, Oakman, & Stolz, 2008; Steinhäuser, Maier, & Hübner, 2007; Kofman, Meiran, Greenberg, Balas, & Cohen, 2006). Regarding influences of affect on inhibition different inhibition processes have been examined like inhibition of intended actions (Kazén & Kuhl, 2005; Kuhl & Kazén, 1999), inhibition of inappropriate responses (Albert, López-Martín, & Carretié, 2009; Yu, Yuan, & Luo, 2009), or other kinds of inhibition that are slightly different from backward inhibition (Hänze, 1997; Phillips, Bull et al., 2002; Wood, Mathews, & Dalgleish, 2001). It seems as if an elaborated examination of affective influences on backward inhibition effects has yet to come. Thus, the current study offers examination of executive functions in terms of switch costs and backward inhibition effects with different affective stimulation. In order to gain a full pattern of affective influences three affective states were used, positive, negative, and neutral. The neutral affective state made it possible to have a kind of baseline compared to positive and negative affective states.

There are different methods to activate affect (physiological, hypnosis, personality traits etc.) but within an experimental setting in a laboratory with a tight paradigm using situational stimuli like films, pictures, sounds, words etc. seems to be the most convenient procedure (Sokolowski, 2002). Hence, as affective primes, pictures from the international affective picture system, IAPS (Lang et al., 2005) were used. Apart from being an established method (Dreisbach, 2006; Dreisbach & Goschke, 2004), it was already shown in combination with the startle reflex that pictures evoke affect. The startle reflex which is supposed to be a useful measure of human motivation and emotion is modulated by pictures from the IAPS (Bradley, Cuthbert, & Lang, 1999). Normally aversive stimuli increase the startle reflex (e.g. eyeblink) and pleasant stimuli occasion a relative inhibition of reflex magnitude (Bradley et al., 1999; Bradley, Lang, & Cuthbert, 1993; Lang, 1995; Lang et al., 1997). Hence, presenting valent pictures before a task should be sufficient to trigger different affective states.

This study offers a clear combination of short affective stimulation by valent pictures from the IAPS (Lang et al., 2005) but also by valent feedback with the well established task switching

paradigm to discover modulating effects of affect on executive control functions. The task switching paradigm seems to be an appropriate method to cover some of the many processes linked with executive control processes. The main task of executive functions is to guarantee a balance between stable and flexible processes to allow adapted human behaviour. Executive control is described as top-down control processes that enable goal pursuit. Particular processes being necessary to execute task switching are focusing and shifting attention, maintaining and switching task sets, retrieving associated goals, activating task sets, inhibiting distracting information, planning and preparing an action sequence to accomplish a goal, monitoring and checking ongoing processes. An explicitly mentioned function of executive control, inhibition and suppression of irrelevant information in order to execute a current task is covered separately by the backward inhibition effect (Mayr & Keele, 2000).

Kuhl's PSI theory (1996, 2000, 2001) and the dopaminergic theory (Ashby et al., 1999; Dreisbach & Goschke, 2004) allow generating hypotheses about influences of affect on executive control functions represented by switch costs and backward inhibition effects:

1. Influences of affect on switch costs

- a) PSI theory assumes that positive affect facilitates the connection between the loaded intention memory and executing systems in the intuitive behaviour control. It can be presumed that especially in case of a task switch which is a difficult task the intention memory is used and loaded. The simple non-switch tasks can be executed in an automatic way and do not need the intention memory. In case of positive affect the formed intention regarding a switch trial can be connected more easily to the executing system, they can be completed faster compared to switch trials with neutral affect. For non-switch trials affect does not make a difference because the intention memory is not loaded. Therefore smaller switch costs can be expected with positive compared to neutral affect due to reduced reaction times for switch trials.

- b) The prediction of the dopaminergic theory is similar. Enhanced cognitive flexibility and attenuated perseveration under positive affect are expected to result in benefits especially for switch trials. Those trials require the ability to abandon a recently executed task set and to flexibly switch to another one. Therefore it is expected that high flexibility and less perseveration are beneficiary when switching tasks. This should result in reduced reaction times for switch trials under positive affect producing smaller switch costs compared to neutral affect.

c) Predictions concerning influences of negative affect are more speculative but the idea about the facilitated access to the intuitive behaviour control with positive affect (see hypothesis 1a) might be extended to negative affect. Negative affect will prevent intentions stored in the intention memory to be brought into action, access to executing systems will be partly blocked. This is relevant for switch trials when intention memory is loaded. Although the prevention will not be a complete one at least reaction times will be slowed down compared to neutral affect. Therefore increased reaction times for switch trials can be expected with negative affect resulting in larger switch costs compared to neutral affect.

2. Influences of affect on backward inhibition effects

a) PSI theory assumes that positive affect supports overcoming once formed inhibition. If dissolving inhibition is facilitated under positive affect this would result in smaller backward inhibition effects. The formed inhibition for the first task in ABA sequences should be easier to release at the last position in the triplet with a preceding positive affect. In the end, faster reaction times for ABA sequences with positive affect would cause smaller backward inhibition effects.

A problem concerning this prediction might be that definitions of inhibition differ. Kuhl (1996, 2000, 2001; see also Kuhl & Kazén, 1999) describes an inhibition that is used on formed intentions that are going to be executed later. Backward inhibition (Mayr & Keele, 2000) however is used to avoid interference and conflict with a previously executed task set. Although descriptions and definitions of inhibition are different the generated hypothesis might still be valid.

b) To generate hypotheses for inhibition processes and effects from the dopaminergic theory is more difficult and therefore also more speculative. There are no explicit statements about influences of positive affect and increased dopamine levels on inhibition. However, inhibition and assumptions about distractibility can be linked. It is predicted that positive affect increases distractibility. That means that inhibition is weakened and impaired and as a consequence the amount of inhibition to deal with the abandoned task set will be reduced. It might further be possible that the weakened maintenance capability and the enhanced ability to overcome dominant responses with positive affect have an impact on inhibition during task switching. Both assumptions would reduce the necessity to inhibit and suppress the previous task set in order to execute a current task. Therefore the formation of inhibition that takes place after the

first task in a triplet (e.g. ABA) might be affected. Less inhibition in the first place with positive affect (maybe because it cannot be used or maybe it is not necessary to use it) reduces the time needed to overcome it later in the sequence resulting in smaller backward inhibition effects for positive affect compared to neutral affect. Crucial for that effect would be a positive affect between the first and the second task in ABA sequences.

3. Method

3.1 General Information

The main goal of the current study was to examine influences of affective stimulation on executive functioning. The following measures of executive functions were used: 1. switch costs generated with the help of the classical task-switching paradigm comparing switches between two different tasks with task repetitions; 2. backward inhibition effects which need three different tasks in different sequences to be calculated. Both measures were always (except for experiments 6.1 and 6.2) collected in parallel within one experimental setting. However, blocks with and without direct task repetitions were not varied within but between participants because direct task repetitions influence backward inhibition effects (Philipp & Koch, 2006). Participants were assigned by chance either to the task switching group including direct task repetitions or to the backward inhibition group without any direct task repetitions. Switch cost analyses could only be carried out in the group with direct task repetitions and backward inhibition effects were only examined in the group without direct task repetitions¹.

Affective stimuli were inserted into the paradigm on a trial by trial basis either directly before a task as unrelated primes (experiments 1 and 2) or as task-related cues (experiments 3 and 3.1) or after a task as feedback (experiments 4, 5, 5.1, 6.1, and 6.2). The chosen method was to use visual affective stimuli in terms of pictures from the IAPS (Lang et al., 2005) or pictorial feedback.

The paradigm offers different affect positions to be analysed. For backward inhibition effects triplets of tasks are analysed and two positions in the triplets are important. Between the first and the second task inhibition is supposed to be generated and implemented and before the third task this inhibition has to be overcome to be able to execute the last task of an ABA sequence (Mayr & Keele, 2000). As a consequence the affective elements between the first

¹ Task sequencing also allowed analysing backward inhibition effects in the group with direct task repetitions. These analyses did not reveal any interesting results or a constant pattern of influence. Please note, that due to the fact that direct task repetitions had a probability of $p = .33$ the probability of ABA and CBA sequences was only $p = .22$, respectively. In the end that left only a small amount of triplets to be analysed. This also caused the removal of several participants in certain experiments from those additional backward inhibition analyses due to missing data.

and the second and before the third task in a sequence are of importance². In case of valent pictures presented before a task the positions lag-1 and lag-0 are the relevant ones, for feedback the positions lag-1 and lag-2 are of interest (see figure 2). In both cases the positions refer to the overcoming and forming of backward inhibition, respectively. All backward inhibition analyses were carried out with the mentioned valence positions.

For exploring switch costs only sequences with two trials, pairs of trials are needed. To analyse influences of affective stimuli on switch costs, only the position between those two trials is of importance³. Thus, switch cost analyses were carried out with lag-0 valence position when pictures were presented before a trial and lag-1 position when feedback was used after a trial.

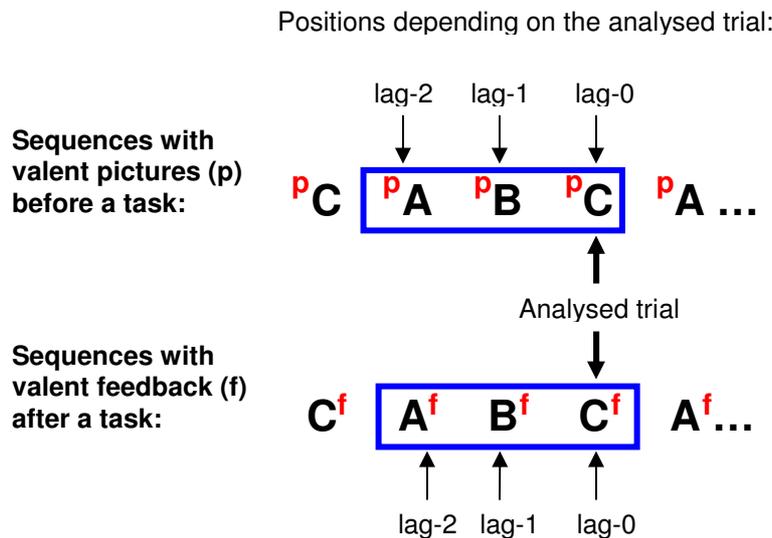


Figure 2: Schematic display of sequences with feedback and pictures and the notation of positions.

² It was also tested in all experiments whether the position before the first task in a triplet had an influence. It is possible that affect at this position might influence the performance of the first task of a triplet which then could influence all further processes like inhibition or reactivation of that task. No interesting findings or constant patterns were observed. The complex design including three affect positions simultaneously also caused missing data for a vast number of conditions in nearly all additionally analysed experiments. To keep analyses as simple as possible and because assumptions and predictions about the position before the first task were weak, it was excluded from the reported analyses.

³ Like for backward inhibition effects also for switch costs the position before the first task in a pair might have had an influence. Again, this position did not reveal any interesting additional information and therefore it was excluded from the reported analyses.

The overall effects of the valence factor containing the three conditions positive, neutral, and negative affect were not of interest. Instead, two contrasts were defined and reported. Positive affect is not supposed to have an impact into the same direction as negative affect (Kuhl, 2001; Kuhl & Kazén, 1999; Isen, 1999, 2000). Ashby and colleagues (1999) for example state that effects of negative mood are more complex and are not merely the opposite of positive mood. Furthermore, mood appears not to be a simple dichotomous phenomenon (Mitchell & Phillips, 2007). Hence, it seems more appropriate to compare each of the two valences (positive and negative) with a kind of baseline, the neutral condition. This resulted in the contrasts positive versus neutral and negative versus neutral that were analysed and reported in the following experiments whenever it was possible.

3.2 Experiments and Results

Nine experiments will be presented. Results of every experiment are discussed directly after its result section. Those discussions are only very brief because most of the time significant results supporting the main hypotheses were scarce. Hence, these direct discussions are used mainly to emphasise the relevant findings and especially to explain changes made for the subsequent experiment based on the results of the current one. An elaborated discussion of all experiments and results is presented in the general discussion (section 4).

3.2.1 Experiment 1

Method

Participants 76 students of the Friedrich-Schiller-University in Jena (between 19 and 30 years old) participated in the single-session experiment (duration approximately 30 minutes). They received 1.50 Euros, a bar of chocolate, and a piece of fruit for participating. The experiment lasted about 30 minutes. Six participants were excluded from analyses because their error rates showed merely correctness by chance.

Task and stimuli The stimuli were presented on a white screen. The three tasks form (Gestalt), line (Linie), and colour (Farbe) were cued with the first letters of the German terms G, L, and F, respectively. The presented target was either a square or a circle (form), drawn in

a thick or a thin line (line), in blue or in green (colour). Participants' task was to press the letter "D" on the keyboard for responses circle, thick, or green and the letter "L" for square, thin, or blue depending on the announced task (see figure 3). Responses had to be given as fast and as accurate as possible. Only six targets were used: a blue, thin circle, a blue, thick circle, a green, thin circle, a blue, thick square, a green, thin square, and a green, thick square. A green, thick circle and a blue, thin square were not included in the target set because in those cases the response key mapping allowed responding correctly without knowing the task. 48 valent pictures⁴ were chosen from the IAPS (Lang et al., 2005) to serve as affective primes in the test blocks (in practice blocks twelve different pictures were used). Pictures were chosen concerning their values of valence (9-point scale) and arousal (9-point scale). As can be seen in table 1, the values from the IAPS were fairly well met by the evaluation of all pictures by the present sample at the end of the experiment. The valence of positive and neutral pictures was slightly overestimated whereas the negative ones were underestimated.

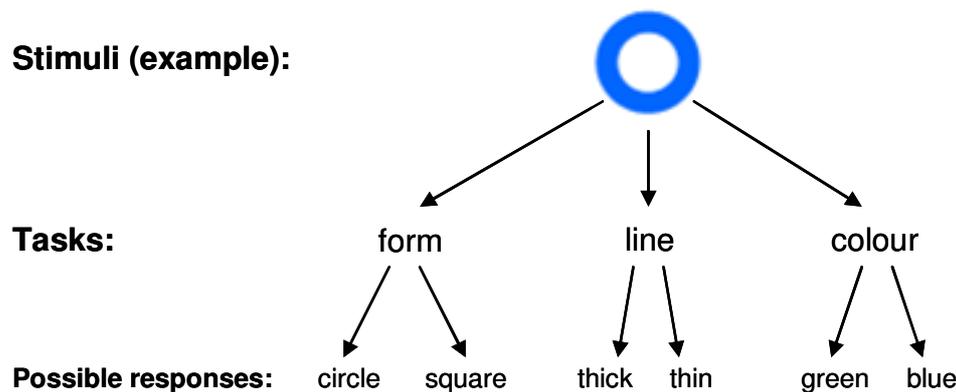


Figure 3: Tasks and response options.

⁴ The following pictures were used: 1050, 1440, 1525, 1710, 2038, 2050, 2071, 2091, 2120, 2190, 2209, 2216, 2276, 2340, 2691, 2880, 2900, 4626, 5510, 5731, 5740, 5833, 5971, 6260, 6312, 7000, 7004, 7006, 7010, 7025, 7035, 7041, 7053, 7161, 7185, 7200, 7330, 8370, 8420, 8496, 8499, 9340, 9421, 9429, 9470, 9495, 9600, 9902.

Table 1: Means of valence and arousal for the 48 prime pictures that were used. Listed are the values from the IAPS (Lang et al., 2005) and the present sample's evaluation.

	IAPS		Present sample	
	valence (range)	arousal (range)	valence (SD)	arousal (SD)
positive	7.8 (7.6 to 8.3)	5.4 (4.5 to 6.7)	7.4 (1.5)	5.2 (2.3)
neutral	5.0 (4.6 to 5.4)	2.6 (1.8 to 3.0)	5.3 (1.2)	3.4 (2.0)
negative	2.8 (2.2 to 3.5)	5.8 (4.6 to 6.9)	2.4 (1.5)	6.3 (2.3)

Trial Procedure A trial started with the presentation of the prime picture. The prime was shown for 500ms on its own in the middle of the screen. It remained on the screen in the background during cue and target presentation until a response was given. The task cue was shown slightly above the centre of the screen in front of the prime also for 500ms. The cue vanished and the target object was presented in front of the prime in the middle of the screen until a response button was pressed. The response was followed by a blank screen for 200ms before the next prime started (see figure 4). Sizes of prime picture, cue, and target (see technical details further below) did not allow a full coverage of the prime picture by the cue or the target.

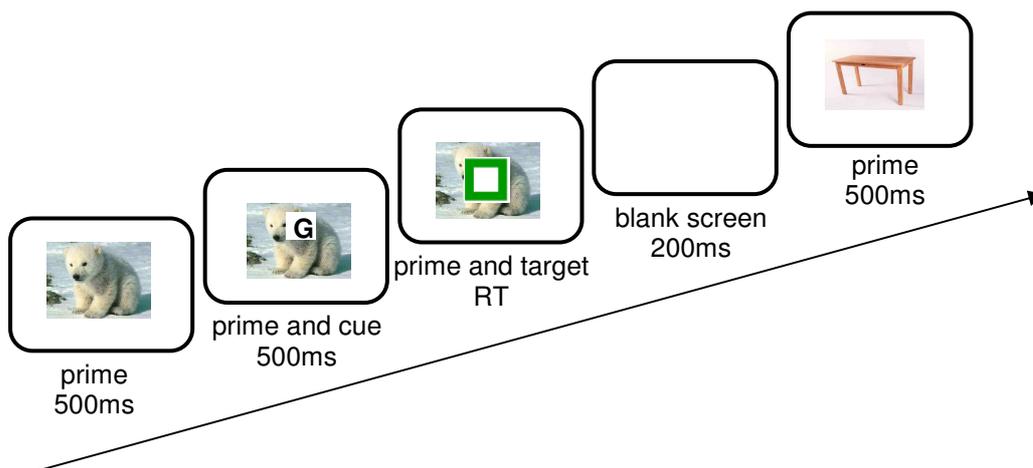


Figure 4: Trial procedure in experiment 1.

Procedure Half of the participants worked on a version that contained no direct task repetitions. In this group the task distribution led to 50% of ABA and CBA sequences, respectively. The other half of the participants had to execute experimental blocks which also included direct task repetitions with a probability of $p = .33$. In both groups tasks were drawn randomly but every task was shown with the same frequency throughout the experiment. All participants were informed at the beginning to which group they belonged.

In all experiments direct stimulus repetitions were avoided. This allowed excluding or at least minimising explanations based on S-R bindings (Waszak et al., 2003).

At the very beginning a written instruction was presented on the screen explaining the tasks and the experimental procedure. It was pointed out that although the valent pictures are irrelevant for task execution they should be attended to carefully, because a recognition test would be carried out with them later.

At first the participants were familiarised with the three tasks with two practice blocks of twelve trials each. Afterwards the recognition test with the twelve pictures from the two practice blocks and twelve new pictures had to be worked on. The pictures were shown on the screen in a random order. Participants had to decide for each of the 24 pictures whether it was a new one or an already familiar picture. Participants received immediate feedback about the correctness of their responses. Then eight test blocks of 48 trials per block followed. After each block a summary was given about errors and average reaction times. For the prime pictures in the test blocks there was also a recognition test similar to the first one but this time the test included only 25 trials for time saving reasons. All 25 trials were drawn randomly from a list containing all 48 prime pictures that were used in the test blocks and 48 unfamiliar but similar pictures from the IAPS (Lang et al., 2005). At last the 48 pictures from the test blocks had to be evaluated on two nine-point-scales. The scales were designed similar to those used by Lang and colleagues (2005). One scale concerned the valence from positive to negative and the other dealt with the arousal level from high to low.

The following technical details were used in all reported experiments. Participants were normally seated in a comfortable distance to the 17-inch monitor and the standard German keyboard. As response buttons always keys of the computer keyboard were used. Stimuli were always presented on a white background. Letter and word cues were presented in Courier New 18-points font, bold and in black colour. The size of the IAPS pictures on the screen was approximately 11 x 9 centimetres. Words written under the pictures were in black, font Terminal with a font size of 16-points. Targets had a size of circa 2 x 2 centimetres on the screen. Direct feedback included a picture sized 2 x 2 centimetres and text in bold Courier

New, font size 14-points in the colours green (for positive feedback) and red (for negative feedback). Feedback for the additional task was given in bold Courier New, font size 24-points in blue (for the correct execution of an additional task) or in red (for missing to press a button or for pressing the wrong button).

Results for backward inhibition effects

In the backward inhibition group the 34 participants showed an error rate of 7.9% (SD = 6.0%) and two participants were excluded from further analyses because their error rates were higher than 19.8% (mean error rate plus two standard deviations). Erroneous responses (7.0% of all trials) and reaction times below 200ms or more than one and a half interquartile ranges (552ms) above the 75th percentile (1109ms) were excluded from analyses (upper limit = 1937ms; 6.3% of all trials) (Tukey, 1977). Further were excluded, like in all other experiments' backward inhibition analyses, the first two trials of each block and the two trials following a wrong response. Only triplets without response errors at any position were analysed. This was a standardised procedure for all experiments.

An analysis of variance (ANOVA) was carried out that included the variables backward inhibition (ABA or CBA), lag-1 valence (positive, neutral, or negative), and lag-0 valence (positive, neutral, or negative). The means of all combinations of variables are presented in table 2 for reaction times and in table 3 for error rates. Instead of reporting results of the two valence variables with three levels each, the valence factors were split up into two contrasts. The neutral valence was contrasted with the positive and the negative one, respectively.

Reaction times A significant backward inhibition effect was found, $F(1,31) = 5.85, p < .03$. Reaction times for ABA sequences were 20ms slower than for CBA sequences (see table 2). Interactions of backward inhibition with the contrasts positive-neutral and negative-neutral at position lag-1 or lag-0 were not significant (all F 's $< 1.1, p$'s $> .31$) (see figure 5). All three-way interactions of backward inhibition and contrasts at positions lag-1 and lag-0 were also not significant (all F 's $< 3.3, p$'s $> .08$).

The two predefined contrasts at both positions did not reach significance (all F 's < 1). Apart from a significant interaction of the contrasts negative-neutral at position lag-1 with positive-neutral at position lag-0, $F(1,31) = 10.50, p < .01$, no other interactions between contrasts were significant (all F 's $< 3.7, p$'s $> .06$). Whereas after a neutral prime at position lag-1 reaction times were speeded up for positive primes (792ms) compared to neutral ones (822ms) at position lag-0, the reaction times show a reversed pattern after a negative prime at position lag-1 (lag-0 positive: 812ms; neutral: 794ms).

Error rates To rule out an explanation in terms of a speed-accuracy trade-off and to check whether valence influences might be on errors, analyses with error rates were carried out parallel to those with latencies. Analyses with error rates were always based on percentaged errors.

There was no significant overall backward inhibition effect ($F < 1$) (see table 3). For position lag-0 the interaction of backward inhibition and the contrast negative-neutral reached significance, $F(1,31) = 5.16$, $p < .04$ (see figure 6). The backward inhibition effect was normal for neutral valence (1.3%) compared to a reversed effect for negative valence (-0.9%). All other interactions of backward inhibition with the contrasts and the three-way interactions of backward inhibition, lag-1 contrasts, and lag-0 contrasts were not significant (all F 's < 1.5 , p 's $> .23$).

None of the predefined contrasts at the two positions or interactions between the contrasts at the two positions reached significance (all F 's < 3.6 , p 's $> .06$).

Table 2: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.

Variable				
Position lag-1	Position lag-0	ABA	CBA	BI (SD)
positive	positive	826	817	9 (148)
	neutral	849	813	35 (170)
	negative	795	805	-9 (111)
neutral	positive	817	767	50 (158)
	neutral	838	805	32 (112)
	negative	830	830	0 (128)
negative	positive	826	798	28 (111)
	neutral	793	794	-1 (130)
	negative	838	805	33 (115)
Total		823	804	20 (46)

Table 3: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.

Variable		ABA	CBA	BI (SD)
Position lag-1	Position lag-0			
positive	positive	6.2	7.6	-1.4 (5.7)
	neutral	7.8	7.5	0.4 (6.8)
	negative	5.2	5.7	-0.6 (7.5)
neutral	positive	8.1	6.6	1.6 (9.8)
	neutral	7.8	6.1	1.6 (8.8)
	negative	5.8	7.1	-1.3 (7.9)
negative	positive	7.7	7.0	0.7 (7.5)
	neutral	8.4	6.4	2.0 (8.4)
	negative	6.4	7.2	-0.7 (7.3)
Total		7.0	6.8	0.3 (2.9)

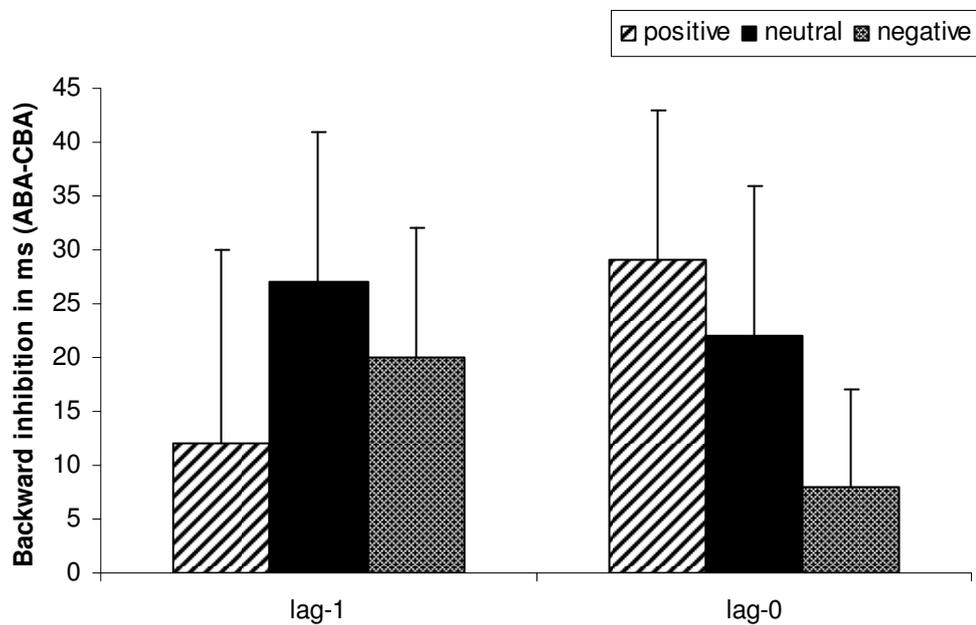


Figure 5: Backward inhibition effects for reaction times (in milliseconds) with positive, neutral, and negative valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.

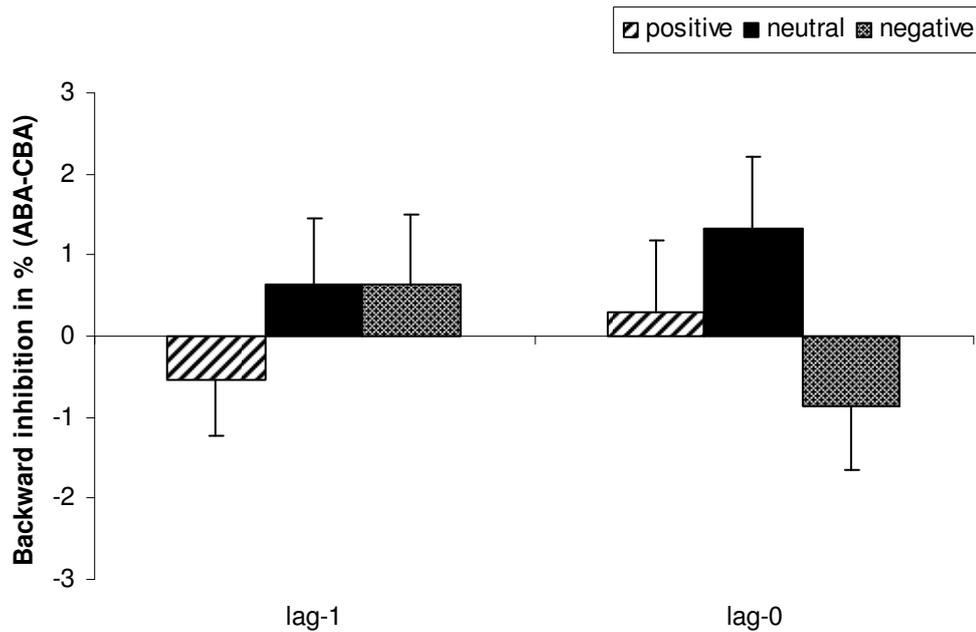


Figure 6: Backward inhibition effects for error rates (in percent) with positive, neutral, and negative valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.

