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ERROR, PRAISE, ACTION AND TRAIT

EFFECTS OF FEEDBACK ON COGNITIVE PERFORMANCE AND MOTIVATION

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Error, Praise, Action and Trait
Effects of Feedback on Cognitive Performance and Motivation

THESIS FOR DOCTORAL DEGREE (Ph.D.)

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Dedicated to all of you who are struggling with a challenging task

If it feels tough, it means that you are probably learning something

ABSTRACT

This thesis investigates the role of trial-based feedback on cognitive performance and motivation. We conducted behavioural tests in the laboratory, functional magnetic resonance imaging (fMRI) to investigate brain activation, and experimentally controlled tests in a non-lab environment; the classroom. **In study I,** we explored the effects of trial-based feedback in a working memory (WM) task. We used a factorial design so that we could study twelve different sequences that varied systematically in external and no external feedback on errors and correct responses. The feedback was delivered as brief sounds. We found that external feedback on errors did not impact on accuracy or reaction time (RT) in this test, which suggests a well-functioning internal error monitoring system. When external feedback was given on the first correct response after an error, we found reductions in performance accuracy. This implies that a sound given at this point may disturb the participants' consolidation of strategy changes. When external feedback was given on all correct responses, participants responded more quickly. This was likely due to more information being extracted from the feedback about their responses being correct or incorrect, as revealed using information theoretical computations. As a result, performance accuracy decreased.

In **study II** and **III,** we followed children's WM training program in school. We started with a group of 112 children randomised into one of four feedback groups; 1) feedback on correct responses; 2) feedback on incorrect responses; 3) no feedback and 4) feedback on correct and incorrect responses. The feedback was delivered as brief sounds as well as occasional verbal sentences. Out of the initially 112 recruited children, only 53 completed ≥20 sessions of WM training. In study II, we investigated if intrinsic motivation and mindset regarding intelligence, contributed to the completion of ≥20 sessions of WM training, since mindset and intrinsic motivation has been suggested to influence motivation to continue with tasks. There was a significant difference in mindset scores between the children who performed ≥20 sessions of training and the children who did not. Mindset scores were lower in the group completing the training, meaning that these children to a greater extent viewed intelligence as something that can change with the help of training. Intrinsic motivation was measured by taking an average of seven chosen questions measuring motivation. A significant positive correlation was found between the motivation score and number of trained sessions. For example, we found that expectations of the training being fun and useful correlated positively with number of trained sessions. Since only half of the recruited participants completed ≥20 sessions of WM training, we recruited more participants to investigate the effects of trial-based feedback for study III.

In study III, we recruited in total 177 children, of whom 133 performed ≥20 sessions of WM training. We investigated the effects of feedback on WM improvement, motivation and effort. We also used a new measure of effort as calculated from the number of trials the participants trained close to their max scores. We found an effect of feedback on WM improvement, where the least improvement was found in the group receiving feedback on both errors and corrects (Group 4). This effect of feedback on WM improvement was not mediated by effort. We found that high motivation and having high WM at the start had a positive impact on effort. This suggests that effort scores may be a good complement to measure motivation to train WM. Our results point towards a mechanism where trial-based feedback influences the performance monitoring system.

Feedback related to a person's trait has been shown to influence long-term development of an entity mindset, where intelligence is viewed as something that does not change with training. **In study IV,** we wanted to investigate if feedback in the form of praise related to a person's trait (you are clever) and feedback related to a person's action (your choice was correct) influenced performance improvements in a shorter perspective. Using fMRI, we measured brain activation patterns as a result of feedback type. This was a within-subject design where participants received both types of feedback at separate visits. We found that trait feedback, when compared to action feedback, reduced motivation, increased stress and impacted negatively on performance improvements. Caudate nucleus and medial prefrontal cortex were found to be more active in the trait condition. Interestingly, this effect was specific for more difficult trials that suggest that trait and task praise can impact on individuals' task attention and level of uncertainty.

In conclusion, adding to previous research regarding the contradictory effects of feedback, this thesis suggests that trial-based error-feedback does not interfere with a person's internal feedback system, unless combined with positive feedback. Negative effects were found when the praise was related to trait or when positive feedback was given in excessive amounts, possibly interfering with the attentional resources needed for the task. Previous research on praise has found negative long-term effects of trait praise and here we found that it may also have immediate short-term effects.

LIST OF SCIENTIFIC PAPERS

I **Appelgren A,** Penny W and Bengtsson SL. (2014) Impact of feedback on three phases of performance monitoring. *Experimental Psychology*, Vol. 61(3):224–233.

II **Appelgren A,** Bengtsson SL and Söderqvist S., (under review), Incremental view on intelligence increases persistence in working memory training.

III **Appelgren A,** Bergman Nutley S, Bengtsson SL and Söderqvist S., (under review), Effects of trial based feedback on effort and improvements during working memory training.

IV **Appelgren A,** Bengtsson SL. (2015) Feedback on Trait or Action Impacts on Caudate and Paracingulum Activity. *PLoS ONE* 10(6): e0129714. doi:10.1371/journal.pone.0129714.

CONTENTS

LIST OF ABBREVIATIONS

ACC	Anterior Cingulate Cortex
ADHD	Attention Deficit Hyperactivity Disorder
BF	Bayes Factor
BOLD	Blood-Oxygen Level Dependent
CAE	Correct After Error
DR2	Dopamine Receptor 2
E	Error Phase
EEG	Electroencephalogram
ERN/Ne	Error Related Negativity
ERPs	Event Related Potentials
fMRI	Functional Magnetic Resonance Imaging
FS	Feedback Session
FWE	Family Wise Error
GC	General Corrects
IMI	Intrinsic Motivation Inventory
MI	Mutual Information
MQ	Motivation Question
MPFC	Medial Prefrontal Cortex
MRI	Magnetic Resonance Imaging
NFS	No Feedback Session
OCD	Obsessive Compulsive Disorder
PES	Post Error Slowing
ROI	Region of Interest
RT	Reaction Time
SPM	Statistical Parametric Mapping
SPSS	Statistical Package of Social Science
TOI	Theory of Intelligence
WM	Working Memory

1 INTRODUCTION

1.1 FEEDBACK

Feedback has been found to be of great value for learning, but the effects of the feedback depend on type, timing, context and on the receiver (Hattie & Timperley, 2007). Therefore, even if the purpose of feedback is to inform a person about their performance, it does not always lead to improved performance. In this thesis, I investigate which type of trial based feedback that can be beneficial for performance.

1.1.1 Feedback types

Hattie & Timperley, (2007) divided feedback into four different types;

1) Information about the correctness of something (Outcome feedback)
2) Information about how something was done (Process feedback)
3) Information about why one should continue or change (Regulatory feedback)
4) Information about oneself (Person feedback)

The first and the second type of feedback relate to the task, how to change strategy in order to improve. These types of feedback are concrete, whereas the third is related to encouragement on effort and the fourth about someone's abilities or traits. It is no surprise that these different types of feedback do not affect the individual in the same way. When the effects of feedback were to be summarised in a meta-analysis from 3000 papers, only 131 of them could be included due to differences in feedback type, amount, timing and about individual differences (Kluger & DeNisi, 1996).

In this thesis, I look at outcome feedback after each trial e.g. the event being an error or correct response, and I use feedback from all of the above-mentioned types in the different studies. We use;

1) Outcome feedback informing about being correct or not "Correct" (Study I, III, IV)
2) Process feedback informing about an action "Your choice was correct" (Study IV)
3) Regulatory encouraging feedback "Great, continue just like that" (Study III)
4) Person feedback informing about being clever "You are clever" (Study IV)

1.1.2 Origin of feedback

The feedback can also be subdivided from their origin;

1) Internal; if the information comes from within
2) External; if the information comes from the surrounding

There are studies demonstrating that the internal feedback monitoring system is effective for detecting errors in simple reaction time (RT) tasks (Black & Wiliam, 1998; Rabbitt & Rodgers, 1977). These studies found that participants know of their incorrect responses even when the participants' were not given any external information about their mistakes. The reason for arguing that participants knew about their errors was established when the participants were successful in going back to correct their incorrect trials when given the chance. Later, internal error monitoring has been compared to the external system using brain-imaging analysis. The same brain area, anterior cingulate cortex (ACC) has been found to be more activated after errors both when a person knows about their error themselves and when being externally informed (Holroyd et al., 2004).