Results for switch costs

The switch cost group with 36 participants showed an average error rate of 8.6% (SD = 8.7%). Three participants' error rates were higher than 26.1% (mean error rate plus two standard deviations) and they were excluded from all further analyses. Afterwards, the sample showed an error rate of 6.6%. Those trials and reaction times faster than 200ms or more than one and a half interquartile ranges (524ms) above the 75th percentile (1026ms) were excluded from analyses (upper limit = 1812ms; 7.9% of all trials) (Tukey, 1977). Also the first trial in each block and the trial following an error were excluded from analyses. Only complete and correct pairs were analysed. This was standard for all experiments.

For the analysis of variance (ANOVA) the variables switch costs (AA or AB) and valence at position lag-0 (positive, neutral, or negative) were used. The means of all combinations of variables are presented in table 4 for reaction times and in table 5 for error rates. As before, instead of the overall effects of the three-level variable valence results of the defined contrasts positive versus neutral and negative versus neutral were reported.

Reaction times Significant switch costs were found, $F(1,32) = 110.36$, $p < .01$. Switch trials were executed more than 180ms slower than non-switch trials (see table 4). Interactions of switch costs with the contrasts positive-neutral or negative-neutral were not found (all F 's < 1.2, p 's > .29) (see figure 7).

The contrasts positive-neutral and negative-neutral were also not significant (all F 's < 1).

Error rates For error rates there were also significant switch costs with 2.7% more errors in the switch condition than in the non-switch condition, $F(1,32) = 32.58$, $p < .01$ (see table 5).

No interactions of switch costs with the contrasts were found (all F 's < 3.7, p 's > .06).

None of the predefined contrasts did reach significance (all F 's < 1).

Table 4: Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.

Variable				
Position lag-0	AB	AA	SC	(SD)
positive	807	627	180	(106)
neutral	815	626	189	(115)
negative	806	635	171	(110)
Total	809	629	180	(99)

Table 5: Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.

Variable				
Position lag-0	AB	AA	SC	(SD)
positive	7.6	4.7	2.9	(5.0)
neutral	8.1	4.4	3.8	(4.9)
negative	6.6	5.1	1.5	(5.1)
Total	7.4	4.7	2.7	(2.7)

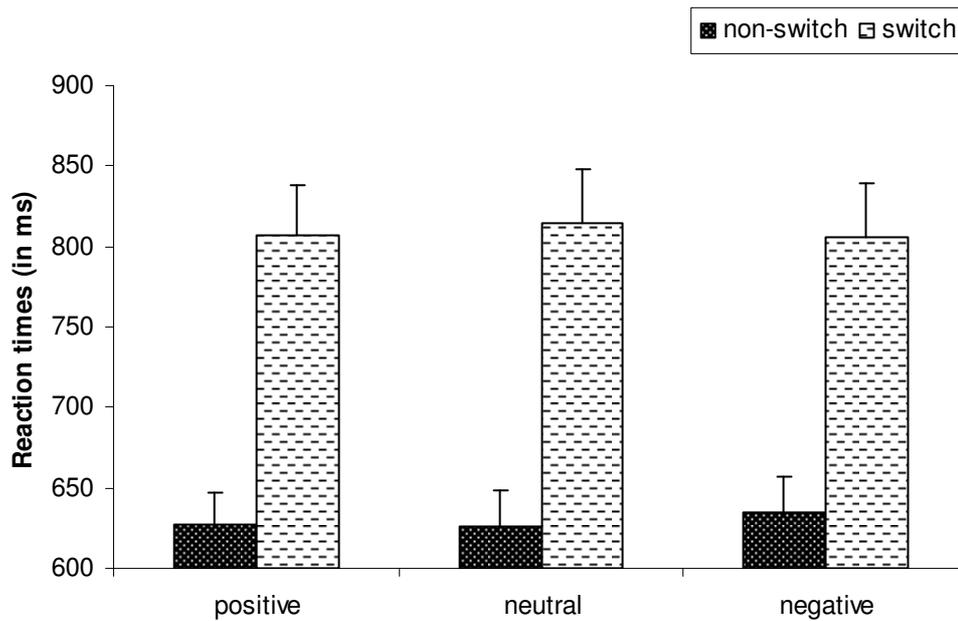


Figure 7: Reaction times (in milliseconds) for non-switch and switch trials after a positive, neutral, or negative picture at position lag-0, respectively. Error bars refer to standard errors.

Discussion

For reaction times an influence of valence on cognitive measures like backward inhibition effects or switch costs was not found, significant interactions of the two contrasts positive-neutral and negative-neutral with the two measures did not emerge.

For latencies a significant backward inhibition effect was found. The paradigm with the chosen tasks and stimuli seems to be an efficient method to measure backward inhibition effects. What would have been expected following the dopaminergic theory for valence position lag-1 was a reduction of the backward inhibition effect under positive compared to neutral affect. On a descriptive level this prediction looks like being fulfilled (see figure 5). The cause for the smaller effect with positive affect was predicted to be increased reaction times for ABA sequences but the found pattern appears to be more complex. The main cause for the smaller effect with positive affect are increased reaction times for CBA sequences (neutral: 801ms; positive: 812ms) but also a reduction of reaction times for ABA sequences (neutral: 828ms; positive: 823ms) contributed to the difference (see table 2).

Following PSI theory at position lag-0 smaller backward inhibition effects were predicted under positive affect compared to neutral affect caused by a reduction of reaction times for ABA sequences. However, data show a decreasing linear pattern for backward inhibition effects from positive to neutral to negative (see figure 5). This pattern is mainly caused by

increasing reaction times for CBA sequences from positive (794ms) to neutral (804ms) to negative (813ms) (see table 2).

Contrary to reaction times, for error rates some significant interactions were obtained. Besides latencies error rates are a second possibility to detect influences of affective stimulation on executive functions. Valence might not influence reaction times, but error rates in a kind of a monitoring function that for example helps to avoid errors in certain conditions. However if this is not the case it is important to make clear that no speed-accuracy trade-off exists. Error rates should always show patterns of results similar to those for reaction times. For the current experiment a speed-accuracy trade-off cannot be assumed.

For error rates a significant interaction of backward inhibition with the contrast negative-neutral at position lag-0 was found. With a negative valence at this position the backward inhibition effect was reversed (see figure 6). This was mainly caused by a reduction of error rates in ABA sequences from neutral (8.0%) to negative (5.8%) whereas for CBA sequences error rates with neutral and negative affect were identical (6.7%). It seems as if a negative valence at position lag-0 helps to avoid errors in the more difficult ABA sequences. Normally it is more difficult to execute the last task in ABA sequences because of the inhibition that is inflicted on that task. In general that is expressed in higher reaction times and error rates. In the current experiment at least error rates after negative affect showed a different pattern, errors in ABA sequences could be reduced to an amount that even allowed a reversed backward inhibition effect. The PSI and the dopaminergic theory did not make any specific predictions concerning the difference between negative and neutral affect neither for reaction times nor for error rates. Before interpreting that effect any further a replication would be desirable and useful.

For reaction time analyses significant switch costs were found. As for backward inhibition effects interactions with valence were not found. The switch costs for the three valences hardly differed (see table 4) and not even a pattern of possible influences of valence on switch costs can be described.

As for reaction times analyses based on error rates also showed significant switch costs but contrary to backward inhibition analyses no significant interactions were found.

A reason for having missed significant influences of affect on backward inhibition effects or switch costs might have been the presentation of the valent stimuli. Participants could have ignored the valent pictures because they were not relevant for executing the tasks. The pictures might have flown by as a kind of visual background noise while participants

concentrated on the real task. To check this assumption a sensitivity measure d' was calculated. Every participant had to complete a recognition test concerning the valent pictures at the end of the experiment. The relative frequency for hits was 0.94 and 0.15 for false alarms. This resulted in $d' = 2.6$ which is a fairly high value and gives reason to believe that the participants at least noticed the pictures in a kind of way that allowed them to remember those pictures later in the experiment. However, even with this high recognition rate it is still an open question, whether participants also encoded the valence of the pictures. It might not be necessary to know the valence of a picture to remember it as a former part of the previous test blocks. Hence, for the next experiment an additional task was created to support focusing on the valence of the prime pictures. The same experiment was carried out again but this time the valence of the pictures was specified in written form directly below the pictures. Also attention was drawn to the pictures with an additional task. Participants had to notice when the valence content of the picture and the written valence word under the picture did not correspond. This will hopefully advance encoding *and* processing of the valence information because with the additional task attention is constantly drawn to it.

3.2.2 Experiment 2: Additional task

Method

Participants 69 students of the Friedrich-Schiller-University in Jena (between 18 and 40 years old) participated in the single-session experiment for partial fulfilment of course requirements. The experiment lasted about 30-40 minutes.

Task and Stimuli Task and stimuli were the same as in experiment 1. The same prime pictures were used plus two additional neutral pictures⁵, altogether 50 pictures. This was necessary to guarantee that within a block no picture was presented twice, because sometimes none, one, or two additional tasks were included. In table 6 the results of the evaluative testing of the pictures at the end of the experiment are presented compared to the values from the IAPS (Lang et al., 2005). This time the neutral pictures show nearly identical evaluation values. As in experiment 1 the negative ones are still slightly underestimated but for the positive pictures the understatement increased.

⁵ The two additional pictures were numbers 5520 and 7080 from the IAPS (Lang et al., 2005).

Table 6: Means of valence and arousal for the 50 prime pictures that were used. Listed are the values from the IAPS (Lang et al., 2005) and the present sample's evaluation.

	IAPS		Present sample	
	valence (range)	arousal (range)	valence (SD)	arousal (SD)
positive	7.8 (7.6 to 8.3)	5.4 (4.5 to 6.7)	7.2 (1.5)	5.5 (2.0)
neutral	5.1 (4.6 to 5.4)	2.6 (1.8 to 3.0)	5.2 (1.0)	3.2 (1.9)
negative	2.8 (2.2 to 3.5)	5.8 (4.6 to 6.9)	2.5 (1.5)	6.5 (1.9)

Trial Procedure The trial procedure was identical to that in experiment 1.

Procedure As in experiment 1, half of the participants worked on a version that contained no direct task repetitions, the other half had to deal with direct task repetitions. The probabilities for ABA, CBA, and repetition sequences were the same as in experiment 1 for the different groups.

The three tasks (form, line, and colour) were explained by means of a written instruction on the screen. In this experiment valence of the pictures was also labelled below every picture. For example, below a picture with a negative valence the word 'negative' was written in German. All pictures with the appropriate valence words that were used in the practice blocks were presented to the participants before testing started. This was followed by two practice blocks with twelve trials each to allow participants to familiarise with the tasks. Then an additional task was introduced. Normally, the valence of the picture and the written valence word were identical. But sometimes this was not the case and participants were requested to register the discrepancy and press the space button immediately. For the additional task the trial procedure was slightly changed. The prime was shown for 900ms instead of 500ms to leave enough time for identification and a correct response. No cue and no stimuli followed but feedback was shown for 1750ms. If no button was pressed within the 900ms feedback read "Zu langsam! Bild und Text haben nicht übereingestimmt!" (Too slow! Picture and text did not match!). If the space button was pressed within the 900ms positive feedback was shown reading "Richtig! Sehr gut erkannt!" (Correct! Well recognised!). If any other button was pressed within the 900ms the following feedback was shown: "Leider falsche Taste!" (Wrong button press!). Another two practice blocks were presented with twelve trials each and two additional tasks, respectively. Again, as in experiment 1 in practice blocks different pictures were used as in test blocks. Therefore, before the test blocks started the 50 test pictures were all shown to the participants with the appropriate valence word written below it.

After that, ten test blocks with 48 trials per block had to be completed. Within these ten blocks nine additional tasks were presented. Four blocks had no additional task at all, three blocks one and the other three blocks two additional tasks, respectively. Positions of the additional tasks in the block sequence and within a block were chosen randomly. After each block again a summary about errors and average reaction time was presented.

At last the 50 pictures from the test blocks had to be evaluated on two nine-point-scales. As in experiment 1 the first scale concerned valence from positive to negative and the second one dealt with the arousal level from high to low.

Results for backward inhibition effects

The 35 participants of the backward inhibition group showed an error rate of 7.5% (SD = 7.4%). Two participants were excluded from further analyses because their error rates were higher than 22.4% (mean error rate plus two standard deviations). Erroneous responses (5.9% of all trials) and reaction times below 200ms or more than one and a half interquartile ranges (764ms) above the 75th percentile (1380ms) were excluded from analyses (upper limit = 2526ms; 5.7% of all trials) (Tukey, 1977). Additional to wrong responses and reaction times slower than 2526ms also additional tasks and the two tasks following such a task were excluded.

The identical analyses as in experiment 1 were carried out. Means of all variables and combinations of variables are presented in table 7 (reaction times) and table 8 (error rates).

Reaction times This time a significant backward inhibition effect was not found ($F < 2.7$, $p > .11$) (see table 7). All interactions of backward inhibition with the two contrasts at positions lag-1 and lag-0, respectively, as well as the three-way interactions were not significant (all F 's < 1) (see figure 8).

For position lag-1 both contrasts and for position lag-0 the contrast negative-neutral did not reach significance (all F 's < 1), but the contrast positive-neutral at position lag-0 was significant, $F(1,32) = 5.53$, $p < .03$. Reaction times after neutral primes at position lag-0 (994ms) were 20ms slower than after positive primes (974ms). Interactions between contrasts were not significant (all F 's < 3.0 , p 's $> .09$).

Error rates There was no significant backward inhibition effect ($F < 1$). Also none of the interactions with backward inhibition did reach significance (all F 's < 3.0 , p 's $> .09$) (see table 8).

For the contrasts and also the interactions between the contrasts no significant results could be observed (all F 's < 3.1 , p 's $> .08$).

Table 7: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.

Variable					
Position lag-1	Position lag-0	ABA	CBA	BI	(SD)
positive	positive	958	956	3	(165)
	neutral	996	981	15	(125)
	negative	1002	989	12	(157)
neutral	positive	985	981	4	(125)
	neutral	981	979	2	(139)
	negative	1023	978	45	(160)
negative	positive	994	970	24	(146)
	neutral	1021	1005	16	(137)
	negative	988	980	8	(188)
Total		994	980	14	(51)

Table 8: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.

Variable					
Position lag-1	Position lag-0	ABA	CBA	BI	(SD)
positive	positive	6.1	5.6	0.4	(5.4)
	neutral	5.8	5.4	0.4	(7.1)
	negative	5.7	6.7	-1.0	(8.3)
neutral	positive	6.2	6.3	-0.1	(5.3)
	neutral	6.4	4.9	1.5	(5.4)
	negative	6.5	5.6	1.0	(6.6)
negative	positive	7.1	5.5	1.6	(6.7)
	neutral	4.7	5.5	-0.8	(6.3)
	negative	5.7	5.4	0.3	(6.6)
Total		6.0	5.7	0.4	(2.2)

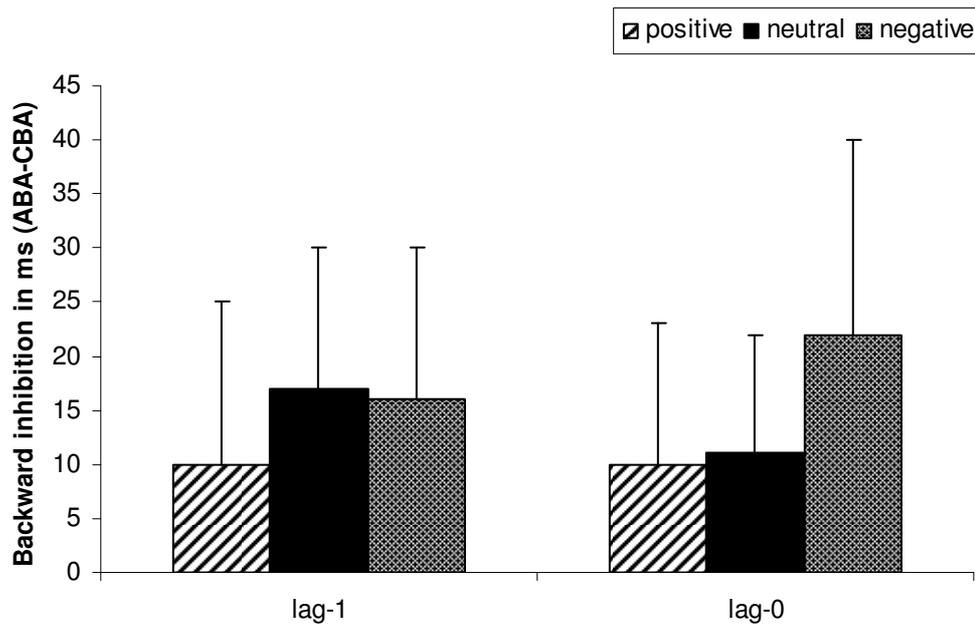


Figure 8: Backward inhibition effects for reaction times (in milliseconds) with positive, neutral, and negative valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.

Results for switch costs

The average error rate of the switch cost group (34 participants) was 8.1% (SD = 6.9%). Two participants with error rates higher than 21.9% (mean error rate plus two standard deviations) were excluded from all further analyses. The remaining sample showed an error rate of 6.8%. Erroneous responses and reaction times below 200ms or more than one and a half interquartile ranges (704ms) above the 75th percentile (1291ms) were excluded from analyses (upper limit = 2347ms; 7.0% of all trials) (Tukey, 1977). As for backward inhibition analyses every additional task and the following trial were not included in the analyses.

The carried out analyses were the same as in experiment 1. In tables 9 (reaction times) and 10 (error rates) means of all combinations of variables are presented.

Reaction times Significant switch costs were found, $F(1,31) = 89.02$, $p < .01$, switch trials were 161ms slower than non-switch trials (see table 9). The interaction of switch costs with the contrast negative-neutral reached significance, $F(1,31) = 5.14$, $p < .04$. Switch costs after neutral primes (143ms) were smaller than after negative primes (182ms) (see figure 9). The interaction of switch costs and the contrast positive-neutral was not significant ($F < 1$).

For the two predefined contrasts no significant results were obtained (all F 's < 3 , p 's $> .09$).

Error rates For error rates also significant switch costs were found, $F(1,31) = 25.91, p < .01$. 2.2% more errors were made in switch than in non-switch trials (see table 10). Interactions of switch costs with one of the two contrasts did not reach significance (all F 's $< 1.4, p$'s $> .26$). The contrast positive-neutral was significant, $F(1,31) = 5.58, p < .03$, with 1% more errors after neutral primes (6.6%) than after positive ones (5.6%). The other contrast was not significant ($F < 1$).

Table 9: Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.

Variable				
Position lag-0	AB	AA	SC	(SD)
positive	951	789	162	(112)
neutral	960	817	143	(125)
negative	991	809	182	(109)
Total	967	805	162	(97)

Table 10: Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.

Variable				
Position lag-0	AB	AA	SC	(SD)
positive	7.0	4.1	2.9	(4.8)
neutral	7.3	5.8	1.5	(4.4)
negative	7.8	5.6	2.2	(3.3)
Total	7.4	5.2	2.2	(2.4)

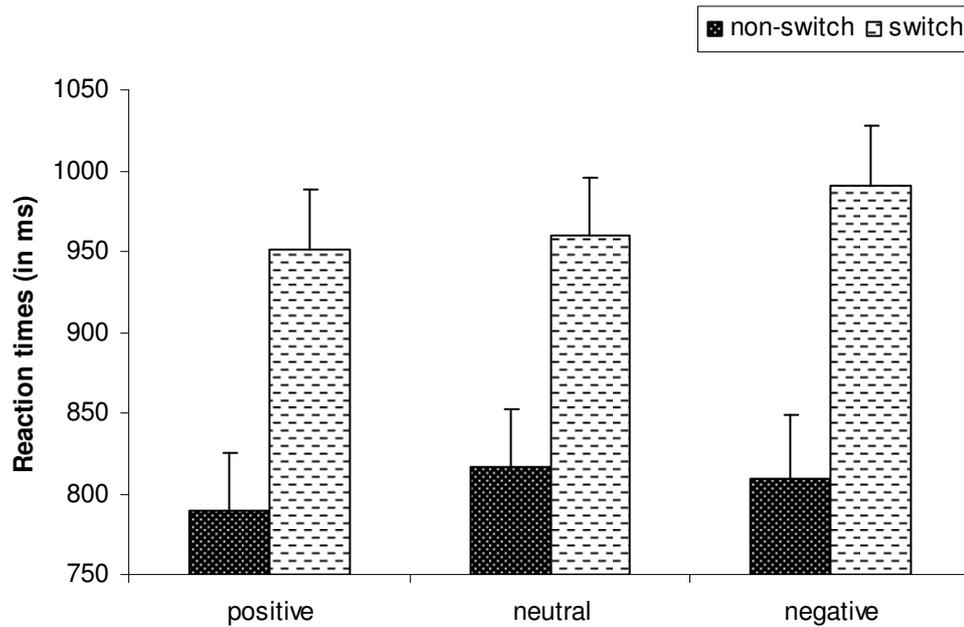


Figure 9: Reaction times (in milliseconds) for non-switch and switch trials after a positive, neutral, or negative picture at position lag-0, respectively. Error bars refer to standard errors.

Discussion

In this second experiment reaction times were generally slower and backward inhibition effects and switch costs smaller. The additional task that increased the difficulty of the experiment might have slowed down latencies in general.

Again, an interaction of backward inhibition with valence was not found, this time neither for reaction times nor for error rates. Although the general backward inhibition effect based on reaction times was only slightly smaller than in experiment 1 (14ms versus 20ms) it did not reach significance this time.

For latencies at position lag-1 the backward inhibition effect after positive primes is again smaller than after neutral ones and this time expectations from the dopaminergic theory were met. The descriptive difference was mainly due to reduced reaction times for ABA sequences with positive affect (positive: 985ms; neutral: 996ms). Reaction times for CBA sequences were nearly identical (positive: 975ms; neutral: 979ms). The pattern of backward inhibition effects at position lag-0 from experiment 1 could not be replicated. Considering PSI theory the expected smaller backward inhibition effect after positive primes was not even reached on a descriptive level. Backward inhibition effects for positive and neutral primes hardly differ (see figure 8).

Error rates did not reveal any significant result. The significant interaction of backward inhibition effects and the contrast neutral-negative that was found in experiment 1 was not replicated.

For switch costs a significant interaction with the contrast negative-neutral based on reaction times was found. Switch costs were larger after a negative prime. This seems mainly due to an increase of reaction times for task switches of nearly 30ms with negative primes (see table 9 and figure 9). This pattern was exactly predicted with PSI theory. If this finding could be replicated it would confirm the idea of the PSI theory that with negative affect the connection between the intention memory and the executing systems of the intuitive behaviour control is disturbed and partly blocked. That slows down execution of the switch trials with negative affect compared to positive affect. The pattern of switch costs for the contrast positive-neutral is completely contrary to the predicted one by the PSI and the dopaminergic theory. With positive affect switch costs are larger than with neutral affect. However, this interaction was not significant.

A speed-accuracy trade-off for the significant interaction cannot be assumed.

In this second experiment it was tried to direct attention to the valence of the prime pictures. An additional task was used that asked participants to actively compare the valence information of the picture with a given written information below the picture. A recognition test with the prime pictures like in experiment 1 was not carried out due to time constraints, the experiment should not last longer than 45 minutes. Therefore a sensitivity measure could not be calculated.

In this experiment only an interaction between valence and switch costs was found. The additional task seemed not enough to enhance the perception of the valence of the stimuli in a way that allowed a substantial impact on switch costs and backward inhibition effects. Therefore, for the following experiment the relevance of the valent pictures was again intensified. The pictures should gain importance and influence when they are connected more tightly to the tasks. Hence, the irrelevant pictures concerning the tasks were turned into cues for the three different tasks. In the next experiment every task had three different cue pictures because none of the three valences positive, neutral, and negative should be missed out. Thus, participants had to deal with nine different pictures and they had to learn, which pictures are cueing which tasks in an extensive procedure at the beginning of the experiment. The additional task was retained so that attention was still directed towards the valence information of the pictures.

3.2.3 Experiment 3: Valent cues

Method

Participants 62 students of the university in Jena (between 18 and 37 years old; three participants failed to name their age) participated in the single-session experiment. They received a bar of chocolate and a token worth 2 Euros to be honoured in the university cafeteria or later during data collection 3 Euros and a bar of chocolate. The experiment lasted about 40 minutes. One participant had to be excluded from analyses due to a programming error in the executed condition. Further eleven participants were excluded because their error rates showed merely correctness by chance.

Task and Stimuli The tasks and task stimuli were the same as in experiment 1 and 2. The purpose of the valent pictures changed. They were not used as elements unrelated to the tasks anymore but as cues for the three different tasks. Every task had three different cues, a positive, a negative, and a neutral picture. The nine pictures for the three different tasks were again chosen from the IAPS (Lang et al., 2005)⁶, taking into account the results from the evaluations in experiments 1 and 2. Valence and arousal values of the pictures are presented in table 11. The present sample's evaluation of the negative pictures was nearly identical to the values from the IAPS. Once more the positive pictures were underestimated whereas this time the neutral ones were slightly overestimated.

Table 11: Means of valence and arousal for the nine pictures used as task cues. Listed are the values from the IAPS (Lang et al., 2005) and the present sample's evaluation.

	IAPS		Present sample	
	valence (range)	arousal (range)	valence (SD)	arousal (SD)
positive	7.9 (7.6 to 8.0)	5.0 (4.9 to 5.1)	7.4 (1.6)	5.4 (2.0)
neutral	5.2 (5.1 to 5.2)	2.8 (2.6 to 3.0)	5.8 (1.4)	3.9 (1.8)
negative	2.4 (2.4 to 2.5)	5.1 (5.0 to 5.2)	2.4 (1.4)	5.0 (2.4)

⁶ The following pictures were chosen: numbers 1811, 2150, 2340, 2880, 2038, 5740, 2900, 9340, and 2141.

Trial Procedure The trial procedure was slightly modified due to the fact that cue and prime were identical in this experiment. A trial started with the presentation of the cue prime picture. It remained in the middle of the screen on its own for 500ms and then also during target presentation until a response was given. The target was presented in front of the cue prime in the middle of the screen until a response button was pressed. The response was followed by a blank screen for 200ms before the next cue prime picture was shown.

As in experiment 2 the additional task was also used in the current experiment. The trial procedure was the same as in the previous experiment with one small change. The prime picture was not shown for 900ms but for 1000ms. All other features were identical concerning the additional task.

Procedure Two versions, one with the other without direct task repetitions were used as usual with the same probabilities as in experiments 1 and 2.

The introduction to the tasks and the cues was varied depending on their mapping. One positive, one negative, and one neutral picture were combined as a cue set, respectively. In three different experimental versions the three cue sets were matched differently on the three different tasks following the rules of the Latin square. During practice phase the participants could be introduced to the tasks in one of three orders: 1. colour, form, and line, 2. form, line, and colour, 3. line, colour, and form. With this procedure sequence effects of task introduction or effects of task and cue combination were expected to be avoided. A long and extensive introduction phase was necessary because the cues were linked to the tasks arbitrarily. The combination of cues and tasks had to be learned first. Participants got introduced to the first task with a block of eight trials at the beginning of the experiment after the written general instruction. Then the second task was explained and also practiced with eight trials. Two blocks with 16 trials each followed in which the first and the second task were practiced together. After that the third task was introduced, again with eight training trials. Then two blocks with 20 trials each were presented with all three tasks. With the completion of those two blocks the introduction and training phase of tasks and cues ended. The additional task was explained to the participants and practiced at once with two blocks of 18 trials, respectively. In each of the two blocks two additional tasks were included at a random position. Then the test phase of eight blocks, each with 56 trials began. Three blocks were without an additional task, three blocks contained one and two blocks two additional tasks, respectively. The position of an additional task in the block sequence and within a block was again arbitrary.

The first two trials of a test block were drawn randomly. The remaining 54 trials were 18 line, colour, and form tasks, respectively. This number of trials allowed the presentation of each possible cue target combination (three cues per task and six targets) once in a block. After each block participants were informed about their performance concerning speed and accuracy. In the end the nine cue prime pictures had to be evaluated on the twine-point-scales.

Results for backward inhibition effects

In the backward inhibition group the 26 participants showed an error rate of 12.1% (SD = 11.9%) and two participants were excluded from further analyses because their error rates were higher than 35.9% (mean error rate plus two standard deviations). Erroneous responses (9.8% of all trials) and reaction times below 200ms or more than one and a half interquartile ranges (1231ms) above the 75th percentile (1989ms) were excluded from analyses (upper limit = 3836ms; 7.6% of all trials) (Tukey, 1977). Again additional tasks and the two trials following such a task were excluded from analyses.

In a first step it was tested whether the three different mappings of cue pictures to the three tasks represented with the factor version (version1, version2, version3) influenced any of the relevant variables. This was not the case and therefore the variable version was not included in the following analyses.

Identical analyses as in the experiments before were carried out. Means of combinations of variables for reaction times and error rates are presented in table 12 and table 13, respectively.

Reaction times A significant backward inhibition effect was not found ($F < 1$) (see table 12). Also, interactions of one of the two contrasts at positions lag-1 and lag-0 with backward inhibition did not reach significance (all F 's < 3.2 , p 's $> .08$) (see table 12 and figure 10). The three-way interaction backward inhibition x contrast negative-neutral at position lag-1 x contrast positive-neutral at position lag-0 was significant, $F(1,23) = 4.30$, $p < .05$. After a neutral cue at position lag-1 a reversed backward inhibition effect of -65ms emerged for a positive cue at position lag-0 and a normal backward inhibition effect of 14ms for a neutral cue at the same position. This pattern changes for a negative cue at position lag-1 especially concerning the positive cue at position lag-0. Whereas the combination lag-1 negative plus lag-0 neutral revealed a backward inhibition effect of 15ms (which is nearly identical to the 14ms of the combination lag-1 neutral plus lag-0 neutral) the combination lag-1 negative plus lag-0 positive obtained a backward inhibition effect of 144ms. All other three-way interactions were not significant (all F 's < 1).

Table 12: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.

Variable					
Position lag-1	Position lag-0	ABA	CBA	BI	(SD)
positive	positive	1272	1252	20	(248)
	neutral	1373	1358	15	(286)
	negative	1351	1360	-9	(217)
neutral	positive	1233	1298	-65	(305)
	neutral	1376	1362	14	(250)
	negative	1355	1345	10	(207)
negative	positive	1306	1163	144	(233)
	neutral	1457	1442	15	(271)
	negative	1330	1314	17	(251)
Total		1339	1322	18	(97)

Table 13: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.

Variable					
Position lag-1	Position lag-0	ABA	CBA	BI	(SD)
positive	positive	11.7	10.2	1.5	(6.3)
	neutral	8.8	8.4	0.5	(8.0)
	negative	8.7	9.7	-1.1	(7.5)
neutral	positive	10.9	9.4	1.5	(7.9)
	neutral	9.9	8.0	1.8	(6.9)
	negative	11.1	9.8	1.3	(8.9)
negative	positive	10.6	10.6	0	(8.2)
	neutral	9.5	8.9	0.5	(8.2)
	negative	12.0	8.2	3.8	(7.9)
Total		10.3	9.2	1.1	(2.9)

The contrast positive-neutral at position lag-0 was significant, $F(1,23) = 17.64$, $p < .01$. Reaction times were faster after a positive cue (1254ms) compared to a neutral cue (1395ms) at position lag-0. All other contrasts did not reach significance (all F 's < 4.3 , p 's $> .05$). A further significant result can be reported for the interaction of the contrasts negative-neutral at positions lag-1 and lag-0, $F(1,23) = 6.24$, $p < .03$. For a neutral cue at position lag-1 reaction times are only slightly faster after a negative cue (1350ms) compared to a neutral one (1369ms) at position lag-0. This pattern is intensified after a negative cue at position lag-1. Reaction times after a negative cue at position lag-0 are now faster (1347ms) than after a neutral one (1450ms). All other interactions were not significant (all F 's < 2.6 , p 's $> .12$).

Error rates For error rates no significant backward inhibition effect was found ($F < 3.5$, $p > .07$) (see table 13). None of the interactions of backward inhibition with the contrasts (all F 's < 1) or the three-way interactions (all F 's < 1.2 , p 's $> .28$) were significant.

All contrasts and all interactions between contrasts failed to reach significance (all F 's < 1).

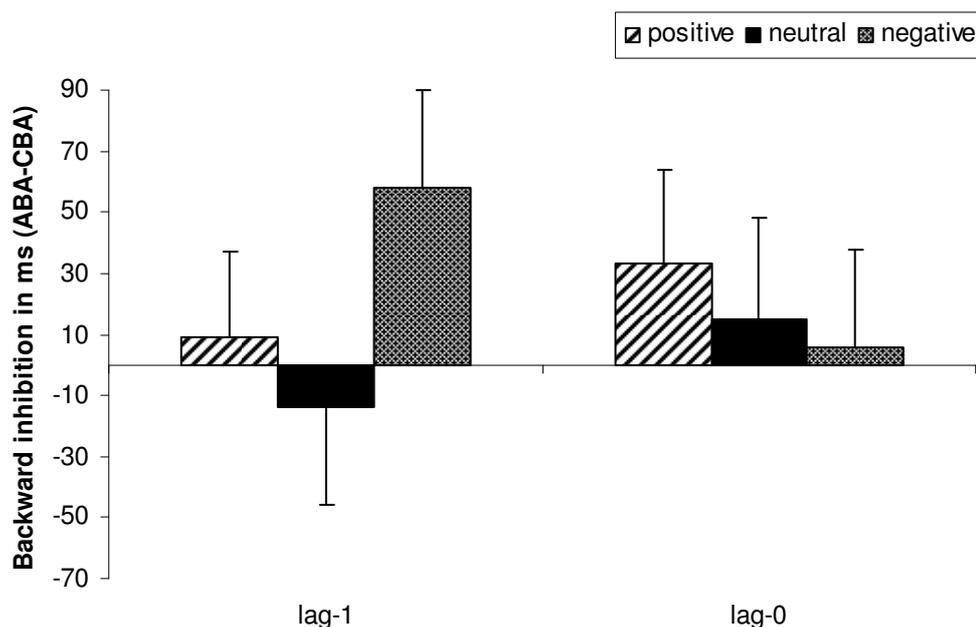


Figure 10: Backward inhibition effects for reaction times (in milliseconds) with positive, neutral, and negative valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.

Results for switch costs

The switch cost group with 24 participants showed an average error rate of 10.8% (SD = 8.3%). Two participants showed error rates higher than 27.5% (mean error rate plus two standard deviations) and were excluded from all further analyses. Afterwards, the sample showed an error rate of 9.0%. Those trials and reaction times faster than 200ms or more than one and a half interquartile ranges (1058ms) above the 75th percentile (1755ms) were excluded from analyses (upper limit = 3342ms; 7.0% of all trials) (Tukey, 1977).

It was also tested whether the factor version had an impact on relevant variables. This was not the case and therefore the factor was not included in reported analyses. Analyses as in the previous experiments were carried out. The means of all combinations of variables are presented in table 14 for reaction times and in table 15 for error rates.

Reaction times Significant switch costs were found, $F(1,21) = 122.53$, $p < .01$. Non-switch trials were 335ms faster than switch trials (see table 14). Interactions of switch costs with the two contrasts were not significant (all F 's < 1.2 , p 's $> .30$) (see figure 11).

The contrasts positive-neutral, $F(1,21) = 23.87$, $p < .01$ and negative-neutral, $F(1,21) = 5.94$, $p < .03$ reached significance. Reaction times were faster after positive (1090ms) and after negative cues (1129ms) compared to neutral ones (1197ms), respectively.

Error rates For error rates there were also significant switch costs, $F(1,21) = 6.11$, $p < .03$, with switch trials producing approximately 1.9% more errors than non-switch trials (see table 15). None of the two contrasts did interact significantly with switch costs (all F 's < 3.1 , p 's $> .09$).

The contrasts positive-neutral and negative-neutral did not reach significance (all F 's < 1).

Table 14: Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-0			
positive	1247	932	315 (155)
neutral	1370	1023	346 (156)
negative	1301	957	344 (188)
Total	1306	971	335 (142)

Table 15: Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-0			
positive	9.0	6.9	2.1 (4.3)
neutral	10.2	7.0	3.2 (5.6)
negative	9.6	9.1	0.5 (6.5)
Total	9.6	7.7	1.9 (3.6)

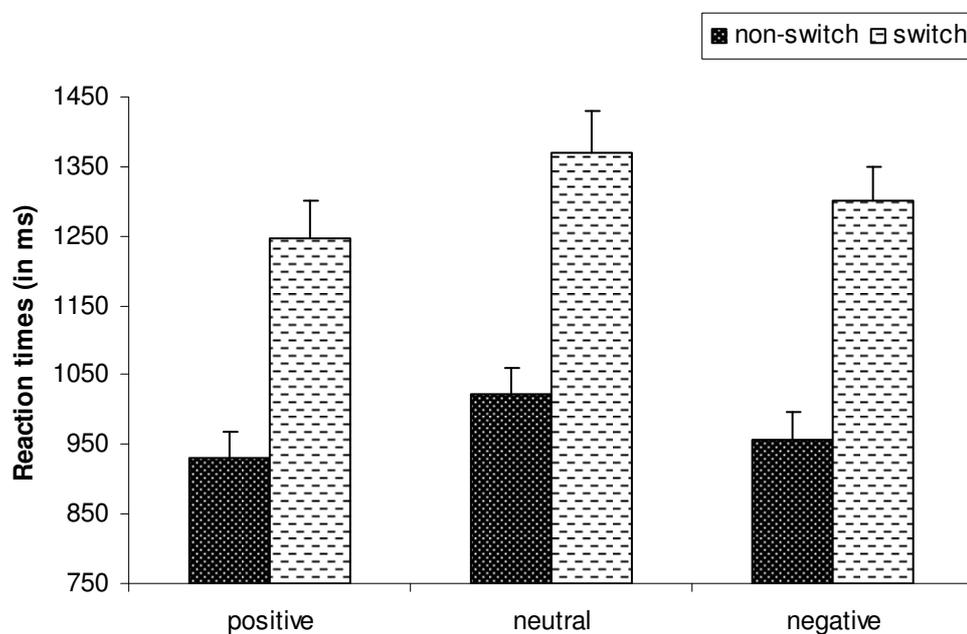


Figure 11: Reaction times (in milliseconds) for non-switch and switch trials after a positive, neutral, or negative picture at position lag-0, respectively. Error bars refer to standard errors.

Discussion

In the third experiment again no two-way interactions of backward inhibition with the two contrasts were found but for the first time a three-way interaction reached significance. Only the combination of certain lag-1 and lag-0 valences made a difference. Noticeable are the enormous differences between backward inhibition effects that produced that result. That is, 144ms for the combination negative-positive and -65ms for the combination neutral-positive. It is difficult to speculate about that finding because neither PSI theory nor the dopaminergic

theory made any predictions about such an interaction or a prediction about influences of negative affect at all. At first, a replication of this finding would be useful.

On a descriptive level the pattern of backward inhibition effects for affect at position lag-1 was different compared to experiments 1 and 2 especially for the contrast positive-neutral. With neutral cues a reversed backward inhibition effect was observed whereas after a positive cue a small normal effect can be described. Reduced reaction times for ABA sequences as well as increased latencies for CBA sequences with neutral compared to positive affect caused this difference.

Reinforced was the impression that for lag-0 valence a smaller backward inhibition effect for positive compared to neutral affect as predicted seems not to exist. Again the size of the backward inhibition effect decreased from positive to neutral to negative like in experiment 1. A trend about whether reaction times in ABA or CBA sequences caused the pattern cannot be described because the general reaction time level for the three different valences differed greatly (average reaction times for ABA and CBA sequences taken together - positive: 1254ms; neutral: 1395ms; negative: 1343ms).

Significant results with error rates were not found and a speed-accuracy trade-off for the found results based on reaction times cannot be assumed.

The switch costs analyses did not reveal any significant result neither for reaction times nor for error rates. The finding of the previous experiment (interaction of switch costs with the contrast negative-neutral for latencies) was not replicated. Quite the contrary, the switch costs for those two valences are nearly identical in this experiment (see table 14). The pattern for switch costs with positive and neutral affect was in accordance with the predictions. Switch costs with positive affect were smaller than with neutral affect. This was mainly due to a reduction of reaction times for switch trials with positive affect. This can be explained with facilitated access of formed intentions to executing systems according to PSI theory as well as with enhanced flexibility according to the dopaminergic theory. However, this interaction was not significant.

This time participants had to pay attention to the prime pictures because they served as the task cues. Although an interaction of valence and measures of executive control could not be observed a three-way interaction of backward inhibition, the contrast negative-neutral at position lag-1, and the contrast positive-neutral at position lag-0 was found. A replication of this interaction was aimed for with the next experiment. The high general error rate, the huge variance regarding reaction times as well as the generally high latencies and complaints from

participants concerning the difficulty of the tasks made it necessary to simplify the experiment before collecting more data. Participants reported that they did not mind the additional task which was a rare event. The high error rates as well as the high drop out rate show that the difficulty of the experiment was generally high so that participants might not have taken the additional task too serious. Thus, the additional task was omitted in the next experiment. Also only positive and neutral affect was used for two reasons: first of all that simplified the experiment further because only six cues have to be learnt and matched with the three tasks. Secondly, this valence combination seems still promising enough to produce a significant interaction even though the three-way interaction was obtained with involvement of negative affect. An interaction can still be expected because the pattern for negative valence at position lag-1 and positive versus neutral affect at position lag-0 is similar although less pronounced to that for a positive valence at position lag-1 and positive versus neutral affect at position lag-0 (see table 12).

3.2.4 Experiment 3.1: Valent cues 2

Method

Participants 36 students of the university in Jena (between 18 and 30 years old) executed sequences without direct task repetitions, only backward inhibition effects were calculated. Data to measure switch costs was not collected. Participants received 3 Euros for participating in the single-session experiment that lasted about 30 minutes. Showing merely correctness by chance two participants were excluded from further analyses.

Task and Stimuli Tasks and task stimuli were the same as in experiment 3. The valent cue pictures were partly changed because some pictures were not rated as expected in experiment 3. Also only positive and neutral cue pictures were used to simplify the experiment. An evaluative testing of the three positive and three neutral pictures used in the test blocks at the end of the experiment also included three negative pictures to give participants the opportunity to exploit the 9-point scale and to avoid a bias⁷. Again and also with the changed pictures the present sample underestimated positive pictures and overestimated neutral ones compared to the values from the IAPS (Lang et al., 2005) (see table 16).

⁷ The following pictures from the IAPS (Lang et al., 2005) were used: 2190, 5534, 7484, 2150, 1440, and 2340. The three additional negative ones were: 2900, 9340, and 2141.

Table 16: Means of valence and arousal for the three positive and the three neutral pictures used as task cues, as well as for the three additionally evaluated negative pictures. Listed are the values from the IAPS (Lang et al., 2005) and the present sample's evaluation.

	IAPS		Present sample	
	valence (range)	arousal (range)	valence (SD)	arousal (SD)
positive	8.1 (7.9 to 8.2)	4.8 (4.6 to 5.0)	7.4 (1.5)	5.4 (2.2)
neutral	4.9 (4.8 to 4.9)	3.3 (2.4 to 4.2)	5.2 (1.6)	3.9 (2.0)
negative	2.4 (2.4 to 2.5)	5.1 (5.0 to 5.2)	2.4 (1.6)	5.2 (2.5)

Trial Procedure The trial procedure was identical to experiment 3 with one difference: the additional task was no longer used to further simplify the experiment.

Procedure Only the version without direct task repetitions was carried out. Probabilities were the same as in the preceding experiments.

The method of introducing tasks and cues was the same as in experiment 3. Only the part with explaining and practicing the additional task was of course omitted.

The test phase consisted of twelve blocks with 38 trials each. The first two trials of a test block were drawn randomly from a special list. The remaining 36 trials were 12 line, colour, and form tasks, respectively. This block length allowed presenting each possible cue target combination (two cues per task and six targets) exactly once in a block. Again a summary about errors and average reaction time was presented at the end of each block.

The experiment ended with the evaluation of the six cue prime pictures plus the additional three negative pictures on the two nine-point-scales.

Results for backward inhibition effects

The remaining group of 34 participants showed an average error rate of 10.5% (SD = 12.5%) Data of three participants was not used in the further analyses because their error rates were higher than 35.5% (mean error rate plus two standard deviations). Erroneous responses (7.7% of all trials) and reaction times below 200ms or more than one and a half interquartile ranges (1052ms) above the 75th percentile (1747ms) were excluded from analyses (upper limit = 3325ms; 7.9% of all trials) (Tukey, 1977).

As in experiment 3 the factor version was tested, but no influence on relevant variables was found and the factor was not included in the reported analyses.

The identical analyses as in all previous experiments were carried out with the difference that the factor valence at both positions only had two levels, positive and neutral. Therefore no results can be reported for the contrast negative-neutral. Means of all variables and combinations of variables are presented in table 17 (reaction times) and table 18 (error rates).

Table 17: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the two valences at the two positions, respectively.

Variable		ABA	CBA	BI (SD)
Position lag-1	Position lag-0			
positive	positive	1174	1127	47 (143)
	neutral	1270	1195	76 (130)
neutral	positive	1190	1139	51 (138)
	neutral	1220	1172	48 (163)
Total		1214	1158	55 (79)

Table 18: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the two valences at the two positions, respectively.

Variable		ABA	CBA	BI (SD)
Position lag-1	Position lag-0			
positive	positive	7.2	8.5	-1.3 (5.4)
	neutral	8.6	6.5	2.1 (4.1)
neutral	positive	8.2	7.4	0.7 (4.5)
	neutral	8.2	7.3	0.8 (3.5)
Total		8.0	7.5	0.6 (2.0)

Reaction times A significant backward inhibition effect of 55ms was found, $F(1,30) = 15.45$, $p < .01$ (see table 17). An interaction of backward inhibition with the contrast positive-neutral at any position did not emerge (all F 's < 1) (see figure 12). Also the three-way interaction of backward inhibition with the contrast at both positions did not reach significance ($F < 1$).

The contrast positive-neutral at position lag-0 was significant, $F(1,30) = 7.84$, $p < .01$. Reaction times were faster after a positive cue (1158ms) at position lag-0 compared to a neutral one (1214ms). The contrast at position lag-1 and the interaction between the contrasts were not significant (all F 's < 3.2 , p 's $> .08$).

Error rates There was no significant backward inhibition effect for error rates ($F < 2.9$, $p > .10$) (see table 18). No interactions of backward inhibition with the contrast positive-neutral at positions lag-1 and lag-0 were found (all F 's < 3.5 , p 's $> .07$) but the three-way interaction reached significance, $F(1,30) = 5.06$, $p < .04$. The difference between a positive (0.7%) and a neutral cue (0.8%) at position lag-0 after a neutral one at position lag-1 is not very big but for a positive cue at position lag-1 positive and neutral cues at position lag-0 differed greatly. There is a reversed backward inhibition effect of -1.3% after a positive cue and a normal one of 2.1% after a neutral cue (see table 18).

The two contrasts and the interaction between them were not significant (all F 's < 1).

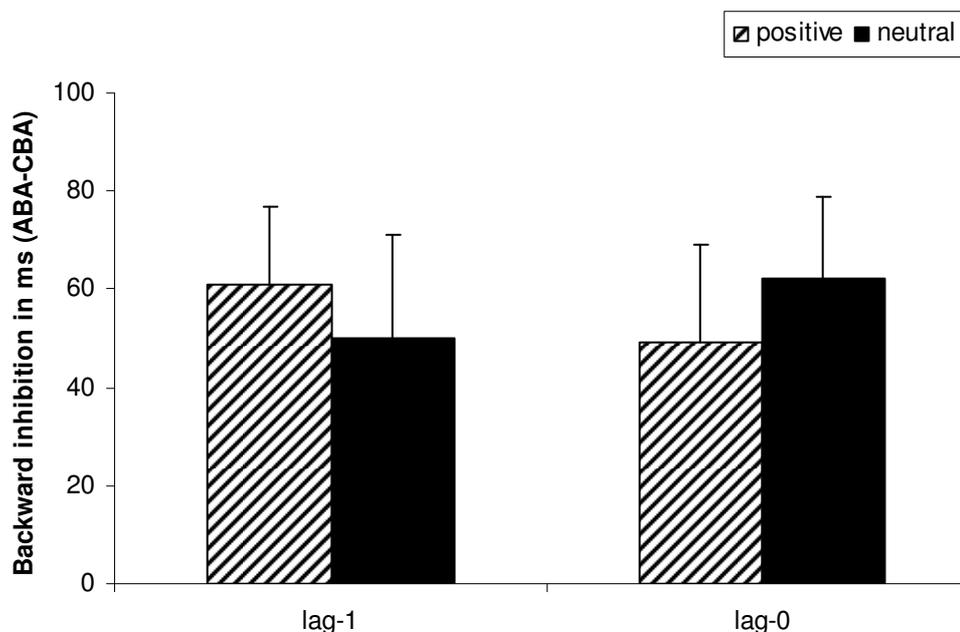


Figure 12: Backward inhibition effects for reaction times (in milliseconds) with positive and neutral valence at positions lag-1 and lag-0, respectively. Error bars refer to standard errors.

Discussion

Simplifying the experiment clearly helped to reduce response errors and drop out rates. But reaction times were still quite high and the cut-off limit for reaction times remained above 3000 milliseconds.

Again no interactions of backward inhibition effects with the contrast (in this experiment only positive-neutral) were found and also the three-way interaction of the preceding experiment was not replicated. The descriptive pattern for lag-1 affect was like in experiment 3 and contrary to the predictions of the dopaminergic theory. The backward inhibition effect after positive affect was larger compared to after neutral affect. This was mainly due to increased reaction times for ABA sequences after positive affect (1222ms) compared to neutral affect (1205ms). The prediction from PSI theory for lag-0 backward inhibition effects was correct at least on a descriptive level. The effect was smaller after a positive cue. A reduction of reaction times for ABA sequences after positive affect seems to be the main cause for this pattern (positive: 1182ms; neutral: 1245ms). This was predicted by PSI theory because the positive affect is assumed to help overcoming once formed inhibition which accelerates reaction times for ABA sequences.

For error rates the interaction of backward inhibition, valence at position lag-1 and valence at position lag-0 was significant. Considering the significant three-way interaction for reaction times from experiment 3 it would have been expected to find an average backward inhibition effect for the lag-1–lag-0 combinations positive-neutral and neutral-neutral, a larger effect for positive-positive and a clearly reversed effect for the combination neutral-positive. This expectation was not met. The interaction was mainly due to the large difference between positive and neutral affect at position lag-0 after a positive cue at position lag-1 (positive-positive: -1.3%; positive-neutral: 2.1%) (see table 18).

A speed-accuracy trade-off for the observed effects cannot be assumed.

So far influences of affect on switch costs and backward inhibition effects are rare. A problem might be the method of affective manipulation. Although it was discussed already earlier that picture stimuli can elicit an affective modulation (see for example Bradley et al., 1999; Lang et al., 1997) it can still be doubted whether pictures as they were used in the previous experiments trigger affective states in a way that allows them to have an impact on executive functions. Thus, feedback is now used as affective element. It is supposed to be a stronger affective element because it is relevant for example with regard to goals. Feedback is going to be presented in every trial after the response. To allow a differentiation after correct responses into positive, neutral and negative feedback response speed was used as criterion. Fast

responses guaranteed positive and slow responses lead to negative feedback. No general limits were used but subject based ones that always used the preceding six reaction times to compute individual limits for the current trial. As a side effect of that procedure it is also expected that reaction times are accelerated and variance will be reduced. Taken together, this might increase chances to find a modulating effect of affective stimulation on executive functions.

3.2.5 Experiment 4: Valent feedback

Method

Participants In this experiment 60 students of the Friedrich-Schiller-University in Jena, aged between 18 and 38 years participated. The experiment lasted about 30 minutes and participants received at least 2.50 Euros. They could earn 25 Cents of extra money for every block with a positive end result. With eight test blocks participants could earn maximum extra money of 2 Euros and therefore maximum payment of 4.50 Euros was possible.

One participant had to be excluded because the experiment was started a second time for her after the first program start crashed after some time. Five participants showed merely correctness by chance and were also excluded.

Task and stimuli The actual task was the same as in experiments 1 and 2: squares and circles (task form) in blue and in green (task colour) drawn with a thin or a thick line (task line). Cues to the tasks were the letters F (colour), G (form) and L (line). This time the valent element was included in the paradigm in terms of different feedback. After every task feedback was shown depending on correctness and response speed. Three different kinds of feedback were possible after a correct trial depending on response speed. An expected side effect of this procedure was a speeding up of reaction times and a reduction of variance. After a wrong response a red grumpy (see figure 13) and the text “Falsche Antwort” (“Wrong answer!”) were shown. If the answer was correct three different feedbacks were possible depending on reaction times. The current reaction time was always compared with the six previous reaction times of only correct responses. When the current reaction time was slower than the mean of the second and third slowest reaction time out of the six reaction times then the grumpy face (see figure 13) and the following text were shown: “Zu langsam!” (“Too slow!”). When the current time was faster than the mean of the second and third fastest reaction time (out of the six reaction times) then a smiling face (see figure 13) and the words

“Sehr schön!” (“Very nice!”) were presented. Was the current time in between those two means then the neutral face (see figure 13) without any text was shown.



Figure 13: Examples of feedback faces that were used in experiments 4, 5, 6.1, and 6.2.

Trial Procedure A trial started with the cue presented for 500ms in the middle of the screen. Straight afterwards the target was shown until a response button was pressed. Depending on correctness and response speed feedback was shown for 1000ms which was followed directly by a blank screen for 200ms before the next cue was presented (see figure 14).

Procedure As usual two different versions were used one with the other without direct task repetitions.

The experiment started with written instructions on the screen. It was emphasised that participants could earn some extra money if they were responding correctly and fast enough. First, two practice blocks with twelve trials each were presented without feedback to allow familiarisation with the tasks. Afterwards participants had to complete eight test blocks with 56 trials each. In every block the received positive, negative and neutral feedback were counted. Positive feedback added 10 points to the block score, negative feedback subtracted 10 points, with neutral feedback nothing happened. At the end of each test block the block score was presented as well as the error rate and average reaction time. Only with a positive block score 25 Cents could be earned additionally.