1.1.3 Effect of feedback on performance

Trial-based feedback have different effects when looking at the effects during compared to after the test (Goodman, 1998; Schmidt, Young, Swinnen, & Shapiro, 1989; Wade, 1974). Task feedback can help during the task of solving a puzzle whereas no external feedback (internal feedback) was found to be better for performance when solving a puzzle in the future Goodman (1998). The amount of feedback can influence performance, where both too much and too little feedback have been found to reduce performance in a decision making task (Lam, DeRue, Karam, & Hollenbeck, 2011; Schmidt et al., 1989). It is debated whether positive feedback is beneficial for performance or not (Kluger & DeNisi, 1996). Many people believe that positive feedback is always good for performance. Yet, scientific results show that for example praise regarding admiration directed to someone's character has shown to have negative effects on performance (Blackwell, Trzesniewski, & Dweck, 2007). We need to find out more about the how valence of the feedback influence performance. The issue of feedback type given during a task is discussed in Study I, III and IV.

1.2 ERRORS AND CORRECT RESPONSES

1.2.1 Errors

Errors can be divided into; slips and mistakes (Shalgi & Deouell, 2013). An example of a slip is when pressing the wrong button due to fast responding. People often know when these kinds of errors have occurred. An example of a mistake happens when a person thinks that they made a correct response, for example trying to spell a word for the first time and making a spelling mistake. In our first study we have looked at speeded response tasks where errors in the form of slips are common. These slips occur by accidentally pressing the wrong button caused by a lack of concentration. An individual can receive information from the outside regarding an error but can also monitor their performance through their own internal feedback system. For the slips, external information may not be essential whereas for mistakes it is. The task and the level of difficulty may therefore influence the effects of the feedback.

1.2.2 Reaction time differences

As it turns out, RT often differs depending on the event i.e. correct and incorrect response. A typical sign of that an error has occurred is the slowing following after the error (E+1) before making the next response (Laming, 1968; Rabbitt, 1969). The RT resulting in an error is often quick and the RT following two steps after an error (correct response after an error, CAE) (E+2) have been suggested to be slower than general correct responses (Laming, 1979; Danielmeier, Eichele, Forstmann, Tittgemeyer, & Ullsperger, 2011). These differences in RT in a sequential task, are illustrated in figure 1.

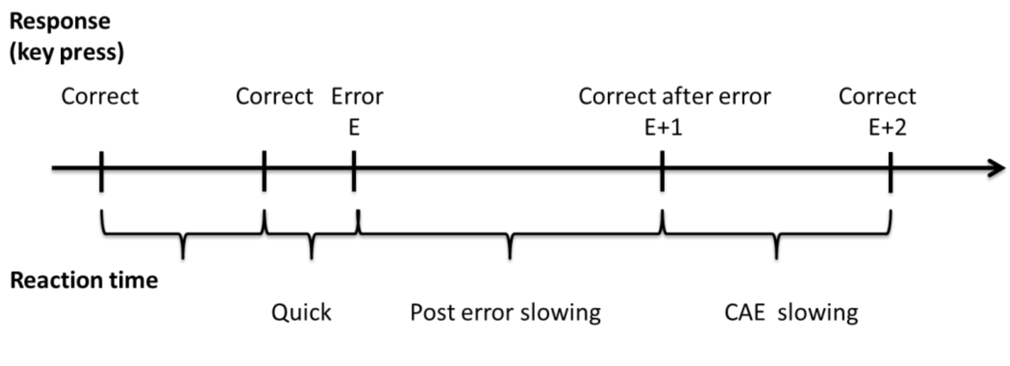


Figure 1. Trials; errors, correct after errors and other corrects and their respective reaction times.

1.2.3 Post-error slowing

The delay before responding which have been found to occur after errors (E+1 (Laming, 1979; Rabbitt, 1966) is commonly referred to as the post-error slowing (PES).The reason behind this slowing that may occur after an errors is a much debated subject. The slowing has been suggested to occur due to a call for adjustment or a response caution in order to gain cognitive control (Dutilh et al., 2012; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). This proposal is supported by findings that post-error slowing lowers the probability of committing a subsequent error in the post-error trial (Danielmeier et al., 2011; Holroyd, Yeung, Coles, & Cohen, 2005). However, others have failed to observe this relationship between post-error slowing and improved performance (Hajcak, McDonald, & Simons, 2003; Rabbitt & Rodgers, 1977). It has also been suggested that post-error slowing reflects the surprise of an outcome being rare (Notebaert et al., 2009). According to this argument, it is the infrequency of the error, rather than an error per se, that results in the slowing. These inconsistent findings is an ongoing debate about if slowing after an error cause better performance accuracy due to an adaptive control mechanism or if the slowing instead reflects a malfunctioning process (Gehring, Goss, Coles, Meyer, & Donchin, 1993).

1.2.4 Performance monitoring and brain activity

Trying to measure what happens during errors has been studied extensively using a number of methods, for review see (Shalgi & Deouell, 2013). A common method to study the process occurring on and after errors is by using speeded response task paradigms such as the Eriksen Flanker task (Eriksen & Eriksen, 1974). By using electroencephalogram (EEG) a negative deflection in the electrophysiological signal, an event related potentials (ERPs), was found to be enhanced following errors compared to correct response in speeded RT paradigms (Falkenstein, Hohnsbein, Hoormann, & Blanke, 1991; Gehring et al., 1993). This signal was found around 50-100 ms after an error, and thus it was named error negativity (Falkenstein et al., 1991). Gehring et al., (1993) recorded from five electrode sites using the EEG and found that the Ne or the error related negativity, ERN, as they termed it, was strongest over the front and middle of the scalp. The region involved in error processing has later bee localized to the anterior cingulate cortex (ACC) (Dehaene, Posner, & Tucker, 1994).

When a person makes an error, anterior cingulate cortex is activated (Holroyd et al., 2004). When participants receive feedback on correct responses, activity in venral striatum has been found to increase whereas negative feedback on errors activates rostral cingulate motor area of the ACC, inferior anterior insula and epithalamus (habenular complex) (Ullsperger & Von Cramon, 2003). Furthermore, some studies have also indicated that the first correct response after an error differ from other correct responses seen in increased right dorsolateral prefrontal cortex (Kerns et al., 2004; King, Korb, Von Cramon, & Ullsperger, 2010; Marco-Pallarés, Camara, Münte, & Rodríguez-Fornells, 2008). We have further evidence supporting this difference from behavioural results in study I and from neuroimaging results from an fMRI study not included in this thesis.

Besides ACC activity increase when an error has occurred, there are also other processes that increase due to the persons reaction to the error. For example, introspective emotional states which show increased activations in the insular cortex (Craig, 2009; Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004) has been shown to be more activated during errors compared to correct responses at certain conditions related to a person's associations (Bengtsson, Dolan, & Passingham, 2011). Furthermore, the error may also evoke thoughts regarding ourselves which is reflected in increased medial prefrontal cortex activity (Bengtsson et al., 2011) an area often seen active when individuals self-reflect (Kelley et al., 2002; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Ochsner et al., 2005). Self-reflections may also occur when reflecting on correct responses and may differ depending on feedback type, which turn could influence both performance and motivation, as we demonstrated in study IV.

1.3 MOTIVATION

When does a person show signs of motivation? Highly motivated individuals show enthusiasm, interest, curiosity and persist through challenges (Skinner & Belmont, 1993). Motivation involves both the belief and expectancy of being able to do a task and the factors involved in the will to perform the task, explained in the review by Eccles & Wigfield, (2002). For example, an individual who *wants* to become a singer, but does not want to take any action in trying to become one, is not a motivated person. However, if the individual *wants* to become a singer and *believes* in his/her capability to be able to achieve the goal (become a good singer) and act accordingly (start practicing etc.), is a motivated person. The concept of motivation should therefore include the will and actions of trying to peruse a goal.

Expectations about one's abilities are believed to influence motivation (Bandura, 1993). Bandura described two different kinds of beliefs that can influence goal setting and persistence on tasks. We can find out about these beliefs by answering two questions:

1) Can one train to achieve this?