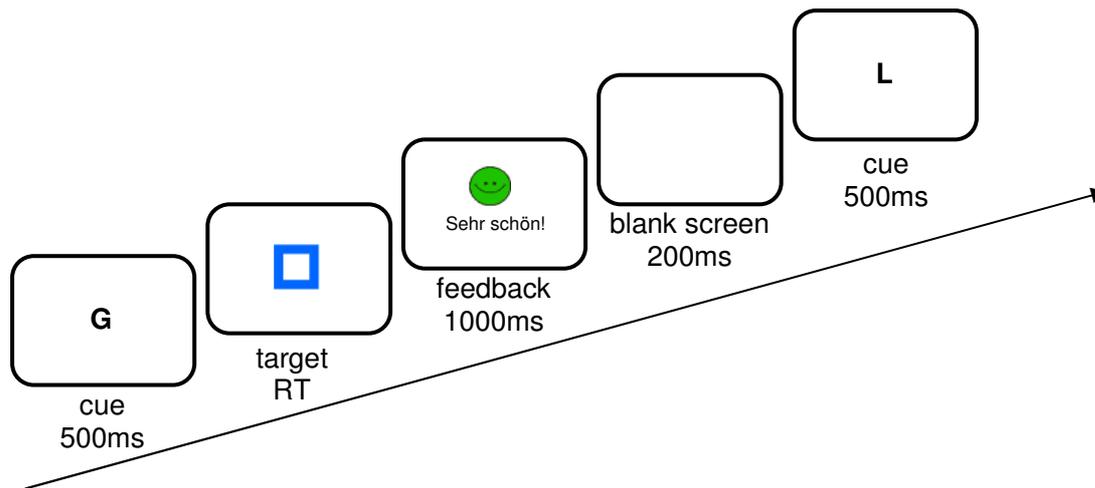


Figure 14: Trial procedure in experiment 4.

Results of backward inhibition effects

The error rate in the group with 28 participants was quite high, 18.2% (SD = 10.7%). Two participants were excluded from further analyses due to higher error rates than 39.6% (mean error rate plus two standard deviations). Afterwards the error rate was 16.4%. Those trials and reaction times below 180ms or more than three interquartile ranges (327ms) above the 75th percentile (702ms) were also excluded (upper limit = 1683ms; 5.0% of all trials) (Tukey, 1977).

The same analyses were carried out as in the experiments before with two adjustments concerning the relevant valence positions. In the previous experiments only valent elements preceding a trial were used. Thus lag-0 valence related to the valence shown before the last trial in a triplet, lag-1 to the valence before the second trial. In the current experiment valent feedback was used which is presented after the response in every trial (see figure 2). The corresponding and reported valence positions to lag-0 and lag-1 from the previous experiments are lag-1 (valent element before the last trial) and lag-2 (valent element before the trial in the middle of a triplet).

The means of all combinations of variables are presented in tables 19 (reaction times) and 20 (error rates).

Reaction times There was no overall backward inhibition effect ($F < 1$) (see table 19). The interaction of backward inhibition with the contrast positive-neutral at position lag-2 was significant, $F(1,25) = 7.43$, $p < .02$. At position lag-2 positive feedback produced a reversed backward inhibition effect (-47ms) compared to neutral feedback that showed a normal effect

(6ms) (see figure 15). The other interactions of backward inhibition with the remaining three contrasts were not significant (all F 's < 2.9 , p 's $> .10$). The three-way interaction of backward inhibition with the contrast positive-neutral at positions lag-2 and lag-1 was also significant, $F(1,25) = 4.37$, $p < .05$. After positive feedback at position lag-2 positive feedback at position lag-1 caused a reversed backward inhibition effect of -33ms whereas neutral feedback at the same position produced an effect of -69ms. For neutral feedback at position lag-2 this pattern is reversed. After lag-1 positive feedback the backward inhibition effect is -9ms and after neutral feedback a normal backward inhibition effect of 27ms can be measured (see table 19). The other three-way interactions did not reach significance (all F 's < 3.7 , p 's $> .06$).

The contrast positive-neutral at position lag-2 was significant, $F(1,25) = 5.12$, $p < .04$, as well as the same contrast at position lag-1, $F(1,25) = 8.73$, $p < .01$. At position lag-2 reaction times are faster after positive feedback (553ms) compared to neutral feedback (571ms). Reaction times at position lag-1 are faster after neutral feedback (550ms) compared to positive feedback (583ms). The contrasts negative-neutral at both positions did not reach significance (all F 's < 1.2 , p 's $> .28$). The interaction of the contrasts negative-neutral at position lag-2 and positive-neutral at position lag-1 was also significant, $F(1,25) = 4.26$, $p < .05$. There is hardly a difference between reaction times for positive (572ms) and neutral (565ms) feedback at position lag-1 after negative feedback at position lag-2, but for neutral feedback at position lag-2 this small difference increases (lag-1 positive: 601ms; lag-1 neutral: 555ms). All other interactions between contrasts were not significant (all F 's < 1).

Error rates No significant backward inhibition effect was found for error rates ($F < 1$) (see table 20). The interaction of backward inhibition and the contrast negative-neutral at position lag-2 reached significance, $F(1,25) = 15.27$, $p < .01$. After neutral feedback at position lag-2 a reversed backward inhibition effect of -2.8% was found compared to negative feedback at the same position with a normal effect of 4.1% (see figure 16). All other interactions of backward inhibition with the contrasts were not significant (all F 's < 1.4 , p 's $> .26$). Also none of the three-way interactions reached significance (all F 's < 2.4 , p 's $> .14$).

None of the contrasts or of the interactions between contrasts were significant (all F 's < 2.7 , p 's $> .11$).

Table 19: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.

Variable					
Position lag-2	Position lag-1	ABA	CBA	BI	(SD)
positive	positive	561	594	-33	(90)
	neutral	497	567	-69	(80)
	negative	530	568	-38	(150)
neutral	positive	597	605	-9	(65)
	neutral	568	541	27	(96)
	negative	555	557	-1	(105)
negative	positive	579	564	15	(71)
	neutral	578	551	27	(106)
	negative	579	525	54	(124)
Total		561	564	-3	(26)

Table 20: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the three valences at the two positions, respectively.

Variable					
Position lag-2	Position lag-1	ABA	CBA	BI	(SD)
positive	positive	17.2	17.1	0.2	(13.0)
	neutral	14.8	15.6	-0.8	(14.6)
	negative	14.4	15.3	-0.9	(8.1)
neutral	positive	18.3	17.2	1.1	(12.5)
	neutral	15.5	19.0	-3.5	(14.1)
	negative	13.4	19.4	-6.0	(8.5)
negative	positive	19.0	15.5	3.5	(8.7)
	neutral	17.2	12.0	5.2	(10.4)
	negative	19.4	15.6	3.8	(6.6)
Total		16.6	16.3	0.3	(3.7)

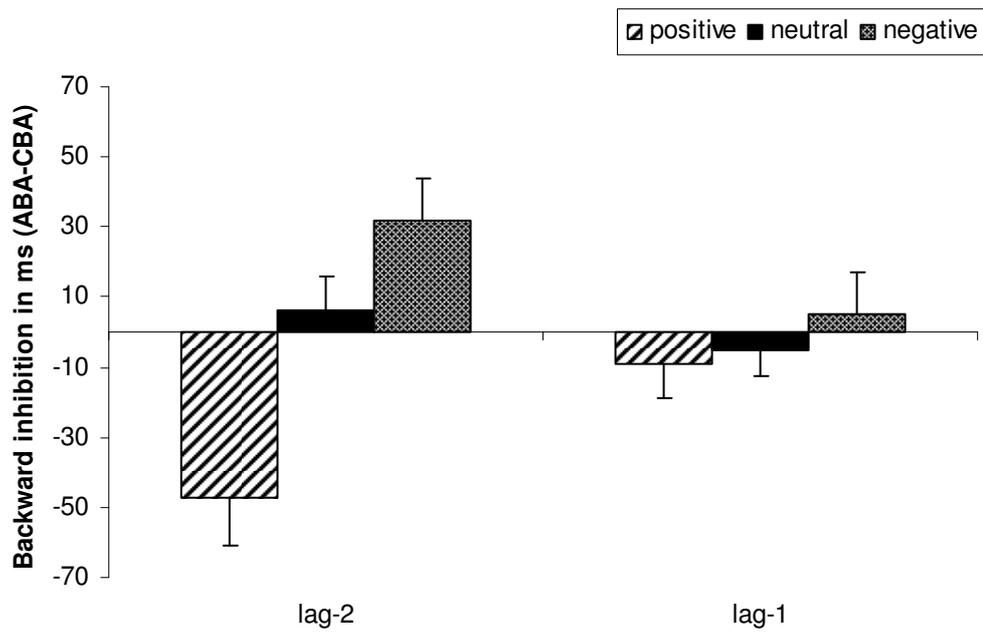


Figure 15: Backward inhibition effects for reaction times (in milliseconds) with positive, neutral, and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.

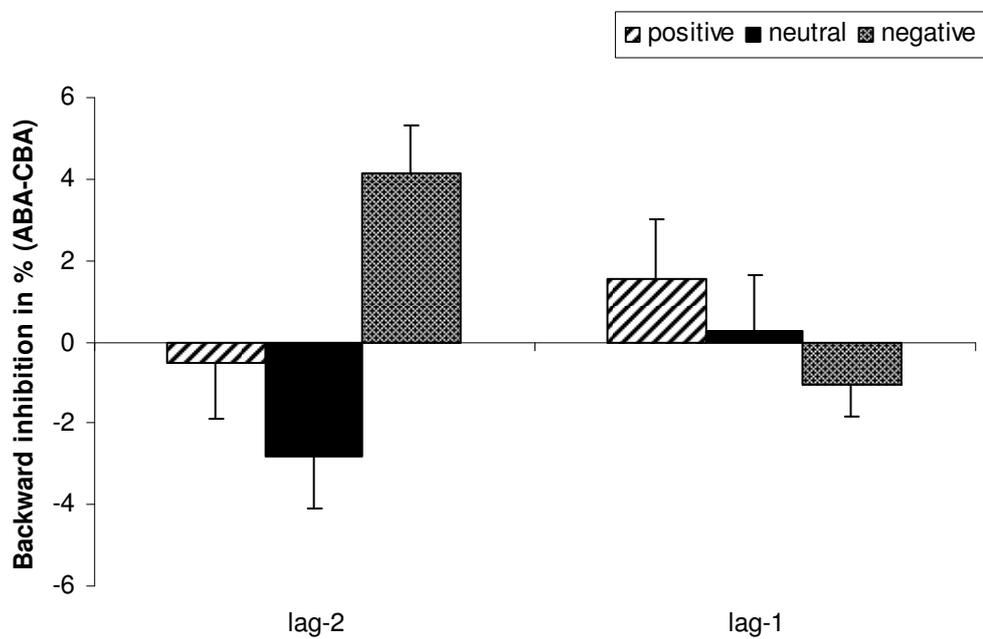


Figure 16: Backward inhibition effects for error rates (in percent) with positive, neutral, and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.

Results for switch costs

The average error rate of the switch cost group (26 participants) was 20.8% (SD = 10.7%). One participant with an error rate higher than 42.3% (mean error rate plus two standard deviations) was excluded from all further analyses. Erroneous responses (19.9% of all trials) and reaction times below 180ms or more than three interquartile ranges (252ms) above the 75th percentile (601ms) were excluded from analyses (upper limit = 1357ms; 8.7% of all trials) (Tukey, 1977).

The same analyses were carried out as in previous experiments with one minor adjustment concerning the relevant valence position. So far the reported position lag-0 referred to the valence shown between a task pair. For the current experiment valent feedback was used which means that now position lag-1 is related to the valence that is shown between a pair of tasks (see figure 2). The corresponding and reported valence position to lag-0 from the previous experiments is lag-1 in the current one.

In tables 21 (reaction times) and 22 (error rates) means of all combinations of variables are presented.

Reaction times Significant switch costs were found, $F(1,24) = 19.49$, $p < .01$. Non-switch trials were 64ms faster than switch trials (see table 21). An interaction of switch costs with one of the two contrasts was not found (all F 's < 4.3 , p 's $> .05$) (see figure 17).

The two contrasts were also not significant (all F 's < 2.1 , p 's $> .16$).

Error rates Also for error rates significant switch costs of 7.5% were found, $F(1,24) = 32.62$, $p < .01$ (see table 22). The interaction of switch costs with the contrast positive-neutral reached significance, $F(1,24) = 8.21$, $p < .01$. Switch costs were larger after positive feedback (11.6%) than after neutral feedback (6.9%) (see figure 18). The other interaction with the contrast negative-neutral was not significant ($F < 2.6$, $p > .12$).

The contrast negative-neutral was significant, $F(1,24) = 7.47$, $p < .02$, with higher error rates after negative (19.5%) compared to neutral feedback (17.0%). The other contrast was not significant ($F < 1.2$, $p > .30$).

Table 21: Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-1			
positive	512	427	85 (86)
neutral	511	443	69 (62)
negative	507	468	39 (96)
Total	510	446	64 (73)

Table 22: Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for all three valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-1			
positive	24.0	12.3	11.6 (9.8)
neutral	20.4	13.5	6.9 (7.9)
negative	21.5	17.4	4.0 (7.8)
Total	21.9	14.4	7.5 (6.6)

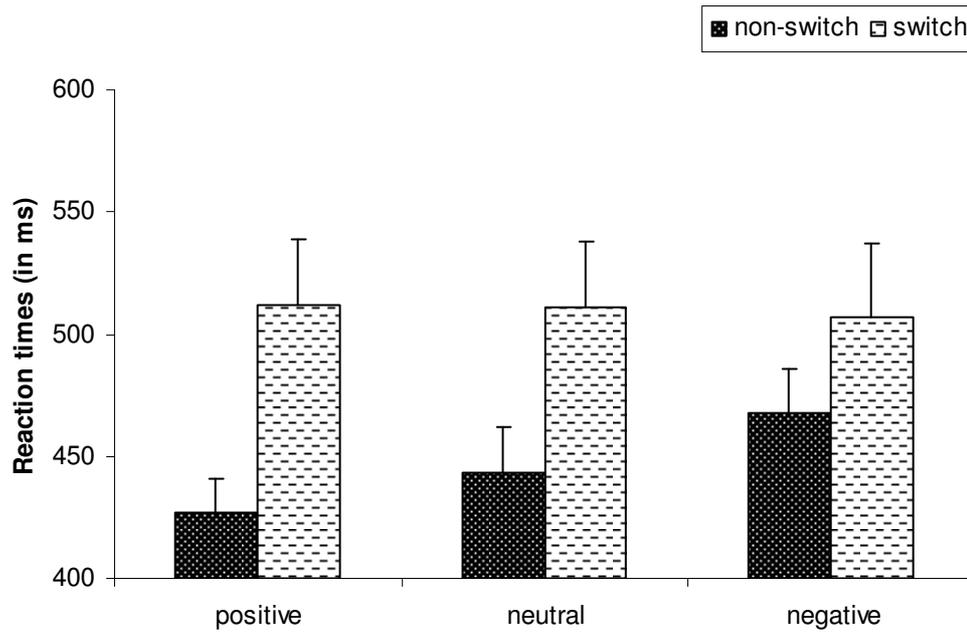


Figure 17: Reaction times (in milliseconds) for non-switch and switch trials after positive, neutral, or negative feedback at position lag-1, respectively. Error bars refer to standard errors.

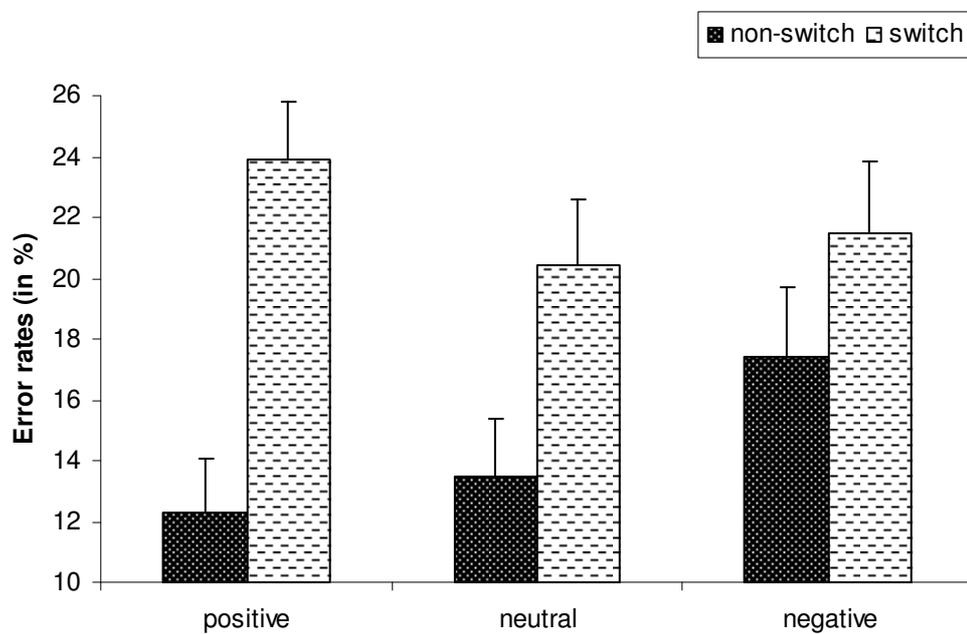


Figure 18: Error rates (in percent) for non-switch and switch trials after positive, neutral, or negative feedback at position lag-1, respectively. Error bars refer to standard errors.

Discussion

This paradigm with performance-related feedback produced high error rates compared to the preceding experiments. However, feedback also allowed considerably accelerated reaction times with the cut-off limit below 1700ms in backward inhibition analyses and below 1400ms in switch costs analyses.

The experiment revealed some interesting results and gives the impression that with feedback relevant influences of affect on measures of executive functions can be achieved. However, it has to be noted that the experiment disclosed confounding variables (Rothermund, 2003). Feedback is not only carrying valence information but it is also connected with the performance in the preceding trial. Therefore the influence on backward inhibition effects and switch costs might not originate in the valence information included in feedback but be an artefact connected with the delivered performance. Hence, before interpreting the found effects it is necessary to separate valence and performance or at least to examine the influence of valence without the underlying performance variable in a further experiment. To make that possible the next experiment did not include neutral feedback anymore. Instead of neutral feedback also positive and negative feedback was given by chance. That allowed analysing influences of real feedback that is performance-related and of random feedback that is based on average performances but still provides feedback containing valent information. If effects reported in the current experiment are affect-related then interactions of backward inhibition effects and switch costs with valence should be observed in analyses with random feedback. Are the effects only recovered with real feedback then influences are highly performance-related.

3.2.6 Experiment 5: Valent feedback 2

Method

Participants 60 students of the Friedrich-Schiller-University in Jena, aged between 18 and 31 years participated. Duration of the experiment was approximately 30 minutes and participants again received at least 2.50 Euros plus 25 Cents of extra money for every block with a positive end result. Eight test blocks allowed maximum extra money of 2 Euros and therefore maximum payment of 4.50 Euros was possible.

Two participants showed merely correctness by chance and were excluded from further analyses.

Task and stimuli Task and stimuli were exactly the same as in experiment 4. Again feedback depended on the comparison of a current reaction time with the six preceding times. To be able to generate performance independent feedback neutral feedback was dispensed. Instead of showing neutral feedback negative or positive feedback was presented by chance. Hence, it was possible to analyse real feedback depending on performance and random feedback with no strong connection to a previous performance. To increase the probability of occurrence for random feedback upper and lower limits to categorise reaction times were slightly changed. The second slowest (formerly the mean of the second and third slowest reaction time) and the second fastest (formerly the mean of the second and third fastest reaction time) reaction times were the new lower and upper limits.

Trial Procedure The trial procedure was identical to that in experiment 4.

Procedure All details and conditions were like in experiment 4.

Results for backward inhibition effects

The 29 participants of the backward inhibition group had an average error rate of 22.4% (SD = 10.4%). Two participants were excluded from further analyses due to higher error rates than 43.2% (mean error rate plus two standard deviations). Erroneous responses (20.9% of all trials) and reaction times below 180ms or more than three interquartile ranges (280ms) above the 75th percentile (643ms) were excluded from analyses (upper limit = 1483ms; 7.0% of all trials) (Tukey, 1977).

Analyses were separated for real and for random feedback. Of the factor valence only two levels, positive and negative remained. Hence, the contrasts positive-neutral and negative-neutral could not be analysed anymore. Apart from that, analyses for random feedback were carried out as in experiment 4. For real feedback separate analyses had to be carried out for valence positions lag-2 and lag-1 because of missing data in certain conditions in case of combined analyses. Split analyses for random and real feedback and the generally high error rate caused data loss in several combinations of variables.

The means of all variable combinations for reaction times concerning random feedback are presented in table 23 and concerning real feedback in table 24. Means of error rates for random feedback are presented in table 25 and for real feedback in table 26.

Reaction times Random feedback No significant backward inhibition effect was found ($F < 1$) (see table 23). Interactions of backward inhibition with valence positions lag-2 or lag-1 did not reach significance (all F 's < 1) (see figure 19, left side). Also the three-way interaction was not significant ($F < 1$).

Positive and negative feedback at position lag-1 differed significantly, $F(1,26) = 7.39, p < .02$. Reaction times were faster after negative feedback (504ms) compared to positive feedback (518ms). An interaction between valences at positions lag-2 and lag-1 was not found ($F < 1.9, p > .18$).

Real feedback For analyses with lag-2 valence a significant reversed backward inhibition effect of -28ms was found, $F(1,26) = 5.50, p < .03$ (see table 24). Also the interaction of backward inhibition and lag-2 valence reached significance, $F(1,26) = 14.68, p < .01$ (see figure 19, right side and table 24). After positive feedback at position lag-2 a reversed backward inhibition effect of -73ms was found. After negative feedback a normal effect of 17ms was observed. A significant difference between reaction times after positive (497ms) and negative (518ms) feedback at position lag-2 was observed, $F(1,26) = 4.53, p < .05$.

For analyses with lag-1 valence no significant results were found (all F 's < 1) (see table 24).

Error rates Random feedback A significant reversed backward inhibition effect was found, $F(1,26) = 4.29, p < .05$ (see table 25). CBA sequences produced 3.1% more errors than ABA sequences. All other factors and interactions were not significant (all F 's $< 3.4, p$'s $> .07$) (see figure 20, left side).

Real feedback For lag-2 valence no significant backward inhibition effect or a main effect for lag-2 valence were found (all F 's $< 2.7, p$'s $> .11$), but the interaction of backward inhibition and lag-2 valence reached significance, $F(1,26) = 6.93, p < .02$ (see figure 20, right side and table 26). The backward inhibition effect was reversed after positive feedback at position lag-2 (-6.4%) whereas it was normal after negative feedback (2.0%).

For analyses with lag-1 valence no significant results were found (all F 's $< 4.1, p$'s $> .05$) (see table 26).

Table 23: Random feedback - Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the two valences at the two positions, respectively.

Variable					
Position lag-2	Position lag-1	ABA	CBA	BI	(SD)
positive	positive	504	511	-7	(102)
	negative	500	513	-13	(80)
negative	positive	525	533	-8	(97)
	negative	503	498	5	(89)
Total		508	514	-6	(47)

Table 24: Real feedback - Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.

Variable	Position lag-2			Position lag-1		
	ABA	CBA	BI (SD)	ABA	CBA	BI (SD)
positive	461	533	-73 (89)	513	514	-2 (45)
negative	526	510	17 (84)	510	515	-5 (93)
Total	494	522	-28 (62)	515	511	-3 (58)

Table 25: Random feedback - Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for all combinations of the two valences at the two positions, respectively.

Variable					
Position lag-2	Position lag-1	ABA	CBA	BI	(SD)
positive	positive	20.3	25.2	-5.0	(19.6)
	negative	18.4	24.6	-6.3	(16.5)
negative	positive	21.1	23.2	-2.1	(12.7)
	negative	22.2	21.4	0.8	(14.3)
Total		20.5	23.6	-3.1	(7.8)

Table 26: Real feedback - Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.

Variable	Position lag-2				Position lag-1			
	ABA	CBA	BI	(SD)	ABA	CBA	BI	(SD)
positive	16.6	23.1	-6.4	(11.3)	21.0	23.5	-2.5	(11.1)
negative	22.5	20.5	2.0	(10.6)	20.9	17.6	3.3	(8.9)
Total	19.5	21.8	-2.2	(7.2)	21.0	20.6	0.4	(6.7)

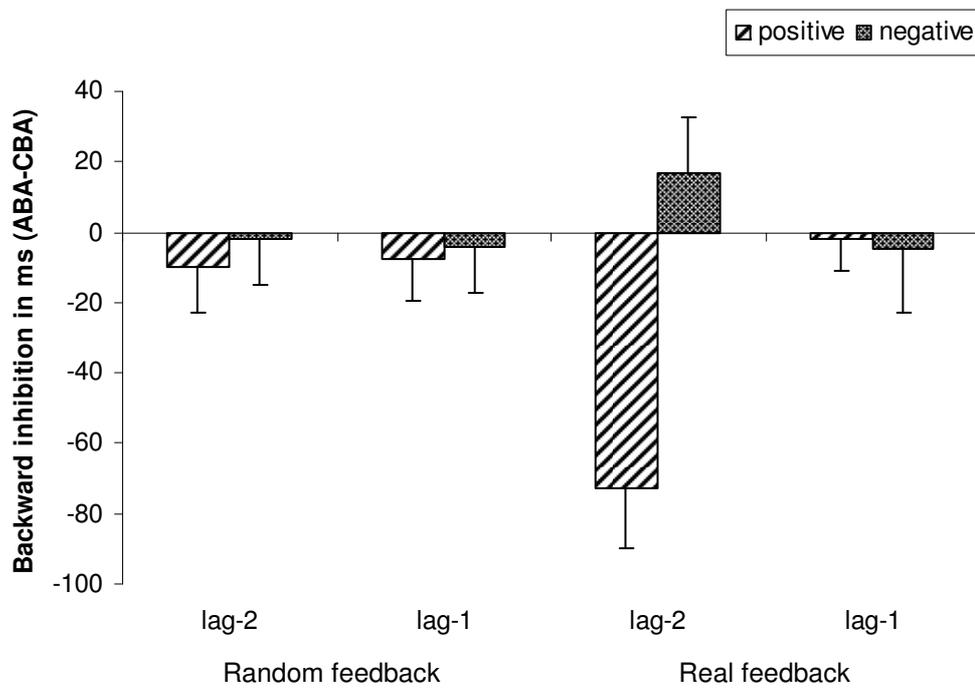


Figure 19: Random and real feedback - Backward inhibition effects for reaction times (in milliseconds) with positive and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.

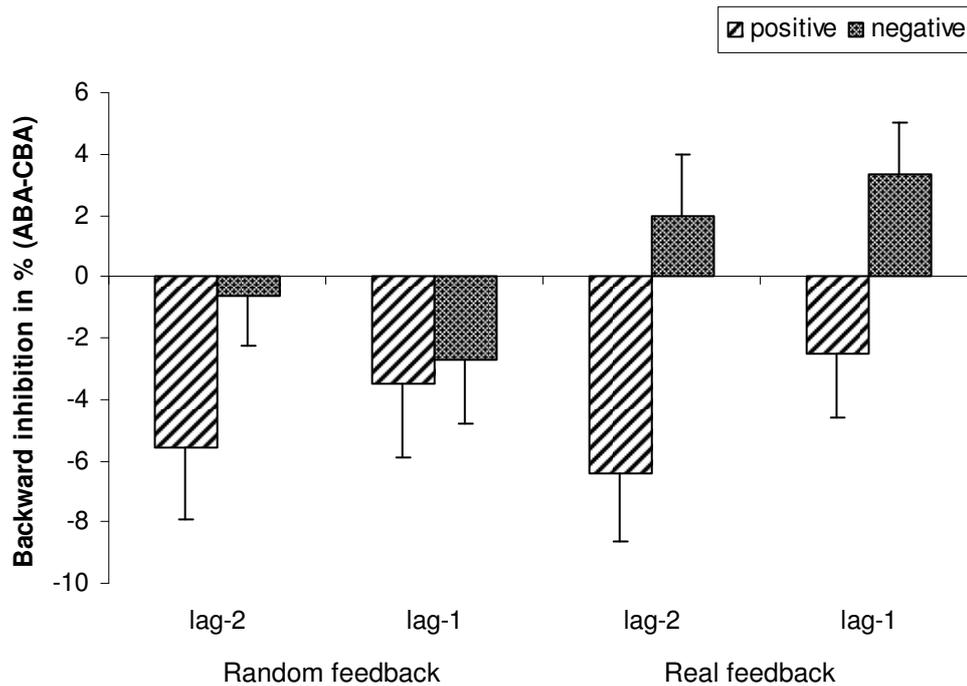


Figure 20: Random and real feedback - Backward inhibition effects for error rates (in percent) with positive and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.

Results for switch costs

The switch cost group with 29 participants showed an average error rate of 18.1% (SD = 10.9%). Erroneous responses and reaction times faster than 180ms or more than three interquartile ranges (263ms) above the 75th percentile (609ms) were excluded from analyses (upper limit = 1398ms; 5.8% of all trials) (Tukey, 1977).

Analyses were separated for real and random feedback. Means of all combinations of variables are presented in table 27 (random feedback) and table 28 (real feedback) for reaction times and in table 29 (random feedback) and 30 (real feedback) for error rates.

Reaction times Random feedback Significant switch costs were found, $F(1,28) = 35.33$, $p < .01$, with task repetitions 75ms faster than task switches (see table 27). The interaction of switch costs with valence and the main effect of valence did not reach significance (all F 's < 1) (see figure 21, left side).

Real feedback Also significant switch costs were found, $F(1,28) = 26.02$, $p < .01$ (see table 28). Switch trials were 73ms slower than non-switch trials. An interaction of switch costs with valence was not found ($F < 1$) (see figure 21, right side), but the factor valence reached

significance, $F(1,28) = 16.58$, $p < .01$. Reaction times were slower after negative feedback (494ms) compared to after positive feedback (466ms).

Error rates Random feedback Significant switch costs of 8.6% were found, $F(1,28) = 33.97$, $p < .01$ (see table 29). Also the valence factor was significant, $F(1,28) = 5.36$, $p < .03$, with more errors after negative feedback (18.0%) compared to positive feedback (14.8%). The interaction of switch costs with valence was not significant ($F < 1.1$, $p > .32$) (see table 29).

Real feedback Also for real feedback significant switch costs were found, $F(1,28) = 38.01$, $p < .01$. 9.0% more errors were made after switch trials compared to non-switch trials (see table 30). No further significant results were observed (all F 's < 2.9 , p 's $> .10$).

Table 27: Random feedback - Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-1			
positive	516	439	77 (70)
negative	514	440	74 (76)
Total	515	440	75 (68)

Table 28: Real feedback - Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-1			
positive	502	430	72 (89)
negative	532	457	75 (83)
Total	517	443	73 (78)

Table 29: Random feedback - Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-1			
positive	19.5	10.0	9.5 (10.7)
negative	21.8	14.2	7.6 (7.8)
Total	20.7	12.1	8.6 (7.9)

Table 30: Real feedback - Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-1			
positive	21.1	12.1	9.0 (11.7)
negative	18.8	9.9	8.8 (11.1)
Total	19.9	11.0	8.9 (7.8)

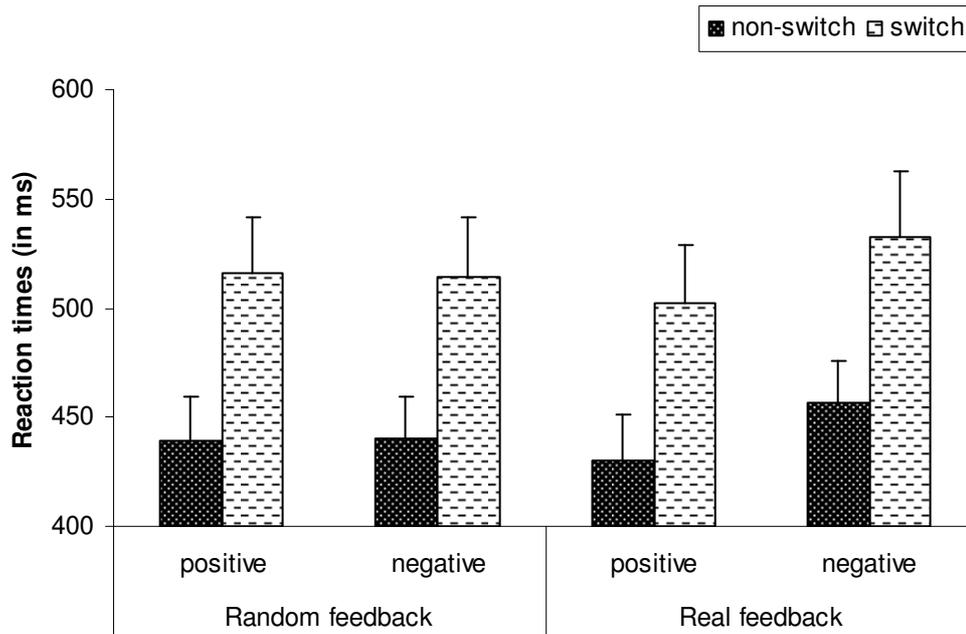


Figure 21: Random and real feedback - Reaction times (in milliseconds) for non-switch and switch trials after positive or negative feedback at position lag-1, respectively. Error bars refer to standard errors.

Discussion

For a real affective modulation of backward inhibition effects an interaction should have been found for random feedback but no significant results were observed. Backward inhibition effects for lag-2 and lag-1 valence were very small (see figure 19, left side). These hardly existent differences did also not allow comparing the found pattern to predictions from the PSI and the dopaminergic theory. However, some of the effects found in experiment 4 were rediscovered in the current experiment with real feedback. In experiment 4 a significant interaction of backward inhibition effects with the contrast positive-neutral at position lag-2 was found. The total pattern in experiment 4 showed a reversed backward inhibition effect for positive feedback, a slightly normal one for neutral and a clearly normal one for negative feedback (see figure 15). In the current experiment the interaction of backward inhibition with valence at position lag-2 for real feedback reached significance. The corresponding pattern was even more extreme than in experiment 4. A huge reversed backward inhibition effect is observed after positive feedback and a clearly normal effect after negative feedback. This interaction might have a simple origin because it is found with real feedback. It could depend completely upon the performance because feedback is connected with the performance. The rationale is as follows: positive feedback also indicates that the participant produced a fast

reaction time. Participants did a good job on the trial, their performance was correct and fast. Therefore the task in that trial, the corresponding task set, and everything else connected with that task can be stored as an episode with the label “well done”. The task is rounded off more completely as other tasks. Is the task repeated indirectly like in ABA sequences it can be executed faster because accessibility is improved. If the first trial in an ABA sequence produced a slow reaction time feedback is negative. The episode cannot get rounded off as nicely and completely as with positive feedback because the performance was bad. Thus, when it is repeated indirectly its execution is slowed down. Reaction times for ABA-positive and ABA-negative sequences at position lag-2 show exactly the described pattern with 461ms and 526ms, respectively. However, performance also had an impact on CBA sequences. CBA-positive sequences had an average reaction time of 533ms and CBA-negative sequences of 510ms. If the same task as in the beginning does not have to be executed again in the end of a triplet performance of the first task leads to different implications. In case of a CBA sequence (which does not include an indirect task repetition) and positive feedback at position lag-2 a disadvantage or a disturbance is produced that leads to higher reaction times. On the contrary when the lag-2 task ends with negative feedback and there is no need to repeat the recently executed task at position lag-0 this seems to be a kind of relief and reduces reaction times for those CBA sequences.

With this total result pattern it can be suspected that for backward inhibition effects only real feedback at position lag-2 has an impact. This was confirmed with a further analysis that included the factors backward inhibition effect, lag-2 real and random feedback. The three-way interaction reached significance, $F(1,26) = 6.67, p < .02$.

Considering error rate analyses for random feedback the significant reversed backward inhibition effect is a striking result. Already reaction time analyses showed on a descriptive level that all backward inhibition effects for random feedback were reversed (see figure 19, left side). And the reversed backward inhibition effects were more pronounced with positive feedback for both positions (lag-2 and lag-1). This applied for error rates and for reaction times (see figures 19 and 18, left side, respectively). It seems as if positive random feedback at least helps to avoid errors (and also to respond more quickly) in difficult sequences (like ABA) compared to negative feedback. Besides that, like for latencies also for error rates the effects of experiment 4 could not be replicated with random feedback but with real feedback. The significant interaction of the backward inhibition effect and the contrast negative-neutral at position lag-2 in experiment 4 was partly rediscovered in experiment 5. The pattern in experiment 4 showed a reversed backward inhibition effect after positive and neutral feedback

compared to a normal effect after negative feedback (see figure 16, left side). In experiment 5 a clearly reversed backward inhibition effect after real positive feedback is contradicted with a normal one after real negative feedback (see figure 20, right side). This effect corresponds to the effect with latencies and therefore a speed-accuracy trade-off regarding this effect is unlikely. The explanation given for the effect with latencies of course also applies for error rates.

Analyses for switch costs did not show any interesting results, neither for reaction times nor for error rates. Switch costs for real and random feedback regarding latencies were very similar (see tables 27 and 28). Also the effect from experiment 4 (significant smaller error rates after neutral compared to positive feedback) regarding error rates could not be replicated. Nonetheless, it can be noted that the error rates for real and for random feedback showed a small trend: smaller switch costs after negative compared to positive feedback (see tables 29 and 30).

To sum up experiments 4 and 5, the found effects in experiment 4 are mainly caused by performance-related factors. The non-existent interactions of valence with the measures of executive functions in random feedback analyses allow concluding that valence, at least in a direct way does not have any influence at all on backward inhibition effects and switch costs. However, results with real feedback revealed some interactions. With the presented explanation the question is, whether the presentation of feedback is necessary to produce the described effect. Affect is said to energize goal directed behaviour, and it can, as feedback provide a basis to inform about the status of a goal (Emmons & Kaiser, 1996). It is possible that the effect is mainly caused by the performance but that feedback about that performance is necessary to produce an impact. Maybe participants need the affirmation in terms of external feedback to really store the episode in a complete way. If feedback is not necessary the interaction should also emerge when there is no feedback given but reaction times are split into fast and slow ones and on this way an artificial “valence” factor is created with slow reaction times imitating the negative affect and fast reaction times imitating the positive affect. To test that assumption the next experiment was without any valent stimuli.

3.2.7 Experiment 5.1: No valence

Method

Participants 43 students of the Friedrich-Schiller-University in Jena (between 19 and 26 years old) participated in the single-session experiment that lasted about 20 minutes. They received 2.50 Euros.

Task and stimuli Task and stimuli were like in the preceding experiments. The three basic tasks form (circle or square), line (thick or thin), and colour (green or blue) were used again but no feedback or valent primes like in previous experiments.

Trial Procedure The trial procedure had to be changed slightly because no feedback or prime was used. It started with the letter cue for 400ms in the middle of the screen. Then the target followed at the same position and stayed on the screen until a response was given. A blank screen was shown for 800ms before the next cue was presented.

Procedure The procedure was the same as in all preceding experiments apart from the fact that only the version without direct task repetitions to analyse backward inhibition effects was carried out. The experiment started with instructions and two practice blocks with twelve trials each. They were followed by eight test blocks with 56 trials, respectively. Average error rate and reaction time were presented at the end of each block.

Results for backward inhibition effects

The tested group showed an average error rate of 5.1% (SD =3.5%). Two participants had to be excluded from further analyses due to error rates higher than 12.2% (mean error rate plus two standard deviations). The remaining 41 participants showed an error rate of 4.7%. Those trials and reaction times below 200ms or more than three interquartile ranges (528ms) above the 75th percentile (1035ms) were excluded from analyses (upper limit = 2619ms; 3.0% of all trials) (Tukey, 1977).

The sample with 41 participants was split into two halves. The first half contained the 20 participants with the fastest average reaction times and the second half the remaining participants. This was done to allow a fairer fragmentation of reaction times into three artificial valences depending on general response speed. The reaction time distribution of the two halves was broken into thirds, respectively. The fastest 33 % were the “positive” ones, the slowest 33% the “negative” ones. The third in between were the “neutral” reaction times. For the fast group limits were 519ms and 704ms, for the slow group 908ms and 1085ms.

An analysis was carried out with the factors backward inhibition (ABA versus CBA), and artificial valence (positive, neutral, or negative at position lag-2) which was split into the two

contrasts positive-neutral and negative-neutral. Means from all combinations of variables for reaction times and error rates are presented in tables 31 and 32, respectively.

Reaction times A significant backward inhibition effect of 28ms was discovered, $F(1,40) = 15.33, p < .01$ (see table 31). The interaction of backward inhibition and the contrast negative-neutral was also significant, $F(1,40) = 5.45, p < .03$. The backward inhibition effect was larger after a negative, meaning a slow performance (66ms) compared to after a neutral, meaning a fast performance (19ms) (see table 31 and figure 22). The other interaction was not significant ($F < 1.1, p > .31$).

Not surprisingly the contrasts positive-neutral, $F(1,40) = 22.46, p < .01$, and negative-neutral, $F(1,40) = 10.14, p < .01$, reached significance. Positive (751ms) was faster than neutral (821ms) and neutral was faster than negative (866ms).

Error rates No significant backward inhibition effect was found ($F < 3.1, p > .08$). Also none of the interactions or the two contrasts reached significance (all F 's $< 1.2, p$'s $> .30$) (see table 32).

Table 31: Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for the three artificial valences at position lag-2, respectively.

Variable	ABA	CBA	BI (SD)
Position lag-2			
positive	750	752	-2 (66)
neutral	830	811	19 (103)
negative	899	833	66 (84)
Total	826	799	28 (45)

Table 32: Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for the three artificial valences at position lag-2, respectively.

Variable	ABA	CBA	BI (SD)
Position lag-2			
positive	4.8	4.9	-0.1 (3.0)
neutral	5.1	4.5	0.6 (4.7)
negative	5.6	4.1	1.4 (3.4)
Total	5.2	4.5	0.6 (2.3)

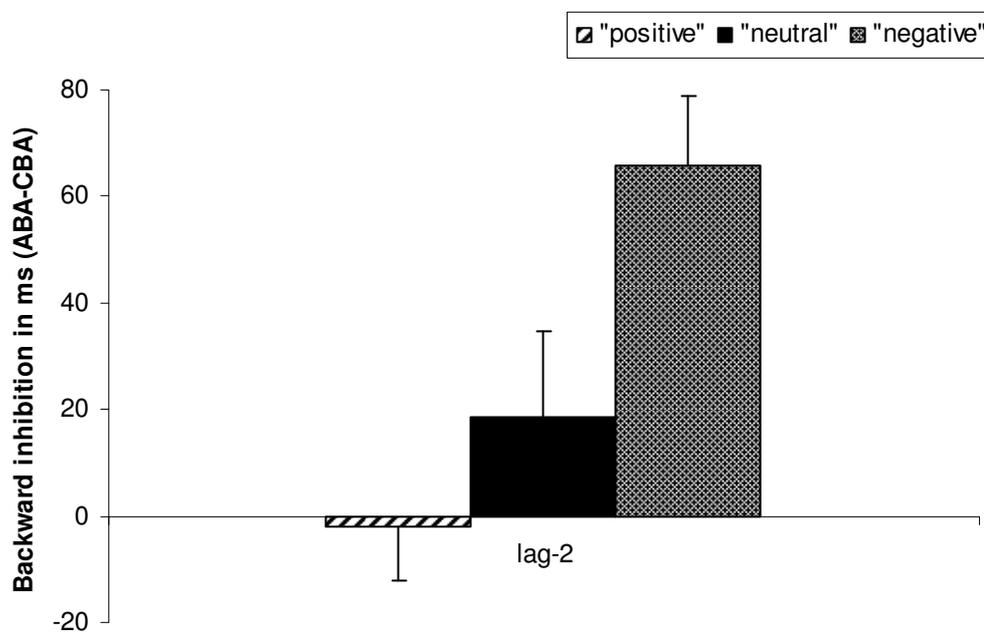


Figure 22: Backward inhibition effects for reaction times (in milliseconds) with artificial valences positive, neutral, and negative at position lag-2, respectively. Error bars refer to standard errors.

Discussion

In this experiment a backward inhibition effect was discovered. With regard to experiments 2, 3, 4, and 5 that did not reveal a general backward inhibition effect, this can be seen as a confirmation that the paradigm works especially because in the current experiment the tasks line, colour and form were used for the first time without any additional valent stimuli, a pure paradigm concerning backward inhibition was carried out.

An interaction of backward inhibition and the contrast negative-neutral was found which supports the idea of feedback not being necessary to allow participants to benefit from a good task performance at position lag-2. Participants do not need an external affirmation about their performance to round up a recently executed task. The complete pattern of backward inhibition effects under the three “valences” positive, neutral, and negative in the current experiment are comparable to effects in experiment 5 for real feedback (see figure 19, right side). After a good performance at position lag-2 ABA sequences are faster than CBA sequences leading to a (in experiment 5.1 only slightly) reversed backward inhibition effect. With a bad performance at position lag-2 meaning reaction times were slow a normal backward inhibition effect can be observed. With the results of the current experiment there are no more doubts about the fact that the interaction between backward inhibition effects and valence is an artefact because it only emerges with real feedback.

Error rate analyses did not allow the assumption of a speed-accuracy trade-off.

In the next two experiments the paradigm was changed in a more radical way in order to detect affective influences on executive functions. The paradigm was attuned to the ideas Kuhl and Kazén’s (1999) experiments are based on. Sequences of four tasks were presented, each with a cue displayed beforehand that told participants the succession of the next four tasks in a trial at once. This made internal cuing of tasks necessary which increases working memory load. This procedure also allows to prepare tasks in advance and then inhibit them until they have to be executed which makes the paradigm more similar to the one used by Kuhl and Kazén (1999; see also Kazén & Kuhl, 2005). Intention memory should definitely be loaded with this new paradigm. Dreher and colleagues (2001) showed that significant backward inhibition effects could also be found with triplets that were presented separately from each other by inter triplet intervals of five to nine seconds. Again feedback was used as valent element in the paradigm.

In the following two experiments data to calculate backward inhibition effects and switch costs were collected in two separate experiments. It was not possible anymore to collect data regarding switch costs that also included the possibility to analyse backward inhibition effects. Using all 27 possible combinations of three tasks in sequences of always four tasks with the same probability for all tasks to appear, direct task repetitions would have been extremely seldom. Also the demand of only analysing error free triplets and pairs made it necessary to separate the two data collections to minimize data loss in several conditions.

3.2.8 Experiment 6.1: Prearranged quadruples, backward inhibition effects

Method

Participants 63 students of the Friedrich-Schiller-University in Jena (aged between 18 and 38 years) participated in the single-session experiment that lasted at least 30 minutes. Experiment duration could be as long as 60 minutes because inaccurate sequences had to be repeated after each block. The repetition of inaccurate sequences was carried out to reduce data loss. Participants received at least 3 Euros plus 25 Cents of extra money for every block with a positive end result. With eight test blocks participants received 5 Euros at most.

An abortion criterion was used additionally in this experiment. If the error rate of the first two test blocks was higher than 40% the experiment was abandoned. In this way two participants dropped out and received 1.50 Euros for participating. Further two participants were excluded from analyses because they showed merely correctness by chance⁸.

Task and stimuli Task and stimuli were the same as in the preceding experiments. Only this time all eight possible target stimuli were used, meaning all combinations of the two features of every task: form (square – circle), line (thick – thin), and colour (blue – green). It did not seem necessary anymore to hold back certain stimuli because task sequence information was given completely in advance always for the next four tasks with a general cue. Feedback design was like in experiments 4 and 5 but the upper and the lower reaction time limits were again changed and adjusted induced by participants complaining about the difficulty to earn any of the possible extra money. Again real positive and negative feedback was shown as well as positive and negative random feedback. The limit to show real negative feedback was the mean of the slowest and the second slowest reaction time (comprising reaction times of the six preceding tasks which were responded to correctly). The limit for positive feedback represented the mean of the second and third fastest reaction time. Reaction times in between those limits were given positive or negative feedback by chance.

Trial Procedure The trial procedure was changed. Four tasks were presented in prearranged sequences, respectively. Information about the task sequence in a trial was given in advance with a general cue, before presenting the first task. The cue contained for example the words “Farbe - Linie - Gestalt - Linie” (colour - line - form - line) one below the other and announced the next four tasks that had to be completed. A four task sequence started with such a cue. It was presented until the participant pressed the space key. This key press was

⁸ To compute average error rates all trials were used those from the regular blocks and those from the repeated sequences. Error rates only based on the trials from the regular blocks did not change the number or the identity of participants to be excluded from further analyses due to increased error rates.

followed by a blank screen for 500ms. The first target followed until a response button was pressed. Immediately, response feedback was presented for 1000ms and followed by another blank screen for 300ms. Then the second target was shown, again until a response button was pressed, followed by feedback for 1000ms and then a blank screen for 300ms. A third and a fourth target with feedback and blank screen were presented exactly in the same manner. Then the cue for the next trial with four tasks was shown. This was the procedure for the test blocks, for practice blocks it was altered slightly: no feedback was presented and the blank screen after the fourth target's feedback was extended to 2000ms.

All combinations of task sequences without direct task repetitions were used. That resulted in 24 possible combinations (ABAB, ABAC, ABCA, ABCB, ACAB, ACAC, ACBA, ACBC; resulting in 24 options with every task starting each of the eight sequences).

Procedure The experiment started with written instructions on the screen. To get used to tasks and trial procedure participants had to complete two practice blocks with four trials each (meaning a total of sixteen tasks) in the above described trial procedure. After that participants were introduced to the rules concerning feedback and earning the extra money. Then eight test blocks were presented with twelve trials each (meaning a total of 48 tasks). That made it possible to present each of the 24 sequences exactly four times during the experiment. Trials that contained a wrong response were repeated at the end of a block after general block feedback with information about accuracy, speed and block score. For those additional trials no points could be collected and therefore no additional money could be earned, although feedback was given after every trial.

Results for backward inhibition effects

The group with 59 participants showed a mean error rate of 12.1% (SD = 8.1%) and three participants had to be excluded due to a higher error rate than 28.4% (mean error rate plus two standard deviations). Then the average error rate was 10.7% (of all trials). Those trials and reaction times below 180ms or more than three interquartile ranges (251ms) above the 75th percentile (604ms) were excluded from analyses (upper limit = 1357ms; 3.7% of all trials) (Tukey, 1977).

Separate analyses had to be carried out for real and random feedback and for lag-1 and lag-2 valence, respectively. Missing data in certain conditions when both positions were analysed together made that necessary.

Reaction time means for all combinations of variables are presented in table 33 (random feedback) and table 34 (real feedback). Average error rates are displayed in tables 35 (random feedback) and 36 (real feedback).

Reaction times Random feedback For analyses with lag-2 position a significant backward inhibition effect of 14ms was found, $F(1,55) = 8.57, p < .01$ (see table 33). The interaction with valence (positive-negative) and the valence factor did not reach significance (all F 's < 1) (see figure 23, left side).

For analyses with lag-1 affect position no significant results were found (all F 's $< 2.4, p$'s $> .13$) (see figure 23, left side).

Real feedback For lag-2 analyses no significant backward inhibition effect and no significant interactions with valence were found (all F 's $< 1.8, p$'s $> .19$) (see table 34 and figure 23, right side). The difference between reaction times after positive and negative feedback at position lag-2 was significant, $F(1,55) = 9.42, p < .01$. Reaction times were faster after positive feedback (479ms) compared to negative feedback (500ms).

For lag-1 analyses a significant backward inhibition effect of 16ms was found, $F(1,55) = 5.72, p < .03$ (see table 34). An interaction with valence did not emerge ($F < 1.9, p > .18$). Reaction times after positive feedback (471ms) compared to negative feedback (511ms) differed significantly, $F(1,55) = 19.72, p < .01$.

Error rates Random feedback For lag-2 analyses no significant backward inhibition effect and no interaction with valence were found (all F 's < 1) (see table 35), but the factor valence was significant, $F(1,55) = 5.48, p < .03$. More errors were made after negative feedback (12.1%) compared to positive feedback (10.2%).

For analyses with lag-1 valence no significant results were found (all F 's $< 1.9, p$'s $> .17$) (see table 35).

Real feedback Lag-2 analyses did not show any significant results (all F 's $< 1.9, p$'s $> .17$) (see table 36).

For lag-1 valence analyses the backward inhibition effect and the interaction with valence were not significant (all F 's $< 3.7, p$'s $> .06$) (see table 36), but significantly more errors were made after negative feedback (13.1%) compared to positive feedback (10.8%), $F(1,55) = 7.30, p < .01$.

Table 33: Random feedback - Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.

Variable	Position lag-2			Position lag-1		
	ABA	CBA	BI (SD)	ABA	CBA	BI (SD)
positive	495	477	18 (50)	495	480	14 (62)
negative	496	486	10 (58)	498	494	5 (58)
Total	496	481	14 (36)	496	487	9 (47)

Table 34: Real feedback - Reaction times (in milliseconds) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.

Variable	Position lag-2			Position lag-1		
	ABA	CBA	BI (SD)	ABA	CBA	BI (SD)
positive	476	481	-5 (48)	475	468	7 (39)
negative	505	495	10 (80)	523	499	25 (90)
Total	491	488	3 (49)	499	483	16 (50)

Table 35: Random feedback – Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.

Variable	Position lag-2			Position lag-1		
	ABA	CBA	BI (SD)	ABA	CBA	BI (SD)
positive	10.4	10.0	0.4 (6.8)	10.9	10.6	0.3 (8.6)
negative	12.1	12.1	-0.1 (9.2)	11.9	11.6	0.4 (9.0)
Total	11.2	11.1	0.2 (6.2)	11.4	11.1	0.3 (5.7)

Table 36: Real feedback – Error rates (in percent) for ABA and CBA sequences and their difference (BI = backward inhibition effect) for each valence separated for positions lag-2 and lag-1.

Variable	Position lag-2			Position lag-1			
	ABA	CBA	BI (SD)	ABA	CBA	BI (SD)	
positive	11.3	11.3	0 (8.8)	11.7	9.9	1.8 (7.1)	
negative	12.7	12.6	0.2 (12.1)	14.1	12.0	2.1 (13.5)	
Total	12.0	11.9	0.1 (7.3)	12.9	10.9	2.0 (7.8)	

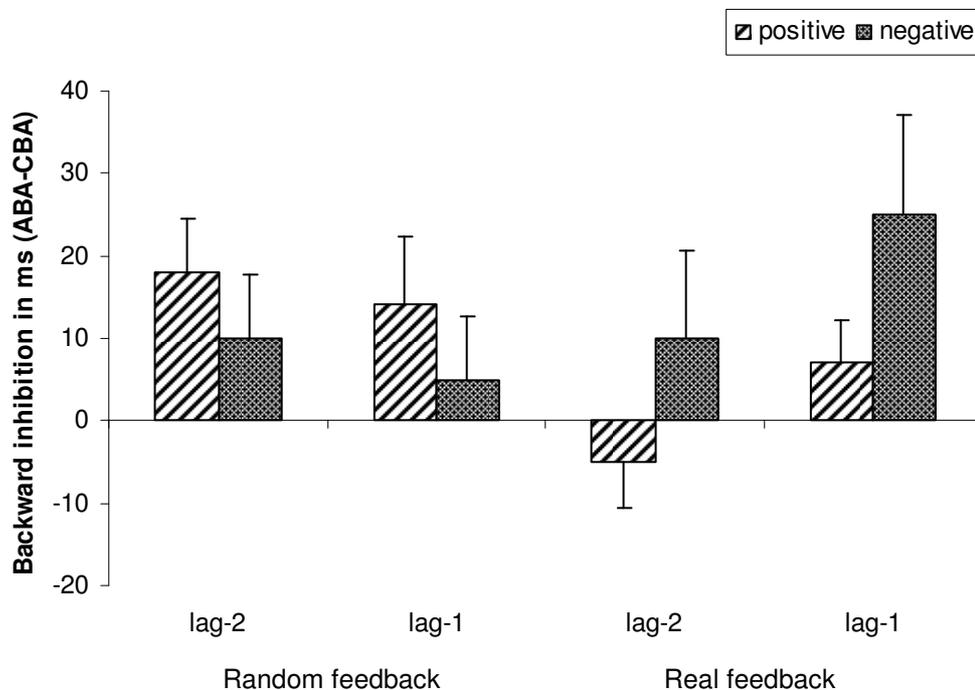


Figure 23: Random and real feedback - Backward inhibition effects for reaction times (in milliseconds) with positive and negative feedback at positions lag-2 and lag-1, respectively. Error bars refer to standard errors.