2) Do I have what it takes to do that training?

This first question defines if the person thinks that one can reach a certain goal via training. The second question describes the belief that the person themselves can do this training. Belief in one's ability is defined as self-efficacy (Bandura, 1993). It has been shown that individuals who expect to do badly also perform worse compared to those that are optimistic (Marshall & Brown, 2004). Moreover, people with high self-efficacy tend to set high goals for themselves and they are also likely to commit strongly to these goals (Bandura, 1993). Zimmerman, (1990) defines persons who believe that they can perform and who find ways to master new skills self-regulated learners. At setbacks, a self-regulated learner takes responsibility for their actions and find out what is necessary, in order to overcome this obstacle. Motivation and its' relation to feedback is investigated in study II, III and IV.

1.3.1 Over-justification effect

When external rewards are given focus can change away from the learning so that a person instead strive to receive a reward (Deci, 1971). In an early study showed that when monkeys solved a puzzle, they were found to do so for a longer time if they were not getting any reward (Harlow, 1950). The experimenter suggested that without reward the monkeys did the puzzle because it was fun. It has also been observed that when children are expecting to get a reward they show less intrinsic interest in the target activity compared to when they are not expecting a reward but receiving a reward, or when they are not expecting nor receiving any reward (Lepper, Greene, & Nisbett, 1973). Another study showed that when students were asked to rate the main reason for learning, they chose grades to be the main reason and increasing one's knowledge was rated as far less important, which is an example of external reward taking over the focus of the actual goal itself (Covington & Müeller, 2001). These examples reflect the over-justification effect.

In the cases when no external reward is given, where does this intrinsic interest come from? It is argued that people get interested in something when they think about what they are able to achieve (Bandura, 1993). If so, an interest can arise in any area. This makes sense looking at children who often find any challenge that they think is possible to master to be fun. With time, associations to a task and its positive outcomes will occur by classical conditioning i.e. a person is more likely to do something they have tried before and achieved, because it increase their self-efficacy (Eccles & Wigfield, 2002).

When becoming skilful at something the fun may arise when being in a flow, which is described as ‘in a condition of high challenges and skills’ (Csikszentmihalyi & LeFevre, 1989). Furthermore, high focus is argued to occur when the task is on the right level of difficulty challenging the subject which is argued to shield against distractions (Halin, Marsh, Hellman, Hellström, & Sörqvist, 2014). In Study II, III and IV we investigated the effects of external feedback on motivation, performance and effort to understand if feedback can influence motivation, focus and persistence when performing a WM training program or a rule-switching task.

1.3.2 Uncertainty and motivation

It is essential to understand what is right and wrong while learning. If there are no indications of the consequences of an action, the individual has to guess whether it was a good or bad move. On the contrary, if external information is given about the outcome, the learning process of the task rule becomes much easier.

In a review by Schultz, (2006), he describes experiments on learning starting already early 1900 with Pavlov’s conditioning experiments. Pavlov was trying to better understand learning by associations of a stimulus and its’ upcoming outcome. In Pavlov’s experiment, they taught a dog to associate the sound of a bell with receiving food. The unconditioned stimulus (the bell) is not in itself rewarding, but after several training sessions where the bell proceeded the upcoming reward (food), the dog started to salivate (anticipate), already when hearing the bell. Similarly, during the same time period Thorndike described the addictive effect of rewards, which encourages a person to behave in the way that was rewarded (The Law of Effect). Skinner termed this strengthening of behaviours by giving positive rewards, reinforcements and that punishments or removal of rewards work as punishers. This led to the understanding that rewards can be predicted, which makes dopamine neurons fire (Schultz, Dayan, & Montague, 1997). The difference between the expected reward and the actual reward received is termed the prediction error. Predictions influence the surprise when receiving the reward in a positive or negative direction depending on the accuracy of the prediction (Schultz & Dickinson, 2000).

Once having learned the task rules, doubt regarding one’s capacity can still vary between individuals and the way feedback is perceived will differ. The experience of feedback can be rewarding, annoying or redundant, depending on the individual’s level of confidence. Some people rely much more on their own acquired capacity, making them more confident while others may feel the need of further guidance e.g. external information, to become certain of their choices (Butler & Winne, 1995). These differences between people may relate to the persons own concept of learning. It is also possible that within an individual, these differences can appear by changing the type of feedback. In study IV, we investigate if we could evoke differences in the feelings of uncertainty by using two types of trial-by-trial feedback.

1.3.3 Beliefs about intelligence

How people approach a task and whether they persist or give up can depend on their way of thinking about learning and their goals, which we studied in a WM training program (Study II, III and IV). Some people set up goals regarding learning, to increase their ego and to look smart, linked to the extrinsic reward of being highly respected. Others set up the learning goals related to being able to master something. These two types of reasons to learn can be defined as self-involving or task-improvement (Ames, 1992). Ames, described that self-involvement nourishes behaviour of outperforming others "to look good" whereas task-goals make children pick more challenging tasks. A number of studies focused on how peoples view intelligence and which effect these different views have on motivation and performance monitoring (Grant & Dweck, 2003; Hong, Chiu, Dweck, Lin, & Wan, 1999). Dweck, (1986) have described two mindsets regarding intelligence; an entity mindset (fixed view) and an incremental mindset (growth view). An entity mindset is when a person believes that intelligence is something fixed and unchangeable. With an incremental mindset on the other hand, intelligence is believed to be something that can vary with effort and training.

Students who view intelligence as something changeable have been found to be happier of their academic progress and obtain higher grades compared to control groups (Aronson, Fried, & Good, 2002). The way people think about intelligence has also been found to influence math grades in adolescent people (Blackwell et al., 2007). A growth mindset has been found to lead to increased math grades in adolescents whereas people with an entity mindset have a more flat trajectory in math grades (Blackwell et al., 2007). With an entity mindset children have been found to report lower levels of comprehension after reading incoherent texts compared to people with an incremental mindset (Miele & Molden, 2010).

Differences in neural activity in response to errors have been found to depend on mindset where entity theorists exhibited enhanced anterior frontal response (P3) to performance relevant feedback on errors compared to incremental theorists (Mangels et al., 2006). The P3-peak was anterior to the mid-ACC, which is an area generally seen active during error monitoring. This suggests that entity theorists activate a stronger error monitoring response and that we do monitor our performance differently depending on thoughts and expectations about our abilities.

1.3.4 The origin of mindsets

Studies show that the origin of a person's mindset develops through long-term exposure of feedback (Gunderson et al., 2013). They investigated how different types of positive feedback influenced the children's way of thinking about learning later on in their lives. Children who received positive feedback related to a process such as; "you have done a great job", has been associated with the increased likelihood of development of an incremental mindset. Another study also showed that feedback regarding making a good job with something rather than praising someone's character was found to induce a more mastery oriented mindset (Zentall & Morris, 2010).

With an incremental mindset setbacks are viewed upon as challenges (Dweck, 2002; Gunderson et al., 2013). Conversely, receiving feedback about one's traits such as "you are so smart" is associated with development of a fixed orientation. With a fixed orientation, people tend to believe that failures are due to your own inadequacy, can lead to increased helpless behaviour and avoidance of challenges and they have also been found to be more depressed than people with a growth view. People with a growth mindset think that they can improve after a setback with effort and that the skill can be acquired.

In Gunderson et al., (2013) they investigated the amount and type of feedback when parents talked to their children while playing with them during 90 minute sessions, when the child was 14, 26 and 38 months old. Indeed, children who received a lot of process praise were at the age of 7-8 having a more incremental oriented mindset. This suggests that long-term exposure to feedback influence later mindset and motivation. In this American study they could also distinguish between which type of praise the parents gave depending on if their child was a girl or a boy, where girls got more person praise while boys received more process praise, which later influenced their view on intelligence and their motivation and ability beliefs (Gunderson et al., 2013). In our study IV we have looked into the type of feedback (person and process feedback) to investigate if there are also instant differences affecting our behaviour.