Discussion

Also with this method of prearranged quadruples an interaction of backward inhibition and affective stimulation with random feedback was not observed. Although the method to present the tasks must have loaded the intention memory, positive affect could not develop the impact that is predicted by PSI theory. In general effects in this experiment are quite small compared to experiments 4 and 5 for example. A comparison between predicted patterns from the PSI

and the dopaminergic theory with the backward inhibition effects pattern of the current experiment is not indicated because firstly no significant interactions were obtained and secondly, the two theories only made predictions about positive and neutral affect but the current experiment used negative and positive affect. However, it might be noted that for real feedback at position lag-2 the pattern looked exactly as in experiments 5 and 5.1 (see figure 19, right side and figure 22, respectively). As already stated earlier (see discussion of experiment 5) this simply means that showing a good performance at position lag-2 especially helps in ABA sequences when the first task is repeated indirectly. Therefore reaction times for ABA sequences are faster than for CBA sequences. With a bad performance and negative feedback at position lag-2 there is no benefit anymore and reaction times for ABA sequences are slower than for CBA sequences.

For error rates no notable results were found.

3.2.9 Experiment 6.2: Prearranged quadruples, switch costs

Method

Participants 62 students of the Friedrich-Schiller-University in Jena, aged between 18 and 29 years participated. Again, inaccurate sequences had to be repeated after each block. Therefore the experiment lasted 30 up to 60 minutes. Participants received at least 3 Euros plus 25 Cents of extra money for every block with a positive end result (maximum payment: 5 Euros). The same abortion criterion was used as in experiment 6.1. Thus, two subjects dropped out early and received 1.50 Euros for participating.

Task and stimuli For the current experiment only two different tasks were needed and only the tasks colour (blue and green) and form (square and circle) were used. All four possible stimuli were used (green circle, green square, blue circle, blue square). Feedback design was like in the preceding feedback experiments. The upper and the lower reaction time limits were changed yet another time. Reaction times slower than the second slowest time resulted in negative feedback, times faster than the second fastest in positive feedback. Reaction times in between were given positive or negative feedback by chance.

Trial Procedure The trial procedures used in practice and test blocks were identical to those in experiment 6.1. 16 possible sequences of four tasks each exist: AAAA, AAAB, AABA, AABB, ABAA, ABAB, ABBA, ABBA, ABBA, ABBA (also every sequence starting with B). Sequences AAAA and BBBB were not used, which left 14 sequences.

Procedure The procedure was also the same as in experiment 6.1 apart from one difference. In each of the eight test blocks fourteen trials with four tasks each, meaning 56 tasks were presented. That allowed showing each of the fourteen possible task combinations (trials) exactly once in a block.

Results for switch costs

The 60 participants of the tested group showed a mean error rate of 10.8% (SD = 8.1%). Three participants had to be excluded from further analyses due to higher error rates than 27.0% (mean plus two standard deviations)⁹. Erroneous responses (9.5% of all trials) and reaction times below 180ms or more than three interquartile ranges (190ms) above the 75th percentile (514ms) were excluded from analyses (upper limit = 1084ms; 4.9% of all trials) (Tukey, 1977).

Again different analyses were carried out for real and random feedback. Reaction time means for all combinations of variables are presented in table 37 (random feedback) and table 38 (real feedback). Average error rates for all variables are displayed in tables 39 (random feedback) and 40 (real feedback).

Reaction times Random feedback Significant switch costs were found, $F(1,55) = 94.85$, $p < .01$ (see table 37). Switch trials were 46ms slower than non-switch trials. The interaction of switch costs with valence and the factor valence did not reach significance (all F 's < 2.2 , p 's $> .14$) (see figure 24, left side).

Real feedback Also for real feedback switch costs of 48ms were found, $F(1,55) = 93.00$, $p < .01$ (see table 38). The interaction with affect did not reach significance ($F < 1.1$, $p > .30$) (see figure 22, right side). Reaction times after negative feedback (438ms) differed significantly from those after positive feedback (400ms), $F(1,55) = 76.54$, $p < .01$.

Error rates Random feedback Significant switch costs of 1.9% were found, $F(1,55) = 19.52$, $p < .01$ (see table 39). A significant interaction with valence or a significant main effect of valence did not emerge (all F 's < 1).

Real Feedback Significant switch costs were found, $F(1,55) = 5.30$, $p < .03$ (see table 40). 1.6% more errors were made after switch trials compared to non-switch trials (9.2%). No other significant results were found (all F 's < 1.4 , p 's $> .24$).

⁹ To compute average error rates all trials were used those from the regular blocks and those from the repeated sequences. Error rates only based on the trials from the regular blocks did not change the number or the identity of participants to be excluded from further analyses due to increased error rates.

Table 37: Random feedback - Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.

Variable			
Position lag-1	AB	AA	SC (SD)
positive	434	388	46 (42)
negative	437	391	46 (36)
Total	435	390	46 (35)

Table 38: Real feedback - Reaction times (in milliseconds) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.

Variable			
Position lag-1	AB	AA	SC (SD)
positive	422	378	43 (43)
negative	464	412	52 (54)
Total	443	395	48 (37)

Table 39: Random feedback - Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.

Variable			
Position lag-1	AB	AA	SC (SD)
positive	10.1	8.6	1.6 (4.0)
negative	10.9	8.7	2.2 (4.8)
Total	10.5	8.6	1.9 (3.2)

Table 40: Real feedback - Error rates (in percent) for task switches (AB) and task repetitions (AA) and their difference (SC = switch costs) for the two valences, respectively.

Variable	AB	AA	SC (SD)
Position lag-1			
positive	10.0	8.3	1.7 (6.5)
negative	10.6	9.2	1.4 (8.7)
Total	10.3	8.8	1.6 (5.1)

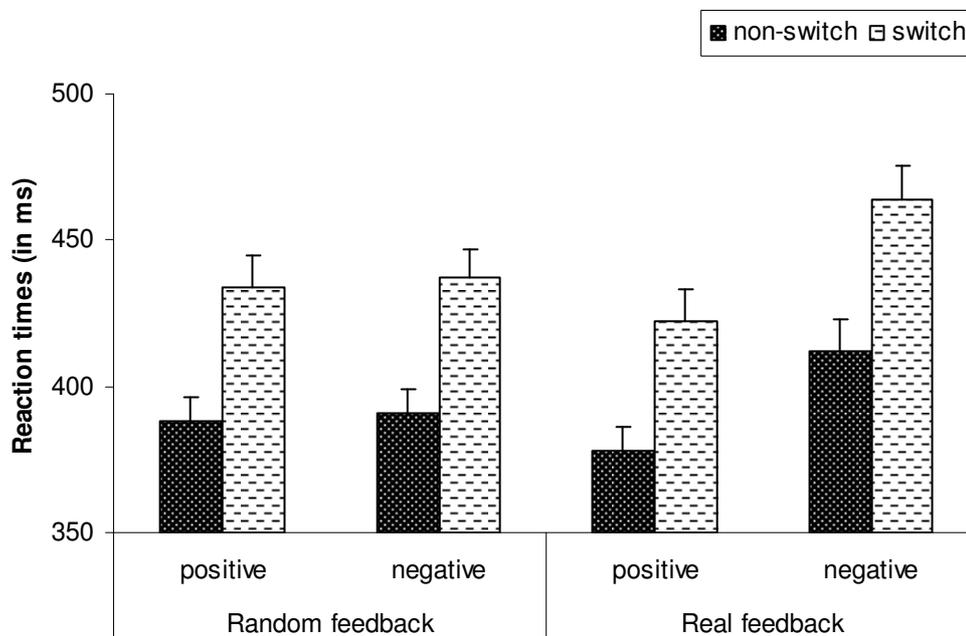


Figure 24: Random and real feedback - Reaction times (in milliseconds) for non-switch and switch trials after positive or negative feedback at position lag-1, respectively. Error bars refer to standard errors.

Discussion

Significant switch costs were still found with the method of prearranged quadruples, although they were quite small in general and compared to the other experiments.

The results of this last experiment considering random feedback confirmed again what has also been shown in all previous experiments. Switch costs are not influenced by affective stimulation. In the current experiment switch costs under the two valences were identical for

random feedback (see table 37). Switch costs are not even influenced by performance-related feedback as this is the case for backward inhibition effects. Also for costs with real feedback the differences between positive and neutral feedback was small (see table 38).

Error rates did not reveal any interesting results.

4. General Discussion

The aim of this study was to detect modulating effects of valence in terms of short affective stimuli on measures of executive control. The measures switch costs and backward inhibition effects were calculated with data that was collected with the established task switching paradigm. The affective element was inserted into the paradigm with two different methods: a prime or a cue in terms of pictures from the IAPS (Lang et al., 2005) before a task or as feedback after a task. Affective pictures or feedback were positive, negative, or neutral. When possible the positive and the negative affective states were compared to the neutral baseline in two different contrasts, positive-neutral and negative-neutral.

In the following section results of the study's nine experiments are discussed considering the two presented models, the PSI theory (Kuhl, 1996, 2000, 2001) and the dopaminergic theory (Ashby et al., 1999; Dreisbach & Goschke, 2004), previous literature, and findings.

Before discussing interactions of backward inhibition effects and switch costs with affect which were of special interest regarding the hypotheses main effects of the backward inhibition effect, switch costs, and valence are recapitulated. In the end technical and theoretical considerations are discussed that offer some explanations for the found result patterns.

4.1 Main Effects

4.1.1 Backward inhibition effects

Significant backward inhibition effects were not found in all of the nine experiments. However, a significant effect was observed in nearly 50% of all analyses based on reaction times (in experiments 1, 3.1, 5, 5.1, and 6.1). Strikingly, the largest and most clear backward inhibition effects were found when only positive and neutral valence were included in the paradigm (experiment 3.1, 55ms) and with no valence at all (experiment 5.1, 28ms). For error rates normal backward inhibition effects were generally very small (between 0.07% and 1.98%) with the largest effects measured in experiment 5 as reversed effects (-3.1% and -2.2%). However, those effects and the only significant main effect with error rates

(experiment 5, random feedback: 3.1%) correspond to reaction time effects which means that a general speed-accuracy trade-off cannot be assumed.

On the one hand this total pattern of significant overall backward inhibition effects could be interpreted as supporting the assumption that the backward inhibition effect is not a very reliable and robust effect especially when compared with switch costs (see further below). This can be used to question the backward inhibition effect as a measure of executive functions (see paragraph 1.1.4 Backward inhibition effect). The other option is to focus more on the fact that for reaction times only without negative affect or with a simplified paradigm a significant backward inhibition effect was observed. This could be interpreted as evidence that affect is influencing backward inhibition effects at least in some way. Maybe negative affect is only an unsystematic disturbance or maybe it is systematic but was just not measurable in the presented experiments.

4.1.2 Switch costs

In line with the literature about task switching (see Allport et al, 1994; Goschke, 2000; Jersild, 1927; Meiran, 1996; Rogers & Monsell, 1995; Spector & Biederman, 1976; Wong & Leboe, 2009) and in contrast to backward inhibition effects, switch costs proved to be a very robust and reliable effect. That applied for reaction time and error rate analyses. In all six experiments that allowed switch cost analyses highly significant costs were found (for reaction times p always $< .01$; for error rates p always $< .03$). What is striking is the fluctuation of the costs from 46ms up to 335ms for reaction times and from 1.6% to 8.9% for error rates. A speed-accuracy trade-off cannot be assumed for any of the experiments.

However, the largest switch costs for reaction times were found in the most difficult paradigm (experiment 3: three valent cues per task and an additional task). Increased task difficulty increased general reaction times, variance, and switch costs whereas at the same time the smallest but still significant switch costs were found with error rates. A corresponding pattern was found in experiments 4 and 5. In those two feedback experiments the importance of response speed was emphasised. Not surprisingly general reaction times dropped and error rates increased. Furthermore, also switch costs for reaction times were quite small (between 64ms and 75ms) and for error rates the largest switch costs regarding all experiments were observed (between 7.5% and 8.9%). This pattern of higher error rates for the benefit of accelerated reaction times was attenuated in experiment 6.2. The prearranged and in advance

announced quadruples allowed the smallest switch costs for reaction times and error rates regarding all experiments. The opportunity to prepare tasks and task sequences is used to complete especially the most difficult tasks with the highest speed and accuracy. However, it has to be noted that experiment 6.2 was also the easiest one with only two different tasks. That might also have added to the finding of small switch costs for latencies and for error rates. In the end, even under all these different conditions switch costs always turned out to be highly significant.

4.1.3 Valence

For analyses that included both contrasts positive-neutral and negative-neutral (experiments 1 to 4) a general trend can be described considering influences of affect on reaction times. Five of the seven significant contrasts show that reaction times after positive primes, cues or feedback are accelerated compared to neutral affect. If the results of experiment 4 are excluded because they included confounding variables four of five significant findings show this trend. It is further striking that all of these four results are achieved with lag-0 valence. This means that positive valence presented directly before an executed task can accelerate general reaction times. For experiments 5 and 6 that only included negative and positive valences in terms of feedback this accelerating effect of positive affect is confirmed. Of the six significant contrasts in five cases the positive affect produced faster reaction times than the negative one.

With error rates less significant results were found than with reaction times. However, the general trend that positive affect seems to speed up reaction times can also be transferred to error rates. In four of the five significant results that were found with positive affect less errors were made compared to neutral or negative affect.

4.1.4 Summary

Summing-up all the reported and briefly discussed main effects three conclusions can be drawn. Firstly, affect can have an influence. Positive affect accelerates general reaction times and reduces general error rates. Secondly, because significant backward inhibition effects seem to depend on how many different valences were used in an experiment it can be

assumed that backward inhibition might be influenced by affect in some way. Thirdly, switch costs are less vulnerable. Switch costs reached significance in all experiments even when the costs were small.

4.2 Backward Inhibition Effects and Affect

4.2.1 Significant interactions

Experiments 1 - 3.1

In general, a speed-accuracy trade-off cannot be assumed. All significant effects for reaction times were always roughly reflected within error rates.

Significant results that showed an interaction of backward inhibition effects with valence were scarce. Considering reaction times a direct influence of valence on backward inhibition is not very likely. A significant interaction of backward inhibition with lag-1/lag-2 or lag-0/lag-1 contrasts of valence was never found apart from when valence was also performance-related (experiments 4 and 5). The only significant two-way interaction was found based on error rates in experiment 1 (apart from another one in experiment 4 but this experiment included confounding variables). A normal backward inhibition effect was observed after neutral primes and a reversed effect after negative primes at position lag-0. This was mainly due to increased error rates for ABA sequences with neutral affect (neutral: 8.0%; negative: 5.8%). An explicit hypothesis concerning negative affect at position lag-0 and backward inhibition was not generated with any of the two models. Only smaller backward inhibition effects were predicted by PSI theory (due to reduced reaction times or error rates for ABA sequences) for positive compared to neutral affect. However, exactly this pattern was found with negative and neutral affect for error rates. A negative cue before the last trial in the triplet seemed to help to reduce errors in ABA sequences. This would mean that the negative affect helps to overcome inhibition which enables faster activation of the current task, disturbing influences can be minimised which results in fewer errors. However, a comparable effect was never replicated therefore the explanation has to be handled with care. The expected two-way interactions predicted with the help of the PSI and the dopaminergic theory were not found neither in analyses for latencies nor in analyses for error rates.

One three-way interaction was found in experiment 3 for reaction times (backward inhibition x contrast negative-neutral lag-1 x contrast positive-neutral lag-0) but it was also never replicated. A similar three-way interaction appeared with error rates in experiment 3.1 (backward inhibition x contrast positive-neutral lag-1 x contrast positive-neutral lag-0) but the pattern of means differed completely. Whereas the interaction for reaction times in experiment 3 showed a clearly reversed backward inhibition effect for the affect combination neutral-positive (-65ms) and a large effect for the combination negative-positive (144ms) the interaction in experiment 3.1 for error rates was caused mainly by the difference between positive-positive (-1.3%) and positive-neutral (2.1%) affect combinations. Therefore, the error rate result of experiment 3.1 is neither a replication of the significant three-way interaction with latencies in experiment 3 nor of the two-way interaction with error rates in experiment 1 also because it included only positive and neutral affect (experiments 3 and 1 included positive, neutral, and negative affect, respectively).

Although the significant three-way interaction in experiment 3 for reaction times was never replicated an attempt to explain it roughly will be made. In terms of forming and overcoming of inhibition it can be assumed that negative affect at position lag-1 seems to produce a lot of inhibition and the positive affect at position lag-0 functions as an additional handicap to overcome that inhibition which results in a huge backward inhibition effect. A neutral affect at position lag-1 seems not to produce that much inhibition. Hence, because there is no or only few inhibition the positive affect at position lag-0 seems to be able to facilitate executing the last trial in the triplet instead of increasing difficulties during overcoming of inhibition. This explanation makes clear that positive affect can have a facilitating or an obstructive effect depending on conditions and circumstances. This fits with ideas about influences of positive affect that assume that it is not simply improving or impairing every performance. For example different memory systems are influenced differently by positive mood (Oaksford et al., 1996), influences of positive mood differ among different tasks although they seem to represent the same constructs like for example flexibility (Phillips, Bull et al., 2002), and factors like whether a task is experienced as boring or not determine whether positive affect facilitates or impairs the performance of a task (Isen, 1999).

Experiments 4 - 6.1

The use of affective stimuli in terms of primes or cues before a task seemed not to have a modulating influence on backward inhibition effects. As a consequence of those first four experiments (experiments 1, 2, 3, and 3.1), it was assumed that the affective stimulation might

not have been enough to elicit an affective reaction that is strong enough to influence backward inhibition effects. Therefore, valent feedback was used next. Feedback has a clear relevance because the amount of additional money that could be earned during an experiment depended on it. However, what feedback experiment 5 showed was that the pure valence without being confounded with performance did not influence backward inhibition effects at all. Only with performance-related feedback an interaction with backward inhibition effects was observed. And this is clearly an artefact as experiment 5.1 showed. In this experiment no feedback was included and only performance of preceding tasks caused the differences in backward inhibition effects. The lack of interactions between valence and backward inhibition effects for random feedback in experiment 5 confirmed the assumption that backward inhibition effects are not modulated by affect.

Based on the predictions made by PSI theory it was then tried to intensify the elements that are assumed to be involved in task switching like intention memory. The required internal cuing of tasks in experiment 6.1 allows planning of task sequences in advance which is supposed to load intention memory. This, on the one hand strengthens processes that are supposed to partake in switching tasks but on the other hand in advance announced task sequences also allow preparation. This means that a lot or all executive control processes could have been executed before reaction time measurement began. This opportunity of preparing tasks in advance was further supported by the trial procedure. Feedback presentation times of 1000ms after every task could have been and were probably used to prepare the upcoming task. The found backward inhibition effects for the different valences which were very small and also very similar in experiment 6.1 seem to confirm this assumption. Also this change of certain features of the paradigm could not reveal significant interactions of backward inhibition effects and valence.

4.2.2 Descriptive patterns

Although significant results concerning direct influences of valence on backward inhibition effects were not obtained the PSI and the dopaminergic theory made exact predictions about what causes reduced or increased backward inhibition effects in certain valence conditions. These predicted patterns can be compared to the found patterns in the reported experiments.

Predictions from the dopaminergic theory (valence at position lag-1/lag-2)

For the valence at the position after the first trial in a triplet the dopaminergic theory predicted smaller backward inhibition effects because of faster reaction times for ABA sequences with positive compared to neutral affect. The reduction of reaction times for ABA sequences is caused either by increased distractibility which makes the use of inhibition less possible or by weak maintenance capability and the increased ability to overcome dominant responses which makes inhibition unnecessary. The predicted pattern was only met in the first and the second experiment with smaller backward inhibition effects for positive affect. This effect was due to a reduction of reaction times in ABA sequences at least in experiment 2. In experiment 1, reaction time reductions for ABA and increases for CBA sequences were responsible in equal parts for the pattern. In both experiments with valent cues (experiment 3 and 3.1) backward inhibition effects were larger for positive compared to neutral affect. However, differences between effects for neutral and positive affect in both experiments were extremely small and a comparison with the predicted pattern seems not appropriate.

In feedback experiments that also differentiated between random and real feedback (experiments 5 and 6.1) only positive and negative affect were included. It is striking that in the relevant condition with random feedback hardly any differences existed between backward inhibition effects after positive and negative feedback. In general a comparison of these results with the predictions is difficult because predictions concern the contrast between positive and neutral affect. The lack of a baseline in terms of neutral affect might have prevented that significant interactions of backward inhibition effects with valence were found in the feedback experiments.

Taken together, the predicted pattern for positive and neutral valence at position lag-1 cannot be confirmed. This conclusion is further strengthened by the fact that when the pattern was found (smaller backward inhibition effects with positive compared to neutral valence) it was by no means due to reduced reaction times for ABA sequences with positive affect at position lag-1/lag-2 as predicted.

Predictions from PSI theory (valence at position lag-0/lag-1)

The prediction for lag-0 valence (or lag-1 valence for feedback experiments) based on PSI theory was that positive affect reduces backward inhibition effects compared to neutral affect. Positive affect is supposed to help overcoming once formed inhibition. Hence, ABA sequences are supposed to be executed faster with positive affect compared to neutral affect. Even more frequently than for the valence at position lag-1 differences in backward inhibition

effects between positive and neutral affect at position lag-0 were hardly recognisable. That applies for experiments 2, 4, 5, and 6.1. In experiments 1 and 3 even the reversed pattern was obtained, larger effects after positive compared to neutral affect. In experiment 1, this was due to increased reaction times for CBA sequences. For experiment 3, a suitable explanation of the pattern is not possible because the reaction time levels in the three different valence conditions differed too much. In experiment 3.1 predictions were met for the one and only time and the difference was caused by a reduction of reaction times for ABA sequences with positive affect.

It can be concluded that apart from missing significant interactions with lag-0 valence also the descriptive patterns found in the experiments do not correspond to the predicted patterns.

4.3 Switch Costs and Affect

4.3.1 Significant interactions

Significant results for influences of affect on switch costs hardly existed. For reaction times only one significant interaction with valence was found in experiment 2. This result was reflected in error rates therefore a speed-accuracy trade-off cannot be assumed. However, this reaction time result and even the descriptive pattern were never replicated. In experiment 2 switch cost after a neutral prime were smaller compared to after a negative prime. Descriptive patterns in all other experiments with three valences presented before the tasks were either in the reversed direction (experiments 1 and 4) or a difference between switch costs with neutral and negative affect did not exist (experiment 3). In experiments that included real and random feedback and therefore only positive and negative affect (experiments 5 and 6.2) differences were hardly existent. This was most surprising for experiment 6.2. Considering PSI theory, intention memory must have been loaded with the prearranged and in advance announced quadruples in this experiment. Therefore the best conditions were established for the facilitating effect of positive affect (hypothesis 1a) and the blocking effect of negative affect (hypothesis 1c) regarding switch costs. However, results showed that switch costs for positive and negative affect especially for random feedback were nearly identical.

In reaction time analyses hardly any differences between switch costs with different affects were observed, costs were very similar in most experiments. The significant interaction in

experiment 2 was mainly due to increased reaction times for switch trials (neutral: 960ms; negative: 991ms). Reaction times for non-switch trials were nearly identical (neutral: 817ms; negative: 809ms). Especially a negative prime seems to increase difficulties during the execution of switch trials. The comparison with the latency for positive affect (951ms) shows that at least in this case positive and negative affect do not have an impact into the same direction. The positive affect seems to reduce difficulties during switching. Increased switch costs for negative compared to neutral affect due to increased reaction times for switch trials were predicted by PSI theory. According to the deductions from that theory negative affect prevents intentions stored in the intention memory to be brought into action. Negative affect blocks access to executing systems, the connection between intention memory and intuitive behaviour control is disturbed and disrupted. However, the validity of this explanation has to be questioned considering all other experiments. As already mentioned not even the descriptive pattern was replicated.

There was one further significant interaction based on error rates. In experiment 4 larger switch costs were found after a positive (11.6%) compared to after neutral feedback (6.9%). This was caused by increased error rates after positive feedback in switch trials. However, this result can be considered of minor importance because experiment 4 included confounded variables. A replication of this effect especially with random feedback would have been important, but the result was never replicated neither in experiment 5 nor in experiment 6.2.

Possible explanation for the lack of significant interactions

The dopaminergic theory offers an explanation why influences of affect on switch costs were not found in the current experiments. It might be that effects of enhanced flexibility and increased distractibility both supposed to be caused by positive affect neutralise each other. Switch trials benefit from enhanced flexibility, reaction times can be accelerated but at the same time switch trials also suffer when distractibility is increased so that as a result neither a benefit nor a loss can be measured. A further element in task switching that can be influenced by affect according to the dopaminergic theory is the maintenance capability. However, this element is not represented with specific switch costs. If maintenance capability is influenced by affect, that cannot be measured with specific switch costs. All that is left in specific switch costs is the pure switching between two tasks, the required maintenance is the same for switch and for non-switch trials because during blocks with both kinds of trials both tasks always have to be kept in mind. A better measure might be general switch costs because this measure also represents maintenance demands. In mixed blocks maintenance demands are much

higher compared to single blocks. Considering Dreisbach's (2006) results the prediction would be that after positive affect when maintenance capability is impaired reaction times in mixed blocks compared to neutral affect should be higher resulting in larger global switch costs. The increased global costs can emerge because single trials are totally unaffected by affective influences because they do not require any complex maintenance capabilities.

4.3.2 Descriptive patterns

The predicted patterns by PSI theory and the dopaminergic theory concerning switch costs were as follows: Both theories predicted smaller switch costs for positive affect compared to neutral affect because reaction times in switch trials are reduced. PSI theory assumes facilitated access of once formed intentions (in the intention memory) to executing systems (in the intuitive behaviour control) with positive affect. That helps especially in case of a switch because their major difficulty makes the use of the intention memory necessary. The dopaminergic theory predicts effects in the same direction but explains them differently. Enhanced flexibility and reduced perseveration with positive affect are supposed to facilitate switching whereas task repetitions are not affected. It has to be noted that the task switching paradigm that was used in the presented experiments did not offer the opportunity to distinguish between the two theories and their respective explanations in case of a significant result in the predicted direction. The predicted descriptive pattern was found in experiments 1 and 3 although the differences in experiment 1 were very small. In both experiments reduced reaction times for switch trials after positive affect were the cause for the reduced switch costs which is in line with the predictions. However, experiments 2 and 4 showed a reversed pattern for positive and neutral affect. In both cases this pattern is due to reduced reaction times for non-switch trials with positive affect. Experiments 5 and 6.2 did not include a neutral affect condition. Therefore comparisons with predicted patterns are not possible. Furthermore, switch costs for positive and negative affect in those experiments were very similar.

Additionally and much more speculative PSI theory allowed deducing a hypothesis concerning negative affect. Reaction times for switch trials after negative affect are supposed to be increased which results in larger switch costs compared to neutral affect. The blocking of the connection between intention memory and the intuitive behaviour control is assumed to be responsible for this effect. This pattern was only met in experiment 2 and it was also significant. In experiments 1 and 4 the predicted pattern was reversed mainly because of

increased reaction times for non-switch trials (although in experiment 1 reduced latencies for switch trials also added to the effect). As already mentioned, in experiments 5 and 6.2 differences were hardly existent.

For influences of affect on switch costs it can be concluded that they do not seem to exist. Patterns according to the predictions were found as often as patterns that contradicted those predictions. It was assumed that maybe general switch costs would be influenced by affect because they also represent maintenance capability (see also paragraph 1.1.2 Task switching paradigm), an element that is also supposed to be influenced by affect (Dreisbach, 2006).

4.4 Possible Causes for the Observed Result Patterns

In the following paragraph assumed causes for the null findings in the present study are discussed. There are technical problems and restrictions related to the affective stimulation and the paradigm that might have prevented that affect influences executive functions. Furthermore, there are two general theoretical considerations that will be discussed further. Firstly, backward inhibition effects and switch costs might not measure executive functions at all and secondly, it can also be concluded that executive functions are simply not influenced by affect. Each of these possibilities will now be discussed in turn.

4.4.1 Technical restrictions

Questioning the choice of tasks used in an experiment is always an option to look for explanations when expected effects were not obtained. Especially considering backward inhibition effects the tasks in the current study were completely different and much easier than the tasks in Mayr and Keele's original study (2000). However, backward inhibition effects have been demonstrated with a lot of different and also much easier tasks (see for example Arbuthnott, 2005; Arbuthnott & Frank, 2000; Gade & Koch, 2005; Phillip & Koch, 2006). Also significant backward inhibition effects were found in nearly 50% of all carried out analyses. Regarding switch costs different researchers have discussed influences of tasks on switch costs and the general performance (Allport et al. 1994; Monsell, Yeung, & Azuma, 2000) but a harmful influence of that kind in the presented experiments is very unlikely

because switch costs were a very stable measure and reached significance in all experiments. Therefore influences caused by the chosen tasks cannot be assumed.

Two further and more plausible technical causes for the reported experiments' result patterns are going to be discussed now in more detail: the chosen affective manipulation and general restrictions of the paradigm.

Affective manipulation

In the domain of valence as a modulating variable for executive functions a lot of changes are imaginable. Maybe affective words or sounds are the better primes in a task switching paradigm to detect an affective modulation of executive control functions. Although there is no real evidence for such an assumption it might still be worth trying in future experiments.

The lack of significant interactions between affect and switch costs or backward inhibition effects in the current study might also have their origin in limited resources like for example attention. According to Baddeley (2007) with a demanding central task, attention has to be focused resulting in less attentional capacity for distracting stimuli. That would mean that the task switching tasks need that much attention that the distracting stimuli, in this case the valent stimuli cannot be processed anymore with the appropriate attention. Of course the difficulty of the central task is debatable because the tasks were quite easy compared for example with Mayr and Keele's tasks (2000). However, for switch costs already the third task that was included in the paradigm to make backward inhibition analyses possible might have increased the difficulty in a sense that make Baddeley's argument more plausible at least for switch costs.

It can further be assumed that the affective stimulation was not strong enough. The trial by trial changes of affect might have weakened its impact. Bradley and colleagues (1999) suggest that a stronger affective manipulation would be to present contiguous blocks of pleasant or unpleasant stimuli, to create a more tonic, sustained mood state. This was for example realised in the experiments by Dreisbach (2006) and Dreisbach and Goschke (2004) who found affective influences on executive functions. They achieved their results with a between-subjects variation of valence. Still, valent elements were shown in every trial but they were of only one valence within a single participant's testing. The trial by trial switches of valence in the current experiments might have been too fast and frequent to allow an affective stimulation to unfold a sufficient impact. Maybe a more continuous presentation of affect for example in a blocked form would rather make it possible for affective influences on executive control measures to take place. However, it has to be noted that PSI theory

considers affect switches to be necessary to allow the four systems to work together efficiently what would contradict the earlier suggested, more consistent mode of affect presentation.

Restrictions of the paradigm

The choice of task cues might be of some importance for backward inhibition effects. Already Arbuthnott (2005; see also Hübner et al., 2003) demonstrated that the cue type can influence backward inhibition. Also the overlapping of cue and target seems to play a role. Unaware of Druey and Hübner's (2007) paper during data collection their findings might offer an explanation *ex post* why in the current study's experiments general backward inhibition effects were not found consistently. Those authors could only find backward inhibition effects when cue and target were presented temporarily overlapping. A previously applied task set was not inhibited when target stimuli and cues were presented separately. The crucial position for this effect is $n-2$. The offered explanation is that with no overlap at position $n-2$ both irrelevant task sets are inhibited at position $n-1$. Therefore ABA and CBA sequences with no overlap should show nearly the same reaction times as ABA sequences with an overlap - what they did. In the current study's experiments 2, 4, and 5 (at least for random feedback) no significant backward inhibition effects were found, differences between ABA and CBA sequences were often very small. Also, in all these experiments cue and target were presented separately. In experiment 3.1 and partly in experiment 6.1 significant backward inhibition effects were found and in those two experiments cue and target were presented in an overlapping mode inasmuch as the intrinsic cuing in experiment 6.1 can be regarded as a cue target overlap. So far the results are in line with Druey and Hübner's (2007) findings. However, some findings do not fit within this explanation. In experiments 1 and 5.1 a significant backward inhibition effect was found without a cue target overlap. And in experiment 3 (cue = valent prime) with a total cue target overlap a significant backward inhibition could have been expected, but it was not observed. Nevertheless, Druey and Hübner's (2007) assumptions should be considered for future experiments.

Regarding the fact that switch costs represent exogenous and endogenous processes (see paragraphs 1.1.2 Task switching paradigm and 1.1.3 Assumed processes underlying switch costs) the length of the cue target interval used in the current experiments might be of some importance. Preparation intervals of 600ms allowed the maximal reduction of switch costs (Rogers & Monsell, 1995). This means all endogenous processes can be executed within this time span. The remaining switch costs are only representing the exogenous processes that can

only be executed with target onset. The CTI in the current experiments was always 500ms (except experiments 6.1 and 6.2). All influences of affect on executive functions could have happened within that time span resulting in remaining switch costs that are uninfluenced by affect because exogenous processes are not influenced by affect. As a consequence, variations in preparation time caused by affect are not represented in the measured switch costs anymore. Therefore it could only be stated that with the paradigm that was used in the reported experiments an influence of affect on exogenous processes included in switch costs can be negated. Whether endogenous processes are influenced by affect cannot be clarified with the results at hand following this rationale. Therefore, future experiments should test the influence of affect on conventional switch costs with shorter CTIs. With such a modification it can be expected that executive processes have also to be executed after target onset and therefore also within the measured reaction time. However, please note that in experiment 6.2 something similar was already tested. With the intrinsic cueing of tasks a cue target interval does not exist anymore and preparation as usual is not possible anymore. Influences of affect should have been visible within the different switch costs but positive and negative switch costs were more similar than ever. Of course the long presentation time of feedback after every trial (1000ms) might have been used for preparation (see also paragraph 4.2.1. Significant interactions) Therefore, experiments with shorter CTIs are absolutely necessary. Both assumptions presented at the end of this paragraph as restrictions of the paradigm allow questioning whether the paradigm that was used was able to measure backward inhibition effects and switch costs adequately. In general it can be stated that backward inhibition effects were found in a sufficient amount of analyses and that switch costs reached significance in all experiments. Of course whether the measured switch costs still represent exogenous processes or not can still be questioned.

Summing-up this paragraph some technical corrections and adjustments are offered in order to increase the possibility of affect to influence executive functions. However, in general it can be assumed that affective stimulation worked and executive functions were measured with switch costs and backward inhibition effects because main effects of valence, switch costs and the backward inhibition effect were found (see further above paragraph 4.1 Main Effects of the Backward Inhibition Effect, Switch Costs, and Valence). With that general assumption two more conclusions can be drawn from the current study based on theoretical considerations. Firstly, backward inhibition effects and switch costs are no measures of

executive control and secondly, affect does not influence executive functions. These two issues will now be discussed further.

4.4.2 Theoretical considerations

Backward inhibition effects and switch costs do not measure executive functions

It can be hypothesised that the measures that were used in the current experiments, switch costs and backward inhibition effects do not measure what they are supposed to. For example it is possible to question whether switch costs are an appropriate measure for executive control functions at all. This would challenge a very influential and well established line of research that started nearly a hundred years ago in 1927 with Jersild's description of "shift loss". It has already been presented and discussed earlier (see paragraph 1.1.3 Assumed processes underlying switch costs) that switch costs include a lot more processes besides the processes of interest, the endogenous processes. Therefore the idea of switch costs not measuring executive functions is not too farfetched. Already other researchers have commented on that topic like Meiran and colleagues (2000) who wrote that switch costs "certainly cannot be taken as a measure of executive functioning" (p. 250). According to these authors this perspective is supported especially by the fact that dissipating seems to have a main share in switch costs. Also the same authors assumed that there are paradigm specific effects in task switching. Already little changes in the paradigm can produce great differences. Important elements seem to be the tasks themselves, the difficulty of the tasks, the nature of the cues if cues are used, and task sequencing.

Concerning switch costs it has already been mentioned that maybe other measures would be better indicators for executive functions. Mayr and Kliegl (2003) demonstrated that switch costs can be split into cue switch and task switch costs. The cue switch costs were assumed to be a better indicator of executive functions. In experiment 3 three different cues per task were used which allowed to analyse cue switch costs and task switch costs. The rationale is to differentiate the non-switch trials that are used to calculate ordinary switch costs into trials with and without a cue switch. Normally, non-switch trials do not include a cue switch. This difference is normally also assumed to add to the size of switch costs because switch trials always need a cue switch. However, it has to be noted that in experiment 3 the frequency of those three different task pairs differed greatly (non-switch trials without cue switch $p = .09$; non-switch trials with cue switch $p = .23$; switch trials $p = .68$). Nonetheless, an analysis was

carried out to collect more information that might be useful for future experiments. Instead of switch costs cue switch and task switch costs were calculated. Cue switch costs are the difference between non-switch trials without a cue switch and non-switch trials with a cue switch. Task switch costs are the difference between switch trials that always require a cue switch and the non-switch trials with a cue switch. The analysis of variance (ANOVA) included the variables switch (non-switch trials without a cue switch, non-switch trials with a cue switch, or switch trials) and valence (positive, neutral, or negative). The valence factor was again split into the two contrasts positive-neutral and negative-neutral. Results showed significant cue switch costs of 303ms ($F(1,21) = 97.39, p < .01$) and significant task switch costs of 238ms ($F(1,21) = 76.36, p < .01$). Of major interest were the interactions with the two contrasts. Whereas the cue switch costs interacted significantly with both contrasts (positive-neutral: $F(1,21) = 5.73, p < .03$; negative-neutral: $F(1,21) = 5.15, p < .04$) task switch costs did not interact (both F 's < 1). Task switch costs hardly differed (positive: 230ms; neutral: 230ms; negative: 255ms) but cue switch costs of 380ms after a neutral cue were large compared to after a positive (253ms) and a negative cue (277ms). Assuming that cue switch costs represent endogenous processes and executive functions these results show that they are influenced and modulated by affect. Considering the results for task switch costs it can even be stated that endogenous processes are the only parts of switch costs that are modulated. These results give reason to believe that switch costs might be too flawed and include too many other processes apart from endogenous ones to be a good measure for executive functions. However, it has to be noted that all other experiments with only one cue per trial also had cue switch costs included in the measured ordinary switch costs. If cue switch costs are influenced by affect in such a dominating way this should have been visible in ordinary switch costs although the impact might have been less pronounced because also uninfluenced task switch costs are included in those switch costs.

Concerning backward inhibition effects it has already been questioned whether they are an executive function at all (see paragraph 1.1.4 Backward inhibition effect). Therefore also backward inhibition effects might not have been the best measure to represent executive functions. Hence, an affective influence on executive functions with that measure would be difficult to detect in case an interaction between affect and executive control functions really exists.

A confirmation of the idea that backward inhibition effects and switch costs are not measuring executive functions can be found in a study by Moritz and colleagues (2004). Patients with obsessive-compulsive disorder worked through a task switching experiment. Switch costs and

backward inhibition effects were calculated. Two further groups were tested, a healthy control group and a mixed anxiety group. Prefrontal areas are supposed to be involved in the clinical picture of obsessive-compulsive disorder. Different results were expected for the obsessive-compulsive disorder group compared to the two other groups because executive functions are located in the prefrontal cortex. It was predicted that patients with an obsessive-compulsive disorder will have problems to disengage from rumination and therefore larger switch costs were expected. This clinical dysfunction is also supposed to be a disorder of disinhibition therefore smaller backward inhibition effects were expected. However, none of the expectations was met. The obsessive-compulsive disorder patients did not show differences concerning switch costs and backward inhibition effects although they showed slowed down general reaction times.

Affect does not influence executive functions

The definite conclusion that is also possible is that affect does not influence executive functions at all. This would imply that affective stimulation worked and that backward inhibition effects and switch costs were measured and are appropriate measures of executive control functions. Influences of valence on the two measures of executive functions were extremely weak and inconsistent therefore a modulating influence of affect on those basic human functions measured with the task switching paradigm must be denied. This hypothesis is supported by some studies that also failed to observe an influence of affective stimulation on executive functions. For example Finkelmeyer, Kellermann, Mathiak, and Reske (2009) tested if odour can influence cognitive control measured with the Stroop task. Aversive and neutral odours could not influence Stroop costs in a significant and consistent way. Brain activities recorded with fMRT were also not modulated by the valent odours. Also the results of Dreisbach's study (2006) seem to support the conclusion partly. The difficulties to find the predicted effects in that study show that affective influences on executive control functions or parts of it are not easy to measure. The reduction of maintenance capability under mild positive affect was only achieved after distractors were included in task sequences in the second experiment.

4.5 Synopsis and Outlook

The nine presented experiments in the current study show that backward inhibition effects are hardly influenced by affective stimulation. The same applies for switch costs. They seem to be even more robust against affective influences.

The theoretical conclusion could be that executive functions are not influenced by affect. That would put an end to this line of research. However, it can also be concluded that the lack of significant interactions results from the two measures backward inhibition effects and switch costs. Other measures might be better indicators of executive functions and therefore also able to represent affective influences on those functions.

Besides these two more radical conclusions it was also discussed that maybe slight changes and adjustments of the methods that were used might increase the probability to detect affective influences on executive control functions. For example using shorter CTIs seems to be promising enough because this maximises the amount of endogenous processes being measured with switch costs after target onset. For backward inhibition analyses it might be helpful to make sure that cue and target are presented in an overlapping manner to increase the probability to measure those effects at all. The results of Dreisbach (2006) further suggest using global instead of specific switch costs as a measure because the maintenance capability that might be influenced by affect is only represented in global switch costs. It is also possible to adjust the presentation or the modality of the affective stimuli. Maybe a blockwise presentation of different affects or using valence only as a between-subjects factor is a better method to present affect. Furthermore, affective sounds or words could provide a better stimulation.

Summing up the current study with the presented experiments and referring to the title of this study it can be stated that affective stimulation in terms of primes, cues, and feedback was not able to modulate executive functions measured with specific switch costs and the backward inhibition effect.

5. References

- Ach, N. (1910). *Über den Willensakt und das Temperament*. Leipzig: Quelle & Meyer.
- Adolphs, R. & Damasio, A.R. (2001). The interaction of affect and cognition: A neurobiological perspective. In: J.P. Forgas (Eds.), *Handbook of Affect and Social Cognition* (pp. 27-49). Mahwah, NJ: Erlbaum.
- Albert, J. López-Martín, S., & Carretié, L. (2009). Emotional context modulates response inhibition: Neural and behavioural data. *NeuroImage*, (in press).
- Allport, A. (1987). Selection for action: Some behavioral and neurophysiological considerations of attention and action. In H. Heuer & A.F. Sanders (Eds.), *Perspectives on perception and action* (pp. 395-419). Hillsdale, NJ: Erlbaum.
- Allport, A., Styles, E.A. & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umiltà & M. Moscovitch (Eds.), *Attention and performance XV* (pp. 421-452). Cambridge, MA: MIT.
- Arbuthnott, K. (2005). The Influence of Cue Type on Backward Inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 31, 1030-1042.
- Arbuthnott, K. & Frank, J. (2000). Executive control in set switching: Residual switch cost and task-set inhibition. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, 54, 33-41.
- Ashby, F.G., Isen, A.M., & Turken, U. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review*, 106, 520-550.
- Aycicegi-Dinn, A., Dinn, W.M., & Caldwell-Harris, C.L. (2009). Obsessive-Compulsive Personality Traits: Compensatory Response to Executive Function Deficit? *International Journal of Neuroscience*, 119, 600-608.
- Baddeley, A. (1986). *Working memory*. Oxford: Clarendon.
- Baddeley, A. (1992). Working memory. *Science*, 255, 556-559.
- Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, 4, 417-423.
- Baddeley, A. (2007). *Working memory, thought, and action*. Oxford: University Press.
- Baker, S.C., Frith, C.D., & Dolan, R. J. (1997). The interaction between mood and cognitive function studied with PET. *Psychological Medicine*, 27, 565-578.
- Barkley, R. A. (1997). Behavioral inhibition, sustained attention and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, 121, 65-94.

- Barkley, R. A. (2001). The executive functions and self-regulation: An evolutionary neuropsychological perspective. *Neuropsychology Review*, *11*, 1–29.
- Barsalou, L.W., Niedenthal, P.M., Barbey, A.K., & Ruppert, J.A. (2003). Social embodiment. In B.H. Ross (Ed.), *The psychology of learning and motivation*, Vol. 43 (pp. 43–92). San Diego, CA: Academic Press.
- Baumann, N. & Kuhl, J. (2005). Positive affect and flexibility: Overcoming the precedence of global over local processing of visual information. *Motivation and Emotion*, *29*, 123–134.
- Bayliss, D.M. & Roodenrys, S. (2000). Executive processing and attention deficit hyperactivity disorder: An application of the supervisory attentional system. *Developmental Neuropsychology*, *17*, 161–180.
- Beatty, J. (1995). *Principles of behavioral neuroscience*. Dubuque, IA: Brown & Benchmark.
- Ben-Ze'ev, A. (2000). *The subtlety of emotions*. Cambridge, Mass.: MIT Press.
- Bjorklund, D.F. & Harnishfeger, K.K. (1995). The evolution of inhibition mechanisms and their role in human cognitive behavior. In F. N. Dempster & C. J. Brainerd (Eds.), *Interference and inhibition in cognition* (pp. 141–173). New York: Academic Press.
- Bless, H. (1997). *Stimmung und Denken*. Bern: Hans Huber.
- Bless, H. (2001). Mood and the use of general knowledge structures. In L.L. Martin & G.L. Clore (Eds.), *Theories of mood and cognition: A user's guidebook* (pp. 9–26). Mahwah, N.J.: Lawrence Erlbaum.
- Bobrow, D.G. & Norman, D.A. (1975). Some principles of memory schemata. In D. Bobrow & A. Collins (Eds.), *Representation and understanding: Studies in cognitive science* (pp. 131–150). New York: Academic Press.
- Bodenhausen, G.V., Kramer, G.P., & Süsler, K. (1994). Happiness and stereotypic thinking in social judgment. *Journal of Personality and Social Psychology*, *66*, 621–632.
- Bodenhausen, G.V., Sheppard, L.A. & Kramer, G.P. (1994). Negative effect and social judgement: the differential impact of anger and sadness. *European Journal of Social Psychology*, *24*, 45–62.
- Bower, G.H. (1981). Mood and memory. *American Psychologist*, *36*, 129–148.
- Bower, G.H., Gilligan, S.G., & Monteiro, K.P. (1981). Selectivity of learning caused by affective states. *Journal of Experimental Psychology: General*, *110*, 451–473.
- Bradley, M.M., Cuthbert, B.N., & Lang, P.J. (1999). Affect and startle reflex. In M.E. Dawson, A.M. Schell, & A.H. Böhmelt (Eds.), *Startle modification* (pp.157–183). Cambridge, UK: Cambridge University Press.

- Bradley, M.M., Lang, P.J., Cuthbert, B.N. (1993). Startle reflex habituation in human beings: Emotion, novelty, and context. *Behavioral Neuroscience*, *107*, 970-980.
- Clore, G.L., Wyer, R.S. Jr., Dienes, B., Gasper, K., Gohm, C., & Isbell, L. (2001). Affective feelings as feedback: Some cognitive consequences. In L.L. Martin & G.L. Clore (Eds.), *Theories of mood and cognition: A user's guidebook* (pp. 27-62). Mahwah, N.J.: Lawrence Erlbaum.
- Cohen, J.D., Braver, R.M., & Brown, J.W. (2002). Computational perspectives on dopamine function in prefrontal cortex. *Current Opinion in Neurobiology*, *12*, 223-229.
- Colzato, L.S., van Wouwe, N.C., & Hommel, B. (2007). Feature binding and affect: Emotional modulation of visuo-motor integration. *Neuropsychologia*, *45*, 440-446.
- Davidson, R.J. (1992). Prolegomenon to the structure of emotions: Gleanings from neuropsychology. *Cognition and Emotion (Special Issue)*, *6*, 245-268.
- De Jong, R. (2000). An intention-activation account of residual switch costs. In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 357-376). Cambridge, MA: MIT Press.
- De Jong, R., Berendsen, E., & Cools, R. (1999). Goal neglect and inhibitory limitations: Dissociable causes of interference effects in conflict situations. *Acta Psychologica*, *Vol 101*, 379-394.
- Dreher, J.-C., Kohn, P.D., & Berman, K. (2001). The neural basis of backward inhibition during task switching. *NeuroImage*, *6*, part 2.
- Dreisbach, G. (2006). How positive affect modulates cognitive control: The costs and benefits of reduced maintenance capability. *Brain and Cognition*, *60*, 11-19.
- Dreisbach, G. & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 343-353.
- Dreisbach, G., Müller, J., Goschke, T., Schulze, K., Lesch, K.-P., & Brocke, B. (2005). Dopamine and cognitive control: the influence of spontaneous eyeblink rate and dopamine gene polymorphisms on perseveration and distractibility. *Behavioral Neuroscience*, *119*, 483-490.
- Druey, M.D. & Hübner, R. (2007). The role of temporal cue-target overlap in backward inhibition under task switching. *Psychonomic Bulletin & Review*, *14*, 749-754.
- Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion (Special Issue)*, *6*, 169-200.

- Emmons, R.A. & Kaiser, H.A. (1996). Goal orientation and emotional well-being: linking goals and affect through the self. In L.L. Martin & A. Tesser (Eds.), *Striving and feeling: Interactions among goals, affect, and self-regulation* (pp. 79-98). Mahwah, N.J.: Lawrence Erlbaum.
- Estrada, C.A., Isen, A.M. & Young, M.J. (1997). Positive affect facilitates integration of information and decreases anchoring in reasoning among physicians. *Organizational Behavior and Human Decision Processes*, 72, 117-135.
- Fales, C.L., Vanek, Z.F., & Knowlton, B.J. (2006). Backward inhibition in Parkinson's disease. *Neuropsychologica*, 44, 1041-1049.
- Fiedler, K. (1988). Emotional mood, cognitive style, and behavior regulation. In K. Fiedler & J. Forgas (Eds.), *Affect, cognition, and social behavior* (pp.100-119). Toronto: Hogrefe International.
- Finkelmeyer, A., Kellermann, T., Mathiak, K. & Reske M. (2009). Keine Beeinflussung kognitiver Kontrolle im Stroop-Task durch olfaktorisch induzierte Stimmung: eine FMRT Studie. *Poster presented at the 51. TeaP (Tagung experimentell arbeitender Psychologen) in Jena, March 2009*.
- Forgas, J.P. (1989). Mood effects on decision making strategies. *Australian Journal of Psychology*, 41, 197-214.
- Forgas, J.P. (1994). The role of emotion in social judgements: an introductory review and an Affect Infusion Model (AIM). *European Journal of Social Psychology*, 24, 1-24.
- Forgas, J.P. (2001). The affective infusion model (AIM): An integrative theory of mood effects on cognition and judgment. In L.L. Martin & G.L. Clore (Eds.), *Theories of mood and cognition: A user's guidebook* (pp. 99-134). Mahwah, N.J.: Lawrence Erlbaum.
- Gade, M. & Koch, I. (2005). Linking inhibition to activation in the control of task sequences. *Psychonomic Bulletin & Review*, 12, 530-534.
- Garner, J.K. (2009). Conceptualizing the relations between executive functions and self-regulated learning. *Journal of Psychology*, 143, 405-426.
- Goschke, T. (2000). Intentional Reconfiguration and involuntary persistence in task set switching. In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 331-355). Cambridge, MA: MIT Press.
- Gruber, O. & Goschke, T. (2004). Executive control emerging from dynamic interactions between brain systems and mediating language, working memory and attentional processes. *Acta Psychologica*, 115, 105-121.

- Hänze, M. (1996). Zum Einfluß von Stimmung auf analytische und intuitive Urteilstendenzen beim „False-Fame“-Effekt. *Zeitschrift für Psychologie*, 204, 149-166.
- Hänze, M. (1997). Mood and the Stroop interference effect. *Psychologische Beiträge*, 39, 229-235.
- Hommel, B. (1998). Event files: Evidence for automatic integration of stimulus-response episodes. *Visual Cognition*, 5, 183-216.
- Hommel, B. (2004). Event files: Feature binding in and across perception and action. *Trends in Cognitive Sciences*, 8, 494-500.
- Hübner, M., Dreisbach, G., Haider, H., & Kluwe, R.H. (2003). Backward inhibition as a means of sequential task-set control: Evidence for reduction of task competition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29, 289-297.
- Hyman, S.E. & Nestler, E.J. (1993). *The molecular foundations of psychiatry*. Washington, D.C.: American Psychiatric Press.
- Isen, A.M. (1999). Positive affect. In T. Dalgleish & M. Power (Eds.), *The handbook of cognition and emotion* (pp.521-539). New York: Wiley.
- Isen, A.M. (2000). Positive affect and decision making. In M.Lewis & J. Haviland-Jones (Eds.), *Handbook of emotion* (pp. 417-435). New York: Guilford Press.
- Isen, A.M., Shalke, T.E., Clark, M., & Karp, L. (1978). Affect, accessibility of material in memory, and behavior: A cognitive loop? *Journal of Personality and Social Psychology*, 36, 1-12.
- Isen, A.M. & Daubman, K. A. (1984). The influence of affect on categorization. *Journal of Personality and Social Psychology*, 47, 1206-1217.
- Isen, A.M., Daubmann, K.A. & Nowicki, G.P. (1987). Positive affect facilitates creative problem solving. *Journal of Personality and Social Psychology*, 52, 1122-1131.
- Jersild, A.T. (1927). Mental set and shift. *Archives of Psychology, Whole No 89*.
- Kazén, M. & Kuhl, J. (2005). Intention memory and achievement motivation: Volitional facilitation and inhibition as a function of affective contents of need-related stimuli. *Journal of Personality and Social Psychology*, 89, 426-448.
- Kimberg, D.Y., D’Esposito, M., & Farah, M.J. (1997). Effects of bromocriptine on human subjects depend on working memory capacity. *NeuroReport*, 8 3581-3585.
- Kluwe, R.H. (1995). Steuerung von Denkvorgängen in Modellen menschlicher Informationsverarbeitung. In M. Cranach (Eds.), *Freiheit des Entscheidens und Handelns* (pp. 151-170). Heidelberg: Asanger.