1.3.5 The effect of expectations

People tend to match their expectations to their abilities (Marshall & Brown, 2004). For example, individuals with low expectations ascribe poor performance to their abilities whereas people with high expectations take more credit for high performance. There have been number of studies on monkeys reward system when learning how to perform tasks (Schultz, Dayan, & Montague, 1997; Schultz, 1998; Wolfram Schultz & Dickinson, 2000). To study reward, the dopamine system is first measured before learning, just by presenting the reward and later measurements of increases or decreases in dopamine neuron activity can be studied. When monkeys learn to associate a stimulus with a reward in a conditioning experiment they learn the positive consequences of an action and hence starts anticipating the reward already before it happens. Thus when an outcome is better than expected dopamine neurons fire, but when an outcome is as good as expected and when the outcome is worse than expected, dopamine firing decrease (Schultz, 1998). These findings showed a difference between what is expected and what is later received. This effect is termed; the prediction error and have been of great use for later studies on expectations and learning (Schultz & Dickinson, 2000). As discussed by Berridge, (2007) the role of dopamine may particularly be involved in the wanting a reward.

1.3.6 Effort

We were interested in understanding the relationship between effort and motivation from a behavioural perspective and therefore we extracted a score measuring effort in study III. Animal studies suggest that effort can vary between subjects (mice) depending on expressions of dopamine receptor (DR2) in the striatum, which then influence motivation (Trifilieff et al., 2013). An over-expression of postsynaptic D2Rs in the nucleus accumbens increased the willingness to use effort to obtain a goal (motivation) as tested in an congenic mouse models (Trifilieff et al., 2013). In this experiment, pressing a lever to get more attractive food demands more effort than just grabbing less attractive food available, and rats treated with low doses of dopamine antagonists, or mice with mesoaccumbens dopamine depletion chose the less attractive food over the effort of pressing the lever for better food. This indicates that there is a relationship between dopamine levels and motivation to induce effort (Trifilieff et al., 2013). In study III and IV, we have not been looking at dopamine receptors, but we do test if we by the use of feedback can change effort and if feedback influences motivation to continue with a task.

1.3.7 Self-esteem

Self-esteem is a subjective opinion of one’s abilities answering how much a person value themselves (Baumeister et al., 2003). Explicit measures of self-esteem rely in self-ratings, and with that come a problem with reliability. People generally want to rate themselves positively, the average self-esteem in a sample often lies above the midpoint (Baumeister, Tice, & Hutton, 1989). Furthermore, the subjective measure does not have to cohere with an objective measure of a person’s ability. There are a number of questionnaires designed to measure self-esteem. In study IV we used Rosenberg’s global self-esteem measure (Rosenberg, 1965). These two questionnaires measure domain specific and global self-esteem. Global self-esteem is a general self-esteem measure of a sense of being worthy. Domain specific self-esteem on the other hand measures the subjective worthiness in different areas such as social, physical appearance, physical abilities or school related abilities where people may rate themselves differently.

The causality of performance and high self-esteem is complex. In a meta-analysis of 128 studies on self-esteem found a weak positive correlation between performance and self-esteem (Hansford & Hattie, 1982). A confident view of one's abilities is believed to be linked to persistence when facing difficulties (McFarlin, 1985). McFarlin found that participants with high self-esteem take tips or cues into great account and tend to decide for themselves if it was a good idea to continue or give up with a task. Low self-esteem individuals have been found to make more use of direct instructions where they were told to continue or stop. It is possible that high self-esteem individuals can rely on their own judgment whereas low self-esteem individuals need more guidance in line with (Butler & Winne, 1995).

Self-esteem can also have negative consequences when related to results known as achievement-based self-esteem, where only results define the self-esteem. This type of self-esteem is transient and is only kept by performing well. Failure on the other hand forces a person with performance based self-esteem to re-evaluate themselves and their ability, which may cause emotional distress and leading to avoidance of trying again (Crocker, Brook, Niiya, & Villacorta, 2006; Crocker, Luhtanen, Cooper, & Bouvrette, 2003; Hallsten, Rudman, & Gustavsson, 2012). Having this type of self-esteem can result in burn-out effects, which gives further support of the negative consequences of a heightened self-view (Dahlin, Joneborg, & Runeson, 2007).

Externally provided feedback may be beneficial when there is more insecurity or less self-efficacy, such as relying in one's own ability to be able to solve a task. In Study II and III, we wanted to investigate how beliefs regarding one's abilities and feedback influenced persistence and in Study IV, we test correlations of mood scores and self-esteem scores with performance and motivation.

1.4 COGNITIVE PERFORMANCE

1.4.1 Working memory

Working memory (WM) is the ability to remember and use information for a short period of time where simultaneous storage and processing of information is required (Baddeley, 1992). WM capacity is highly related to ability to sustain attention and is a predictor of academic performance (Alloway & Alloway, 2010; Bull, Espy, & Wiebe, 2008; Gathercole, Brown, & Pickering, 2003). There are a number of ways to test WM capacity, such as visual and spatial WM tasks. These tasks involve placement of an object in space at one time (Luck & Vogel, 1997; Vogel, Woodman, & Luck, 2001), verbal tasks such as remembrance of letters (Braver et al., 1997), recall of numbers (Babcock & Salthouse, 1990), recall of words (Chein & Fiez, 2001) or reading tasks (Daneman & Carpenter, 1980).

One popular WM task is the n-back tasks in which the participant is instructed to try to remember when an item has been previously presented n steps earlier or not, for review see (Owen, McMillan, Laird, & Bullmore, 2005). In study I, we used a 2-back task with letters to see how external feedback (sounds) on correct and/or errors during different parts of this task influenced the accuracy.

1.4.2 Working memory training

The importance of WM for every-day functioning and academic performance has motivated research for developing methods to improve WM capacity with non-pharmacological interventions, such as computerized training programs, for review see (Peijnenborgh, Hurks, Aldenkamp, Vles, & Hendriksen, 2015; Spencer-Smith & Klingberg, 2015).

In study II and III we used Cogmed's WM training programs consisting of both visuospatial and verbal tasks (Klingberg, Forssberg, & Westerberg, 2002). The software used, Cogmed's RM (Cogmed and Cogmed Working Memory Training, are trademarks in the U.S. and/or other countries, of Pearson Education, Inc. or its affiliate(s)). A key component of the software is the individualized adjustment of the difficulty levels. This means that participants will perform highly demanding levels if they try their best to improve and thus the training will involve making a large proportion of errors. This makes adaptive WM training suitable for studying motivational aspects of how long a person is willing to continue when the task is tough. From a practical perspective, it can be problematic that the training is so tough. Large dropouts lead to studies with smaller sample sizes and the practical issue of having to recruit a larger proportion of participants. In a study with similar set by Jaeggi, Buschkuehl, Shah, and Jonides, 2014) participants were to perform 20 sessions where each session was about 90 minutes of WM training, which is similar to the setup of Study I and II. In their study, the authors reported the number of participants who did not complete the protocol finding that only 44% of the recruited children managed to perform 20 sessions.

1.4.3 Rule switching task

In study IV we use a rule switching tasks used to study behavioural adjustments when task rules changed from one rule in a task to another which is reflected in differences in reaction time (Monsell, 2003). We used a particular type of rule switching task where a cue is shown that indicate a particular rule which can be more or less easy (bivalent or univalent rule) used in previous studies (Bengtsson and Penny, 2013; Crone, Donohue, Honomichl, Wendelken, & Bunge, 2006; Crone, Wendelken, Donohue, & Bunge, 2006). This task is further described in the method section. This task was in our study not aimed to investigate the switch but to investigate different feedback effects on univalent and bivalent rules.

1.4.4 Cognitive control and distractions

A susceptibility to give in by external cues can result in over-eating, alcohol consumption, violence, drug abuse among many other things and is extensively studied because of its major consequences both for the individual and its' surrounding (Baumeister & Heatherton, 1996). The ability to self-regulate is depending on the recourses available and can be reduced by sleep deprivation (Alhola & Polo-Kantola, 2007) and distractions such as sounds (Halin et al., 2014).

When engaging in the cognitive task with great focus both external and internal side-tracks can obstruct the focus, which is why it is important for us to be able to control this. For example, thoughts about your ability or having a fear of negative evaluations have been found to influence your task-behaviour which was in this case evoked by external evaluation (Van der Molen et al., 2013). Participants with a strong fear of being negatively evaluated was found to have an increased slowing in reaction time when responding to how others would judge them (Van der Molen et al., 2013). This slowing in reaction time to be able to make a correct response, is argued to be due to fewer resources left, when ruminating (Guinote, 2007). Distracting sounds can grasp attention especially when the sound change in a sequence as described by Sörqvist et al., (2012). Distraction can also depend on the will to engage in a task, which can be related to the difficulty of the task as described in Halin et al., (2014). They used a text that was easy to read and found that background speech influenced the recalling of the text negatively. This was however not found for texts that were more difficult to read due to changed font size. The authors argue that higher task-engagement in a more difficult task shield against distractions. While there have been a few studies investigating the distraction of irrelevant sounds, we have looked at different task relevant sounds that indicate a person's outcome.

2 AIMS

The overall aim of the thesis was to investigate effects of internal and external trial-based feedback on errors and correct responses and action or trait related praise.

Study I

The aim of Study I was to investigate the effect of feedback (external/internal) on errors, correct after errors and general correct responses on cognitive performance accuracy and reaction time in a WM task.

Study II

The aim of Study II was to investigate if a person's thoughts regarding intelligence (a person's growth mindset) and their intrinsic motivation as measured by questionnaires influenced the number of days trained in a WM training program.

Study III

The aim of Study III was to investigate the effects of different types of feedback on errors and correct responses on WM training improvement and motivation and to evaluate a new measure of effort.

Study IV

The aim of Study IV was to investigate how positive feedback directed to someone's trait; being smart or someone's action; choosing correctly, influence brain activation, performance and motivation during a rule-switching task.

3 METHODS

3.1 PARTICIPANTS AND ETHICS

In study I and IV we recruited healthy participants by advertisements in Stockholm. In study I, we recruited 63 participants of which 60 participated in the study, 43 females, mean age 26.8 ± 5.1. In Study IV, we recruited 22 participants of which 20 participants were included in the study, 8 female, mean age 24.0 ± 5.6. All participants were fluent in either Swedish or English. None of the participants in the analysed material had any neurological conditions. However, participants who were found to have neurological abnormalities were excluded from the analysis. In study II, we recruited from 112 children, 54 girls, mean age 13 ±0.6 from schools in Stockholm. In Study III, 177 participants were recruited, mean age 13.8 ± 1.3 years old, 93 boys.

All participants decided themselves that they wanted to partake in the studies. They all signed a written informed consent. This consent for study I and IV stated that the participant could terminate the experiment at any given time without the need to give any reason for it and that the name of all participants would be coded. The consent also stated that the information collected were only to be used for research purpose by researchers at the Karolinska Institute. Participants were well informed about all parts of the experiment before starting and agreeing to participate.

The participants knew about the experimental procedure, the scanning procedure as well as the decoding of their names, before signing the consent form. In study IV, the MR-procedure started with information by email followed by a conversation on the phone some days prior to the visit. All participants answered the screening questions in written form. The screening were used to exclude participants so we only included participants who were; right-handed, healthy (no neurological or other medical condition), non-pregnant, participants who had not performed any heart or brain surgery, who had not performed a similar experiments before, who did not have a pacemaker, metal clips, shunts, port-a-chat, prosthesis, pumps or any kind of metal in their bodies. We excluded participants who reported claustrophobia and prescribed medication. In study II and study III, which was a part of collaboration with Cogmed (www.cogmed.com), also involved employers at Cogmed. They were to take part in the data collection and analysis and here the parents to the children were signing the agreement to participation of these studies.

3.2 CONFLICT OF INTEREST

There are no conflicts of interest to report in study I or VI. The studies II and study III were made in collaboration with Cogmed (Cogmed, Pearson Assessments). Stina Söderqvist and Sissela Bergman Nutley are employed at Pearson Assessments who distributes Cogmed’s WM training program. They both declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

3.3 TASKS AND EXPERIMENTAL DESIGN

In study I, we used a 2-back task with letters as stimuli. This WM task is widely used to test the ability to maintain information across a delay (Cohen JD, MacWhinney B, Flatt MR, 1993). White letters were presented centrally on a black computer screen, one letter at the time (Figure 2). If the letter they saw also appeared two letters back the participant made a “yes” response, otherwise they made a “no” response. The “yes” response was made by pressing the button corresponding to the right index finger, while pressing the button corresponding to their right middle finger, on the computer keyboard, made a “no” response. The same letter, regardless if written as capital letter or lowercase letter, was regarded a match. Both capital and lowercase letters were used in the sequences to reduce the possibility that participants solely relied on visual memory. A sequence had 30% hits (“yes” responses).

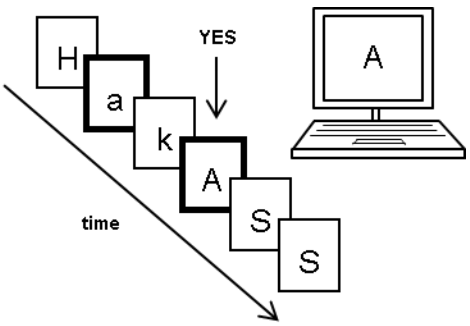


Figure 2) 2-back task with letter

In study II and III we used Cogmeds WM program which is based on previous training programs (Klingberg et al., 2005). The software used was Cogmed’s RM (Cogmed and Cogmed Working Memory Training are trademarks, in the U.S. and/or other countries, of Pearson Education, Inc. or its affiliate(s)), consists of visuo-spatial and verbal WM tasks. The tasks involved memory of both the location and the order of which the stimuli were presented and responses were made by clicking/tapping on the items one at a time in the order they were presented or in the reversed order, for an illustration of one of their tasks (figure 3). Task difficulty was adjusted so that difficulty levels (the number of stimuli to-beremembered) increased following a correct response and decreased following an incorrect response. This way the participants always trained on a challenging level.

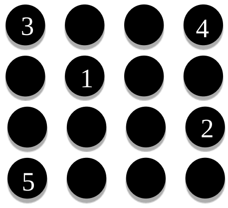


Figure 3. Press on the circles that blink in the correct order. In this illustrative picture, the circles that have blinked have been numbered in the order they blinked which is how the participant later should recall them.

In Study IV we used a rule-switching task (Figure 4). In this task previously used by Crone et al., (2006), the participants responded to symbols that could be either univalent or bivalent by pressing the left or right button on a button box. The univalent trials were associated with fixed responses, e.g. when a symbol of a bow (rule symbol) is followed by a house (response symbol) a left key press is the correct answer, whereas a right key-press is correct when a bow is followed by a car (Fig. 4a). Bivalent trials refer to visual pictures that were associated with different responses depending on one of the two rules possible. For example, if a rule symbol consisting of a square is followed by the response symbol of a butterfly, the participants should press the left button. On the other hand, if the rule symbol is a triangle and is followed by the same response symbol, a butterfly, the participant should press the right button (Fig. 4bc).

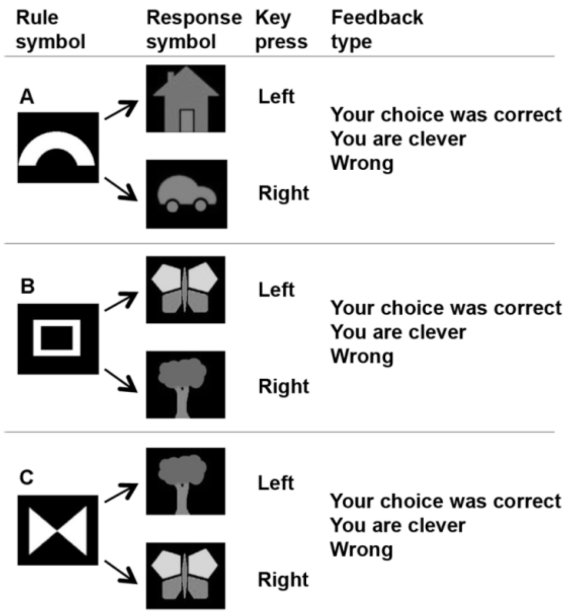


Figure 4abc. Rule-switching task with univalent and bivalent rules

3.3.1 Task setup

In our study I, II and III we are interested in looking at errors and correct responses. In Study I we depicted the events as follows; errors (E), a correct response after an error (CAE) which is the correct response that a participant makes when just previously having made an error (E+1) and general correct (GC) responses which are the correct responses that follow more than 2 steps after an error (E+2, E+3. E+4…) (Figure 5).