- Kluwe, R.H. (1997). Intentionale Steuerung kognitiver Prozesse. *Kognitionswissenschaft*, 6, 53-69.
- Koch, I. & Allport, A. (2006). Cue-based preparation and stimulus-based priming of tasks in task switching. *Memory & Cognition*, 34, 433-444.
- Koch, I., Gade, M., & Philipp, A.M. (2004). Inhibition of Response Mode in Task Switching. *Experimental Psychology*, 51, 52-58.
- Koch, I., Gade, M., Schuch, S., & Philipp, A.M. (in press). The role of inhibition in task switching - A review. *Psychonomic Bulletin & Review*.
- Koechlin, E., Ody, C. & Kouneiher, F. (2003). The architecture of cognitive control in the human prefrontal cortex. *Science*, 302, 1181-1185.
- Kofman, O., Meiran, N., Greenberg, E., Balas, M., & Cohen, H. (2006). Enhanced performance on executive functions associated with examination stress: Evidence from task-switching and Stroop paradigms. *Cognition & Emotion*, Aug2006, 20, 577-595.
- Koole, S.L. & Kuhl, J. (2008). Dealing with unwanted feelings: The role of affect regulation in volitional action control. In J.Y. Shah & W.L. Gardner (Eds.), *Handbook of motivation science* (pp. 295-307). New York, N.Y.: Guilford Press.
- Kray, J. & Lindenberger, U. (2000). Adult age differences in task switching. *Psychology and Aging*, 15, 126-147.
- Kuhl, J. (1983). Emotion, Kognition und Motivation: II. Die funktionale Bedeutung der Emotionen für das problemlösende Denken und für das konkrete Handeln. *Sprache und Kognition*, 4, 228- 253.
- Kuhl, J. (1984). Volitional aspects of achievement motivation and learned helplessness: Toward a comprehensive theory of action-control. *Progress in Experimental Personality Research*, 13, 99-171.
- Kuhl, J. (1996). Who controls whom when 'I control myself'? *Psychological Inquiry*, 7, 61-68.
- Kuhl, J. (2000). A functional-design approach to motivation and self-regulation: The dynamics of personality systems and interactions. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 111-169). San Diego, CA: Academic Press.
- Kuhl, J. (2001). *Motivation und Persönlichkeit*. Göttingen: Hogrefe.
- Kuhl, J. & Kazén, M. (1999): Volitional facilitation of difficult intentions: Joint activation of intention memory and positive affect removes Stroop Interference. *Journal of Experimental Psychology: General*, 128, 382-399.

- Lang, P.J. (1995). The emotion probe: Studies of motivation and attention. *American Psychologist*, *50*, 372-385.
- Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (1997). Motivated attention: Affect, Activation, and action. In P.J. Lang, R.F. Simons, & M.T. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 97-135). Mahwah, N.J.: Lawrence Erlbaum.
- Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (2005). *International affective picture system (IAPS): Digitized photographs, instruction manual and affective ratings. Technical Report A-6*. University of Florida, Gainesville, FL.
- Lantermann, E. D. (1983). Kognitive und emotionale Prozesse beim Handeln. In H. Mandl & G.L. Huber (Eds.), *Emotion und Kognition* (pp. 248-281). München: Urban & Schwarzenberg.
- Larsen, R.J. (2000). Toward a science of mood regulation. *Psychological Inquiry*, *11*, 129-141.
- Lazarus, R.S. (1984). On the primacy of cognition. *American Psychologist*, *39*, 124-129.
- Lazarus, R.S. (1991). *Emotion and adaptation*. New York: Oxford University Press.
- Lee, A.Y. & Sternthal, B. (1999). The effects of positive mood on memory. *Journal of Consumer Research*, *26*, 115-127.
- Levine, L. J. & Pizarro, D.A. (2004). Emotion and memory research: A grumpy overview. *Social Cognition*, *22*, 530-554.
- Luria, A. R. (1973). *The working brain: An introduction to neuropsychology*. New York: Basic Books.
- Logan, G.D. (1985). Executive control of thought and action. *Acta Psychologica*, *60*, special issue: *Action, attention and automaticity*, 193-210.
- Mayr, U. (2002). Inhibition of action rules. *Psychonomic Bulletin & Review*, *9*, 93-99.
- Mayr, U. & Keele, S.W. (2000). Changing internal constraints on action: The role of backward inhibition. *Journal of Experimental Psychology: General*, *129*, 4-26.
- Mayr, U. & Kliegl R. (2003). Differential effects of cue changes and task changes on task-set selection costs. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 362-372.
- Meiran, N. (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 1423-1442.

- Meiran, N. (2000). Reconfiguration of stimulus task-sets and response task-sets during task switching. In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 377-399). Cambridge, MA: MIT Press.
- Meiran, N. & Chorev, Z. (2005). Phasic alertness and the residual task-switching cost. *Experimental Psychology*, *52*, 109-124.
- Meiran, N., Chorev, Z., & Sapir, A. (2000). Component processes in task switching. *Cognitive Psychology*, *41*, 211-253.
- Meyer, W.-U., Reisenzein, R., & Schützwohl, A. (2001). *Einführung in die Emotionspsychologie, Band I*. Bern: Hans Huber.
- Mitchell, R.L.C. & Phillips, L.H. (2007). The psychological, neurochemical and functional neuroanatomical mediators of the effects of positive and negative mood on executive functions. *Neuropsychologia*, *45*, 617-629.
- Mohlman, J., Mangels, J., & Craske, M.G. (2004). The Spider Phobia Card Sorting Test: An investigation of phobic fear and executive functioning. *Cognition & Emotion*, *18*, 939-960.
- Moritz, S., Hübner, M., & Kluwe, R. (2004). Task switching and backward inhibition in obsessive-compulsive disorder. *Journal of Clinical & Experimental Neuropsychology*, *26*, 677-683.
- Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, *7*, 134-140.
- Monsell, S., Yeung, N., & Azuma, R. (2000). Reconfiguration of task-set: Is it easier to switch to the weaker task? *Psychological Research*, *63*, 250-264.
- Nelson, H.E. (1976). A modified card sorting test sensitive to frontal lobe defects. *Cortex*, *12*, 313-324.
- Niedenthal, P.M. (2007). Embodying emotion. *Science*, *316*, 1002-1005.
- Niedenthal, P.M., Winkielman, P., Mondillon, L., & Vermeulen, N. (2009). Embodiment of emotion concepts. *Journal of Personality and Social Psychology*, *96*, 1120-1136.
- Norman, D.A. & Shallice, T. (1986). Attention to action: Willed and automatic control of behaviour. In R.J. Davidson, G.E. Schwartz & D. Shapiro (Eds.), *Consciousness and self regulation* (Vol. 4, pp. 1-18). New York: Plenum.
- Oaksford, M., Morris, F., Grainger, B., & Williams, J.M.G. (1996). Mood, reasoning, and central executive processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 476-492.
- Oatley, K., & Johnson-Laird, P.N. (1987). Towards a cognitive theory of emotions. *Cognition and Emotion*, *1*, 29-50.

- Oatley, K., & Johnson-Laird, P.N. (1996). The communicative theory of emotions: Empirical tests, mental models, and implications for social interaction. In L.L. Martin & A. Tesser (Eds.), *Striving and feeling: Interactions among goals, affect, and self-regulation* (pp. 363-393). Mahwah, N.J.: Lawrence Erlbaum.
- Oosterwijk, S., Rotteveel, M., Fischer, A.H., & Hess, U. (2009). Embodied emotion concepts: How generating words about pride and disappointment influences posture. *European Journal of Social Psychology, 39*, 457-466.
- Otto, J.H., Euler, H.A., & Mandl, H. (2000). Begriffsbestimmung. In J.H. Otto, H.A. Euler, & H. Mandl (Eds.), *Emotionspsychologie: Ein Handbuch* (pp.11-18). Weinheim: Beltz.
- Owen, A.M., Roberts, A.C., Hodges, J.R., Summers, B.A., Polkey, C.E., & Robbins, T.W. (1993) Contrasting mechanisms of impaired attentional set-shifting in patients with frontal lobe damage or Parkinson's disease. *Brain, 116*, 1159–1175.
- Pauli, P. & Birbaumer, N. (2000). Psychophysiologische Ansätze. In J.H. Otto, H.A. Euler, & H. Mandl (Eds.), *Emotionspsychologie: Ein Handbuch* (pp.75-84). Weinheim: Beltz.
- Paulitzki, J.R., Risko, E.F., Oakman, J.M., & Stolz, J.A. (2008). Doing the unpleasant: How the emotional nature of a threat-relevant task affects task-switching. *Personality and Individual Differences, 45*, 350-355.
- Philipp, A.M., & Koch, I. (2006). Task inhibition and task repetition in task switching. *European Journal of Cognitive Psychology, 18*, 624-639.
- Phillips, L.H., Bull, R., Adams, E. & Fraser, L. (2002). Positive Mood and executive functions: Evidence from Stroop and fluency tasks. *Emotion, 2*, 12-22.
- Phillips, L.H., Smith, L., & Gilhooly, K.J. (2002). The effects of adult aging and induced positive and negative mood on planning. *Emotion, 2*, 263-272.
- Rogers, R.D. & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124*, 207-231.
- Rothermund, K. (2003). Motivation and attention: Incongruent effects of feedback on the processing of valence. *Emotion, 3*, 223-238.
- Rubinstein, J.S., Meyer, D.E., & Evans, J.E. (2001). Executive control of cognitive processes in task switching. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 763-797.
- Russel, J.A. (2003). Core affect and psychological construction of emotion. *Psychological Review, 110*, 145-172.

- Schuch, S. & Koch, I. (2003). The role of response selection for inhibition of task sets in task shifting. *Journal of Experimental Psychology: Human Perception and Performance*, 29, 92-105.
- Schwarz, N. (1990). Feelings as information: Informational and motivational functions of affective states. In: E.T. Higgins & R.M. Sorrentino (Eds.), *Handbook of Motivation and Cognition, Vol. 2* (pp. 527-561). New York: Guilford.
- Schwarz, N. & Clore, G.L. (1983). Mood, misattribution, and judgments of well-being: Informative and directive functions of affective states. *Journal of Personality and Social Psychology*, 45, 513-523.
- Schwarz, N. & Clore, G.L. (2003). Mood as information: 20 years later. *Psychological Inquiry*, 14, 296-303.
- Smith, E.E. & Jonides, J. (1999). Storage and executive processes in the frontal lobes. *Science*, 283, 657-661.
- Snyder, M. & White, P. (1982). Moods and memories: Elation, depression, and the remembering of the events of one's life. *Journal of Personality*, 50, 149-167.
- Sohn, M.-H. & Anderson, J.R. (2001). Task preparation and task repetition: Two-component model of task switching. *Journal of Experimental Psychology: General*, 130, 764-778.
- Sokolowski, K. (2002). Emotion. In J. Müsseler & W. Prinz (Eds.), *Allgemeine Psychologie* (pp.337-384). Heidelberg: Spektrum Akademischer Verlag.
- Spector, A. & Biederman, I. (1976). Mental set and mental shift revisited. *American Journal of Psychology*, 89, 669-679.
- Spies, K., Hesse, F., & Hummitzsch, C. (1996). Mood and capacity in Baddeley's model of human memory. *Zeitschrift für Psychologie mit Zeitschrift für angewandte Psychologie*, 204, 367-381.
- Steinhauser, M., Maier, M., & Hübner, R. (2007). Cognitive Control Under Stress: How Stress Affects Strategies of Task-Set Reconfiguration. *Psychological Science*, 18, 540-545.
- Storbeck, J. & Clore, G.L. (2008). The affective regulation of cognitive priming. *Emotion*, 8, 208-215.
- Tranel, D., Anderson, S. W. & Benton, A. (1994). Development of the concept of 'executive function' and its relationship to the frontal lobes. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (pp. 125-148). Amsterdam: Elsevier.
- Tukey, J.W. (1977). *Exploratory data analysis*. Reading, MA: Addison-Wesley.

- Uekermann, J., Channon, S., Lehmkämer, C., Abdel-Hamid, M., Vollmoeller, W., & Daum, I. (2008). Executive function, mentalizing and humor in major depression. *Journal of the International Neuropsychological Society, 14*, 55-62.
- Verbruggen, F., Liefoghe, B., Szmalec, A., & Vandierendonck, A. (2005). Inhibiting Responses When Switching: Does it Matter? *Experimental Psychology, 52*, 125-130.
- Verbruggen, F., Liefoghe, B., Szmalec, A., & Vandierendonck, A. (2006). Selective stopping in task switching: The role of response selection and response execution. *Experimental Psychology, 53*, 48-57.
- Walsh, K.W. (1978). *Neuropsychology: A clinical approach*. Edinburgh: Churchill Livingstone.
- Wang, Y.-M. & Guo, D.-J. (2008). The effects of positive emotions on task switching. *Acta Psychologica Sinica, 40*, 301-306.
- Wang, L., LaBar, K.S., Smoski, M., Rosenthal, M.Z., Dolcos, F., Lynch, T.R., Krishnan, R.R., & McCarthy, G. (2008). Prefrontal mechanisms for executive control over emotional distraction are altered in major depression. *Psychiatry Research: Neuroimaging, 163*, 143-155.
- Waszak, F., Hommel, B., & Allport, A. (2003). Task-switching and long-term priming: Role of episodic stimulus-task bindings in task-shift costs. *Cognitive Psychology, 46*, 361-413.
- Wong, J. & Leboe, J.P. (2009). Distinguishing between inhibitory and episodic processing accounts of switch-cost asymmetries. *Canadian Journal of Experimental Psychology, 63*, 8-23.
- Wood, J., Mathews, A., & Dalgleish, T. (2001). Anxiety and cognitive inhibition. *Emotion, 1*, 166-181.
- Wundt, W. (1896): *Grundriss der Psychologie*. Leipzig: Engelmann.
- Yu, F., Yuan, J., & Luo, Y.-J. (2009). Auditory-induced emotion processes of response inhibition: an event-related potential study. *Cognitive Neuroscience and Neuropsychology, 20*, 25-30.
- Zajonc, R.B. (1984). On the primacy of affect. *American Psychologist, 39*, 117-123.

6. Summary

In everyday life it is a common observation that people are influenced in their behaviour, their actions and performances by affect, emotions, and mood. Emotional influences on one's life are also a personal experience. Everybody can report on situations when emotional and affective conditions had an impact on relationships, the job, everyday actions, routines, thoughts etc. However, the question is whether that general human experience can be measured and represented within a psychological experiment. The aim of the current study was to investigate influences of affective stimulation on executive control functions.

The term executive functions subsumes a number of important human abilities and processes that allow action control, action selection, goal pursuit and the regulation and organisation of behaviour (Baddeley, 1986, 2007, Kuhl, 1984, 2000; Norman & Shallice, 1986). With the task switching paradigm (Jersild, 1927; Rogers & Monsell, 1995) and switch costs as the resulting measure parts of these executive functions can be represented. Switching between two different tasks (e.g. A and B) requires flexible and stable processing at the same time. Attention has to be shifted, tasks sets and response sets switched, and the execution has to be shielded against disturbing influences. A further component that might be important for task switching is the inhibition of the abandoned task set in order to execute a current task without interference. This kind of inhibition is called backward inhibition (Mayr & Keele, 2000) and can also be measured with a slightly changed task switching paradigm. Whereas switch costs are calculated as the difference between switch (e.g. AB) and non-switch trials (e.g. AA) backward inhibition effects require three-task-sequences. The reaction time of the last trial in ABA sequences is compared to the reaction time of the last trial in CBA sequences. A switch is executed in both cases but in an ABA sequence a recently executed task has to be reactivated. Inhibition of this task set (task A), formed to facilitate the execution of the second task in the triplet (task B) has to be overcome first when the last task (again task A) has to be executed again. Slowed down reaction times for ABA sequences compared to CBA sequences are the result. With those two measures, switch costs and backward inhibition effects executive functions can be represented adequately.

The affective stimulation in the current study was realised with affective pictures (from the IAPS, Lang et al., 2005) and feedback within the task switching paradigm. A vast amount of research dealing with influences of mood on different cognitive performances exists (see Isen, 1999, 2000; Levine & Pizarro, 2004 for reviews). However, the examined cognitive functions

are normally quite complex (e.g. creativity or making judgments) and mood as affective stimulation differs considerably from the short affective stimulation that was intended in the current study. Moods are long lasting, object-free, and of low intensity floating in the background whereas affect is short, of higher intensity and sometimes an action tendency is included. Therefore all explanatory models based on mood research are not useable to generate hypotheses for the current study. Also classical models of executive functions (see Baddeley, 1986, 2007; Norman & Shallice, 1986) do hardly include emotional or affective elements that allow deducing useful hypotheses. Therefore two quite different models were used, the first one rather being a personality model and a second model of neuropsychological and -physiological origin. The PSI theory (Kuhl, 1996, 2000, 2001) and the dopaminergic theory (Ashby et al., 1999; Dreisbach & Goschke, 2004) allowed deducing hypotheses about affective influences on switch costs and backward inhibition effects. Both theories predict smaller switch costs with positive affect compared to neutral affect due to a reduction of reaction times for switch trials. For positive affect PSI theory assumes facilitation for the difficult switch trials and the dopaminergic theory predicts enhanced flexibility that supports executing switch trials. A further but also more speculative prediction by PSI theory is larger switch costs with negative compared to neutral affect due to increased reaction times for switch trials because negative affect disturbs the connection between planning and executing systems. Concerning backward inhibition effects both theories predict smaller effects with positive compared to neutral affect. That is due to reduced reaction times for ABA sequences with positive affect. PSI theory assumes that positive affect helps to overcome once formed inhibition. The dopaminergic theory offers two explanations. Firstly, latencies can be reduced with positive affect because increased distractibility weakens inhibition or secondly, the positive affect weakens maintenance capability which also disturbs the forming of inhibition in the first place. Less inhibition used after the first trial in a triplet accelerates reaction times for the last trial because less inhibition has to be overcome before being able to execute the current task.

These hypotheses were tested in nine experiments. In the first four experiments affect was realised in terms of affective pictures from the IAPS (Lang et al., 2005) as primes that were irrelevant for task execution and presented before the tasks or as cues for the tasks. These experiments could not reveal a significant interaction as predicted by PSI theory and the dopaminergic theory although it was tried throughout the four experiments to intensify the focus on the valence information. In the end with the pictures as cues for the tasks the relevance was maximised. Afterwards feedback was used as the valent element. After every

task feedback was shown depending on accuracy and response speed. However, also with this manipulation a significant interaction as predicted could not be observed, at least not with random feedback when valence and performance were not confounded.

According to these results it could be concluded that affective stimulation does not influence executive control functions or that backward inhibition effects and switch costs do not measure executive functions at all. However, before such definite conclusions can be drawn some further possibilities were discussed that can explain at least parts of the null findings or give reasons why no affective modulation was detected. For example technical problems concerning the paradigm might be sorted out first. Or maybe the affective stimulation should be adjusted. These possible changes are recommended to be considered for future experiments.

7. Zusammenfassung

Aus dem täglichen Leben kennt jeder die Erfahrung, dass einen Emotionen und Stimmungen beeinflussen. Das emotionale Erleben beeinflusst zwischenmenschliche Beziehungen, die Arbeit, alltägliche Routinehandlungen, das Denken und die kognitive Leistungsfähigkeit. Das Ziel dieser Studie war es nun diese menschlichen Erfahrungswerte in ein psychologisches Experiment zu übertragen und sie dadurch messbar zu machen. Es wurde der Einfluss affektiver Stimulation auf exekutive Funktionen untersucht.

Unter dem Begriff exekutive Funktionen werden häufig viele verschiedene wichtige Funktionen und menschliche Fähigkeiten zusammengefasst. Diese Fähigkeiten ermöglichen Verhaltensregulation und -organisation, sowie Handlungskontrolle und Handlungsauswahl auszuüben (Baddeley, 1986, 2007; Kuhl, 1984, 2000; Norman & Shallice, 1986). Das so genannte Task-switching-Paradigma und die damit berechenbaren Wechselkosten (Jersild, 1927; Rogers & Monsell, 1995) erlauben es, Teile dieser exekutiven Funktionen abzubilden. Um zwischen zwei unterschiedlichen Aufgaben (z.B. A und B) zu wechseln wird eine flexible aber gleichzeitig auch stabile Verarbeitung benötigt. Aufmerksamkeit muss neu ausgerichtet werden, Aufgaben- und Antwortsets müssen gewechselt werden und die Bearbeitung der Aufgabe muss gegen störende Einflüsse abgeschirmt werden. Eine weitere Komponente die für das Wechseln zwischen Aufgaben wichtig ist, ist die Inhibition des Aufgabensets das gerade eben noch bearbeitet wurde. Mayr und Keele (2000) nannten diese Art der Inhibition „Backward Inhibition“. Durch kleinere Veränderungen am gewöhnlich verwendeten Task-switching-Paradigma können auch Daten zur Berechnung von Backward Inhibition Effekten erhoben werden. Wechselkosten werden aus der Differenz zwischen Aufgabenwechseln (z.B. AB) und Aufgabenwiederholungen (z.B. AA) gewonnen. Für die Berechnung von Backward Inhibition Effekten werden Reihen von jeweils drei Aufgaben benötigt. Die Reaktionszeit der letzten Aufgabe in einer ABA-Reihe wird mit der Reaktionszeit der letzten Aufgabe in einer CBA-Reihe verglichen. In beiden Fällen wird am Ende ein Aufgabenwechsel absolviert, jedoch muss in der ABA-Reihe eine erst kürzlich (nämlich am Anfang der Reihe) bearbeitete Aufgabe wieder reaktiviert und erneut bearbeitet werden. Das Aufgabenset von Aufgabe A wird bei der Bearbeitung von Aufgabe B inhibiert um deren Ausführung zu erleichtern. Diese Inhibition muss dann zuerst überwunden werden bevor Aufgabe A erneut am Ende der ABA-Reihe absolviert werden kann. Das verlangsamt die Reaktionszeiten von ABA-Reihen im

Vergleich zu CBA-Reihen. Die Abbildung von exekutiven Funktionen ist durch die beiden Maße Backward Inhibition Effekt und Wechselkosten gewährleistet.

Die affektive Stimulation wurde in der vorliegenden Studie durch affektive Bilder aus dem IAPS (Lang et al., 2005) und valentem Feedback verwirklicht. Es existiert eine Vielzahl von Forschungsergebnissen zu Einflüssen von Stimmung auf das Denken (siehe Übersichtsartikel von Isen, 1999, 2000; Levine & Pizarro, 2004). Jedoch wurden in diesem Forschungsgebiet meist recht komplexe Fähigkeiten wie Kreativität oder Urteilsfindung untersucht. Des Weiteren unterscheidet sich Stimmung als affektive Manipulation stark von den kurzen affektiven Stimulationen die in der vorliegenden Studie verwendet werden sollten. Stimmungen sind lang andauernd, objektfrei und haben lediglich eine schwache Intensität. Sie bilden eher einen längere Zeit gleich bleibenden Gefühlshintergrund für das menschliche Handeln und Fühlen. Affekt hingegen wirkt kürzer, ist von stärkerer Intensität und beinhaltet manchmal sogar Handlungstendenzen und -motivationen. Diese Unterschiede machen es unmöglich die Erklärungsmodelle der Stimmungsforschung auf Einflüsse kurzer affektiver Stimulation auf exekutive Funktionen zu übertragen. Auch aus den klassischen Modellen für exekutive Funktionen (siehe Baddeley, 1986, 2007; Norman & Shallice, 1986) lassen sich keine brauchbaren Hypothesen für die vorliegende Studie ableiten. Deshalb wurden zwei recht unterschiedliche Modelle zur Hypothesenbildung herangezogen. Die PSI Theorie (Kuhl, 1996, 2000, 2001) bietet ein Modell, das eher dem Bereich der Persönlichkeitspsychologie zu zuordnen ist. Die dopaminerge Theorie (Ashby et al., 1999; Dreisbach & Goschke, 2004) hingegen kommt aus der neuropsychologischen und -physiologischen Forschung. Beide Theorien sagen niedrigere Wechselkosten bei positivem Affekt im Vergleich zu neutralem Affekt voraus. Dieser Effekt soll vor allem durch eine Verringerung der Reaktionszeiten für Aufgabenwechsel zustande kommen. Die PSI Theorie führt das auf Bahnungseffekte durch positiven Affekt zurück, die dopaminerge Theorie auf erhöhte Flexibilität was in beiden Fällen die Bearbeitung der schwierigen Aufgabenwechseldurchgänge erleichtert und beschleunigt. Eine weitere, eher spekulative Vorhersage der PSI Theorie zu negativem Affekt besagt, dass sich die Wechselkosten im Vergleich zu neutralem Affekt erhöhen. Die Ursache dafür wird in der Störung der Bahnung zwischen planenden und ausführenden Systemteilen des Modells gesehen. Bezüglich Backward Inhibition Effekten sagen beide Theorien niedrigere Effekte mit positivem im Vergleich zu neutralem Affekt vorher aufgrund verringerter Reaktionszeiten für ABA-Reihen. Laut PSI Theorie kommt es zu diesen schnelleren Reaktionszeiten weil der positive Affekt hilft die aufgebaute Inhibition schneller zu überwinden. Die dopaminerge Theorie bietet zwei Erklärungen. Höhere Ablenkbarkeit

verursacht durch positiven Affekt verringert die Menge an eingesetzter Inhibition oder der positive Affekt schwächt die Fähigkeit Aufgabenelemente aufrecht zu erhalten was auch die Notwendigkeit des Einsatzes von Inhibition verringert. In beiden Fällen wird am Anfang einer Aufgabensequenz weniger Inhibition gebildet, somit wird die Ausführung von ABA-Reihe erleichtert, da am Ende weniger Inhibition überwunden werden muss.

Diese Hypothesen wurden in neun Experimenten getestet. In den ersten vier Experimenten wurde Affekt in Form von affektiven Bildern vor einer Aufgabe eingesetzt, entweder als irrelevanter Prime oder als konkreter Hinweisreiz für die Aufgaben. Die von den beiden Theorien vorhergesagten Interaktionen konnten nicht gefunden werden obwohl nach dem ersten Experiment versucht wurde die affektive Stimulation immer mehr zu verstärken bis hin zu Experiment 3 indem die affektiven Bilder selbst die Hinweisreize für die Aufgaben waren. Danach wurde Feedback als valentes Element eingesetzt. Nach jeder Aufgabe wurde ein leistungsbezogenes Feedback gezeigt. Jedoch konnte auch mit dieser Veränderung keine signifikante Interaktion erzielt werden, vor allem nicht mit zufälligem Feedback bei dem keine Konfundierung mehr zwischen Valenz und Leistung vorlag.

Diese Ergebnisse legen den Schluss nahe, dass kurze affektive Reize exekutive Kontrollfunktionen nicht beeinflussen können beziehungsweise, dass Backward Inhibition Effekte und Wechselkosten kein exekutive Funktionen messen. Jedoch sollten solch endgültige Schlüsse erst gezogen werden, wenn alle anderen Erklärungsmöglichkeiten, die zum Teil auch diskutiert wurden ausgeschöpft sind. Es wurde zum Beispiel diskutiert, dass eventuell Veränderung am Paradigma und die Beseitigung von technischen Problemen die Bedingungen um affektive Einflüsse auf exekutive Funktionen festzustellen, verbessern könnten. Diese Veränderungen sollten für zukünftige Experimente unbedingt in Betracht gezogen werden.

Ehrenwörtliche Erklärung

Ich erkläre hiermit, dass mir die Promotionsordnung der Fakultät für Sozial- und Verhaltenswissenschaften bekannt ist.

Ferner erkläre ich, dass ich die vorliegende Arbeit selbst und ohne unzulässige Hilfe Dritter angefertigt habe. Alle von mir benutzten Hilfsmittel, persönliche Mitteilungen und Quellen sind in der Arbeit angegeben.

Bei der Datenerhebung haben mich die studentischen Hilfskräfte des Lehrstuhls Allgemeine Psychologie II unterstützt. Weitere Personen waren an der inhaltlich-materiellen Erstellung der Arbeit nicht beteiligt. Insbesondere habe ich hierfür nicht die Hilfe eines Promotionsberaters in Anspruch genommen und Dritte haben weder unmittelbar noch mittelbar geldwerte Leistungen von mir für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

Die Arbeit wurde weder im In- noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt. Weder früher noch gegenwärtig habe ich an einer anderen Hochschule eine Dissertation eingereicht.

Ich versichere, dass ich nach bestem Wissen die reine Wahrheit gesagt und nichts verschwiegen habe.

Ort, Datum

Unterschrift