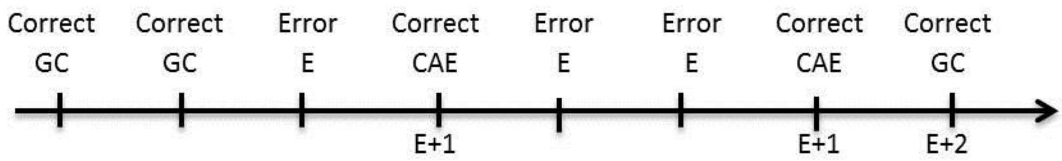


Figure 5. General corrects (GC) responses, errors (E) and correct after errors (CAE).

To indicate the outcome of the responses we used sounds as external feedback. When no sound was used the participant had to rely on their internal feedback system. Sound could be delivered on errors (E), on correct after errors (CAE) and on general correct (GC) responses. A dark sound 74 Hz beep (55ms) indicated an error and a bright sound 740 Hz (55ms) indicated a correct response. In the figures 6, a sound is illustrated with a grey coloured square and no sound with a white square. In study I we wanted to analyse all possible combinations of sound or no sound (external or internal feedback) on the three events (E, CAE and GC), which results in eight individual sequences. Thus, each sequence include information about sound or no sound in these three events; E, CAE, GC. This is depicted [x y z] where the x represents errors, y, represents correct after errors and z represents general corrects [E ,CAE, GC]. For the script where we analysed the data we uses numbers as codes; 1 for sound and 0 for no sound. For example, in sequence [000] there is no sound in either of these events. In [010] the participants get no sound on errors, sound on correct after errors (CAE) and no sound on general correct (GC). With this in mind, we can combine sound or no sound so that we receive eight different sequences with either sound or no sound on each of the three events [E,CAE,GC], [0/1, 0/1, 0/1].

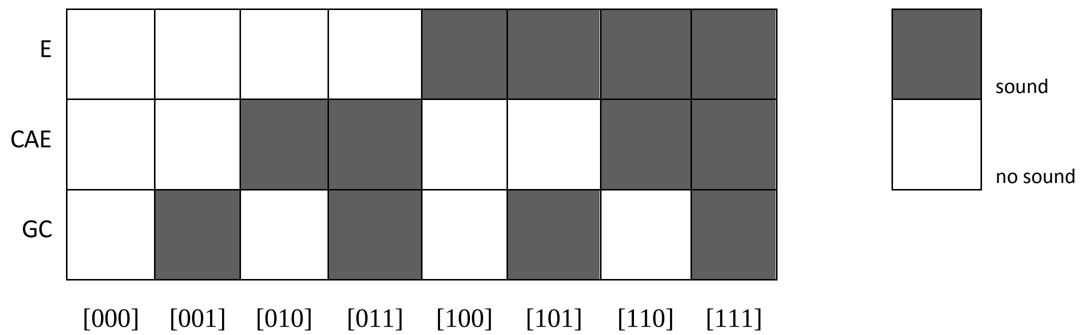
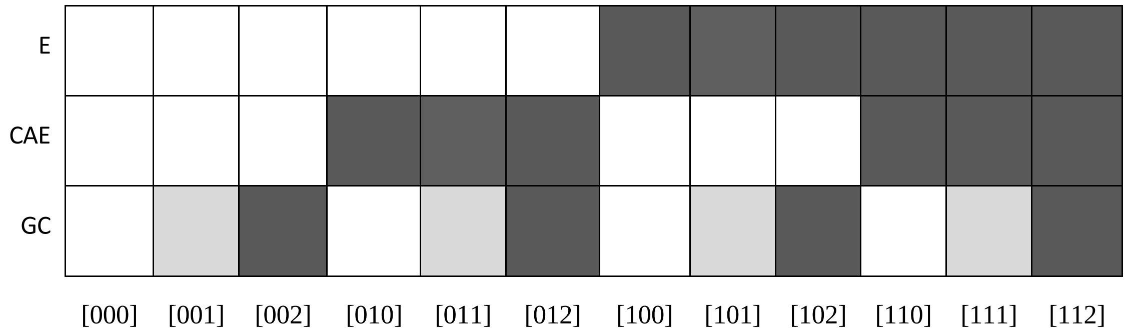


Figure 6. The eight individual sequences, which participants were to perform. Dark square indicate sound and white square indicate no sound.

However, in Study I, we used this design where we also varied the amount of sounds on the general correct responses, resulting in twelve different sequence combinations. On general corrects (GC) we had either no sound, sound on all or sound on 20% of the general correct responses. In figure 7, no sound is displayed by white, sound on 20% of general corrects is displayed by light grey and sound on all is displayed by dark grey.

To analyse the effects of the twelve sequences we decided to use a 2x2x3 design, with a custom made script for Matlab. Errors could have no sound (0) or sound (1), CAE can have no sound (0) or sound (1) and GC can have no sound (0), sound on 20% of the general corrects (1), or sound on all general corrects (2). We use the following notation for E, CAE and GC [0/1, 0/1, 0/1/2]. This way we could analyse the main effects of sound on E, CAE and GC. The twelve sequences we used in the WM task are displayed below in figure 7.



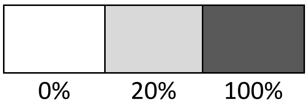


Figure 7. The twelve sequences with external feedback (sounds) given on errors (E), correct after errors (CAE) and general corrects responses (GC) and the different amount of external feedback on GC (0, 20% and 100%).

For study III, the different types of feedback are outlined in figure 8. Four groups who received different combinations of auditory feedback were compared. Group 1 (positive) received a two-tone positive sound on each correct response, a neutral click sound on each incorrect response and occasional verbal feedback sentences for example “well done”, following correct trials. Group 2 (negative) received a descending sound for each incorrect response, a neutral click sound on each correct response and encouraging occasional verbal feedback such as “that was close”, following occasional incorrect trials. Group 3 (none) received a neutral click sound on each correct and each incorrect response and no verbal feedback phrases. Group 4 (combination) received a two-tone positive sound on each correct response and a descending sound for each incorrect response and occasional verbal feedback sentences related to correct and incorrect performance. The total amount of verbal feedback given was balanced between the groups except for the group without feedback.

Feedback groups	1	2	3	4
Corrects two-tone sounds	sound	Click	click	sound
Errors descending sound	click	Sound	click	sound
Comments regarding corrects	Well done			Well done
Comments regarding errors		That was close		That was close

Figure 8. Feedback groups in study II and III with sounds on correct or errors and feedback comments on correct and errors, or no comments or neutral click sounds.

In the fMRI study (study IV) we used a factorial design function where we set up a design with 2 factors with 2 levels each. Our first factor is feedback where we had task (1) or trait (2) feedback. Our second factor is time, where we have time point 1 and 2. Time point 1 was the feedback session (FS) and time point 2 was the no feedback session (NFS). This results in a 2x2 repeated measure ANOVA with the factors feedback (task/trait) and time (FS/NFS) (Figure 9).

	Session	
	FS (1)	NFS (2)
Trait You are clever (1)	11	12
Task Your choice was correct (2)	21	22

Figure 9. Task feedback, Feedback Session (FS) (11), Task feedback, No Feedback Session (NFS) (12), Trait feedback, Feedback Session (FS) (21), Trait feedback, No Feedback Session (NFS) (22)

3.3.2 Questionnaires

In study II, III and IV we also used participants own subjective ratings. In Study IV a minimum of one day before the experiment all participants filled in the following questionnaires using Google forms; Burns depression inventory (Burns, 1989), Rosenberg self-esteem score (Rosenberg, 1979). These questionnaires measure mood (depression) and global self-esteem scores. During three occasions before each scanning session the participants rated their motivation, stress, and task difficulty by answering three questions asked by the experimenter; How motivated are you to continue with the task?; How stressed do you feel right now?; How difficult did you find the task? Ratings were of 1-10; 1-very calm/unmotivated/easy, 10-very stressed/motivated/difficult. The questions were asked before the cognitive task, after FS, and after NFS (difficulty ratings were not given before the task). After the experiment, the participants wrote down how they experienced the feedback during the different sessions with the questions; what did you think about the test with feedback? What did you think about the test without feedback? They were subsequently debriefed about the purpose of the experiment. In study II and III participants answered six selected questions from the Intrinsic Motivation Inventory (IMI) (McAuley, Duncan, & Tammen, 1989) and one in-house question on the first day of their training. The questions were in the field of enjoyment, competence and effort and were translated into Swedish. Additionally, all participants answered three theory of intelligence (TOI) questions (Dweck, Chiu, & Hong, 1995). The questions below are used in study II, III and IV.

Motivation and mindset questions

Motivation Q1. I believe the training will be good for me

Motivation Q2. I believe that I will be pretty good at this type of training

Motivation Q3. I will put effort into the training

Motivation Q4. I believe the training will be challenging

Motivation Q5. I believe the training will be fun

Motivation Q6. It is important for me to do well on this training

Motivation Q7*. I believe I will go through with all of the training sessions

Mindset 1. You have a certain amount of intelligence and you can’t do much to change it.

Mindset 2. Your intelligence is something that you can’t change very much.

Mindset 3. You can learn new things, but you can’t really change your basic intelligence.

*Motivation question 7 was not delivered after the test and not analyzed in average

Burns depression inventory

Answer how much you have experienced what is stated.

You should think of your experience during last 7 days, including today.

1. Feeling sad or down in the dumps
2. Feeling unhappy or blue
3. Crying spells or tearfulness
4. Feeling discouraged
5. Feeling hopeless
6. Low self-esteem
7. Feeling worthless or inadequate
8. Guilt or shame
9. Criticizing yourself or blaming others
10. Difficulty making decisions
11. Loss of interest in family, friends or colleagues
12. Loneliness
13. Spending less time with family or friend
14. Loss of motivation
15. Loss of interest in work or other activities
16. Avoiding work or other activities
17. Loss of pleasure or satisfaction in life
18. Feeling tired
19. Difficulty sleeping or sleeping too much
20. Decreased or increased appetite
21. Loss of interest in sex
22. Worrying about your health

Rosenberg self-esteem score

These questions relate to your opinion about yourself.

1. On the whole, I am satisfied with myself.
2. At times, I think I am no good at all. *
3. I feel that I have a number of good qualities.
4. I am able to do things as well as most other people.
5. I feel I do not have much to be proud of. *
6. I certainly feel useless at times. *
7. I feel that I'm a person of worth, at least on an equal plane with others.
8. I wish I could have more respect for myself. *
9. All in all, I am inclined to feel that I am a failure. *

* Reverse this question

3.3.3 Measure of uncertainty

Shannon & Weaver (1963), describe a theory of which we can get measures of surprise occurring when being uncertain of an outcome. From this theory, we can calculate the reduction of uncertainty by giving certain information using Mutual information (MI). We can quantify the information about how much one variable contains about another, when looking at two random variables mutual dependence, this is the mutual information (MI). High mutual information indicates a large reduction in uncertainty; low mutual information indicates a small reduction in uncertainty. Zero mutual information between two random variables means the variables are completely independent. Intuitively, mutual information is a measure the information that X and Y share e.g., how much one of these variables reduces uncertainty about the other. For example, the mutual information between feedback (variable 1) and outcome (variable 2) is the reduction in uncertainty about outcome (correct/incorrect response) after experiencing feedback. Mathematically this is given by the uncertainty in the outcome, minus the uncertainty of the outcome after having received feedback. The mutual information is a positive quantity reported in bits.

In figure 10, we have two variables X-dark circle and Y-light circle, where X (dark circle) is a sound indicating your correct responses and Y (bright circle) is outcome (correct or incorrect response). A sound will give information to the participant that the choice they just made was correct. The mutual information between feedback and outcome is the reduction in uncertainty about the outcome (correct/incorrect) after experiencing feedback. Our calculation of the mutual information assumes that the subjects have no knowledge of the outcome prior to receiving external feedback. However, subjects may be able to assess whether their response was correct or incorrect using their internal monitoring system, i.e. without external feedback. For more detailed description and equations, see paper 1.

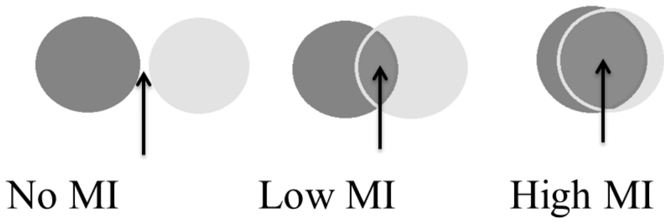


Figure 10. Mutual information between the variable feedback (dark circle) and the variable outcome (bright circle). To the left there is no mutual information (feedback do not reduce uncertainty). In the middle there is high entropy and low mutual information (feedback reduce a little uncertainty about outcome. To the right there is low entropy and high mutual information (feedback reducing uncertainty about the outcome being correct or incorrect).

3.3.4 Bayesian statistics

Baysian hypothesis testing can be used to quantify evidence in favour of the null hypothesis (Wetzels & Wagenmakers, 2012) which p-values do not inform about. This kind of testing is becoming more used in experimental psychology (Dienes, 2011) where two competing hypothesis are assigned prior probabilities. In study I, it was useful for us to quantify how much evidence there was in favour of the null hypothesis that external feedback did not change reaction time or accuracy compared to when no external feedback was given on errors. The output in the Bayesian analysis; Bayes Factor, quantifies the strength of evidence for the alternative versus the null hypotheses from a ratio of prior probability of the alternative hypothesis divided by the prior probability of the null hypothesis (Jeffreys, 1961). If the Bayes factor has a values larger than 1 it depicts favouring the alternative hypothesis. A Bayes factor less than 1 is in favour the null hypothesis. Jeffreys (1961) quantified a Bayes factor as weak, substantial and strong strength of evidence for the null hypothesis where ‘‘weak’’ in the range (1/3 to 1) ‘‘substantial’’ in the range (1/10 to 1/3), and ‘‘strong’’ in the range (1/30 to 1/10). In study 1 we used Log Bayes Factors equivalent to above mentioned categories “weak” (-1.1 to 0), “substantial” (-2.3 to -1.1) and “strong” (-3 to -2.3) evidence for null hypothesis. As exemplified in Dienes, (2011) the Bayes factor (BF) tells us how much more likely it is that our data have occurred under the alternative hypothesis than under the null hypothesis.

3.3.5 Mediation analysis

A mediation analysis tries to determine if the effect of one variable X on the dependent variable Y is explained partly by an effect of X on another variable M, which also has an effect on Y. The analysis tries to determine if the effect of X on Y is mediated by M. A path diagram of a model for simple mediation analysis is illustrated in Figure 11 (see for example Preacher & Hayes, (2004). In this model c denotes the total effect of X on Y, c' the direct effect of X on Y and ab the indirect effect of X on Y.

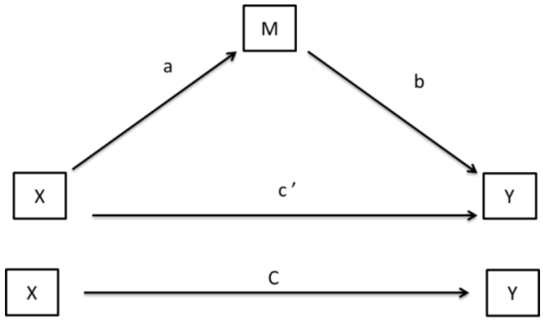


Figure 11. X-dependent variable, M-dependent variable (mediator), Y-independent variable. Path c' is the direct effect of X on Y controlling for M, Path C is the total effect of X on Y.

In Study III, we wanted to investigate if effort mediates the effect of feedback on WM improvements. Since we have four feedback groups, we have a multicategorical X-variable. Hayes & Preacher, (2013) describe a way to analyse the mediation effect when having a multicategorial variable. We used group 4 (feedback on both errors and corrects as our reference group since this is what is used today in Cogmed's WM training program). Statistical inference for the indirect effect can be made using bootstrapping (Preacher and Hayes, 2004) to estimate percentile confidence intervals (CI). If the CI for the indirect effect does not contain zero, one can consider it statistically different from zero. We used the script mediate.ssp for SPSS from Preacher and Hayes (2014) to perform the mediation analysis, using 95% CI and 5000 samples for the bootstrap procedure.

3.3.6 Brain Imaging

In study IV, we have used functional magnetic resonance imaging (fMRI) to look at brain activations during different time points of interest. MRI is an imaging is a commonly used method used to visualize human brain anatomy *in vivo*. MRI has the major benefit of being non-invasive, without any known side effects. MRI also provides good spatial, whole brain resolution and in our study. To perform an MRI, the participant lies in a tube inside a strong magnetic field. The MR-scanner at the MR-research centre in Solna has a magnetic field strength of 3.0 Tesla (30000 gauss). A big magnet containing superconducting liquid helium creates this magnetic field. For a comparison, the magnetic field of earth is around 0.5 gauss. When a person lies in the scanner, the protons (basically the protons in hydrogen atoms) in their body align according to the magnetic B_0 field. By sending in a radio frequent pulse (with a flip angel of 90 degrees) to the B_0 field, a new magnetic field is induced. This pulse excites the protons in the participant's body to a new energy state. When the radio frequent pulse stops the protons emits energy to return to their original B_0 state. A coil placed around the participant's head picks up this energy and by mathematical formulas creates images of the brain. Because different tissues in the body have different proton densities and chemical affinities, we will receive slightly different signals depending on the time it takes for the proton to originate to its' low energy state.

The participants were reminded of that they should not move their head during the whole scanning procedure. Foam pads were used to stabilize the participant's head inside the coil for further reduction of head movements. Since the scanner is loud, earplugs and hearing protection were used for all participants.

Differences of grey and white matter are caused by difference in density, which we see when we receive a structural image of an individual's brain anatomy. More specifically, the difference in grey and white matter, depends on the hydrogen atom in water being chemically bonded with other molecules in fat such as the myelin in white matter, which gives a different MR signal compared to grey matter. When we want to analyse how people react to a certain stimuli, we use something called functional MRI (fMRI). In fMRI we measure the absolute changes in concentration oxygenated blood called the blood-oxygen level dependent (BOLD) signal. The changes in BOLD signals vary due to the differences in oxygenated and deoxygenated blood. When oxygen is bound to the hemoglobin (oxyhemoglobin, Hb-O2) in red blood cells, erythrocytes, the heme component of the protein hemoglobin is covered by oxygen. The oxyhemoglobin is then diamagnetic where oxygen binds and covers the iron on the heme-group, which in turn changes the structure of the haemoglobin (Rhoades & Tanner, 2003).When oxygen is dropped off, the structure of the deoxygenated hemoglobin changes to a paramagnetic structure, making the iron more exposed. This changes the signal in the imaging field so that oxygenated blood where iron is shielded increases the signal compared to deoxygenated blood (Ogawa, Lee, Kay, & Tank, 1990). Thus, fMRI is an indirect measure of neural activation caused by changes in the absolute concentration of deoxy-Hb. This hemodynamic response, when oxygenated blood is delivered to active neuronal tissues changes the concentration of oxygenated blood in areas that are currently more active. BOLD is found to peaks after about 4-5 sec after stimulus onset (Hall et al., 2000). When giving the participant a stimulus, for example a flash of light, more oxygenated blood flow to areas such as the primary visual cortex (Ogawa et al., 1992). In study IV, we compared how people react to different types of feedback using this technique, fMRI.

For the imaging studies we used the 3 Tesla GE scanner (Discovery MR750, GE) using an 8-channel head coil at the MR Research Centre in Solna. The whole brain were covered using 40 contiguous oblique slices with slice thickness 3.0 mm with 0.5 mm gap, with a flip angle 90°, Repetition time (TR) = 2600ms; time echo (TE) = 30ms; Field of View (FOV); 28,8cm; matrix size 96x96. The normalized voxel size was 2x2x2 mm^3. A high-resolution 3D gradient-echo, T1-weighted anatomical image was also collected for each participant. Functional images sensitive to blood oxygen-level dependent (BOLD) contrasts were acquired using gradient-echo, EPI (Echo Planar Imaging, T2*-weighted images. We used the software Cogent (UCL, London, UK) supported by Matlab (r2010a, The Math Works, Natick, MA) for sequence presentation and data collection.

3.3.7 fMRI analysis

In the fMRI study we have used an event related design instead of a block design. Some advantages of an event related design is that trial presentation can be randomized and that difference in neural activity evoked by the experimental conditions during different trials can be tested (D'Esposito, Zarahn, & Aguirre, 1999). However, if two trials adjacent to each other are compared, it is possible that they share some activity and hence not differ from each other. We used a jittered interval between last stimulus with feedback and new stimulus symbol, to separate and de-correlate the event of seeing feedback from the event where a new symbol appeared.

Image processing and analysis were performed using SPM12b (www.fil.ion.ucl.ac.uk/spm/), Wellcome Trust Centre for Neuroimaging, London, UK. The scanner discarded the first six volumes automatically and the remaining volumes were realigned to the first volume to correct for head movements. We set an origin at the anterior commissure for each participant on his or her anatomical scan. The functional images were realigned to compensate for head movement in each of the sessions and a file containing the six movement regressions were created. The volumes were co-registered so that each functional image is placed against the individual's anatomical image. During segmentation the anatomical image was bias corrected for grey and white matter contrast. All subjects' brains are anatomically unique so during normalization the subject brains are adjusted into a standard brain template taken from the Montreal Neurological Institute. The fMRI data were finally smoothed spatially with an isotropic Gaussian filter of 10 mm full width at half-maximum, to reduce variability between subjects and to increase the signal to noise ratio. For each participant, the timing vectors of the individual different onset times of bivalent and univalent key presses, bivalent and univalent rule and cue symbols were made in a 1st level analysis. In the 2nd level analysis all participants' results were put together so that a full-factorial design could be performed to analyse the effects of the experimental conditions on a group level.

3.3.8 Multiple comparisons

In fMRI analysis each volume consist of with about 100 000 of voxels. Using a threshold of $p<0.05$, we would get 5000 false positive voxels when compared to the other 100 000 voxels in a volume. This means we would reject the null hypothesis of having no effect in favour of the alternative hypothesis of a significant effect in 5000 voxels. To minimize the risk of this, we have corrected for multiple comparisons using family wise error (FWE) correction. We report FWE corrected statistics of whole brain activations ($p<0.05$). We also report effects on a more liberal threshold of whole brain ($p<0.001$) uncorrected for multiple comparisons in order to give the reader a more comprehensive picture of the brain activation patterns.

Since our research is partly based on findings from previous papers, we wanted to investigate if we could replicate previous researches findings using similar experimental methods. In order to test for our *a priori* hypothesis (based on previous findings) we look for activations in specific areas that have previously been found more activated in a certain type of task or after a certain type of stimuli. We had an hypothesis that the participant would think more about themselves and their intelligence after the feedback 'you are clever' and hence paracingulum regions were chosen from previous studies by Bengtsson, Dolan, & Passingham, (2011) and Passingham, Bengtsson, & Lau, (2010). When testing our hypothesis that the paracingulum would be more active in trait condition, we studied BOLD activation in 4, 6 and 8-mm spheres (FWE), at the event of seeing the bivalent rule symbol, and at the event of seeing the feedback in the trait feedback and task feedback conditions during the FS and NFS. We also created covariates on the second level SPM analysis where we tested for correlations between BOLD and the different outcome measures; motivation scores, stress scores, difficulty scores and performance accuracy. Because we tested four outcome measures, we corrected the *p*-values for multiple comparisons with Bonferroni's correction. Anatomical locations were further verified by using the Duvernoy atlas (Duvernoy, 1999; Naidich, TP, Duvernoy HM, Delman BN, Sorensen AG, Kollias SS, 2009).

4 RESULTS AND SHORT DISCUSSION

4.1 RESULTS STUDY I

4.1.1 Brief description of study design

We investigated the effects on RT and accuracy of external feedback on errors and correct responses during a sequential WM task in adults. We report results of the effect of feedback and its placement (errors, correct responses after errors and general other correct responses) on performance accuracy and response time.

Hypothesis: Errors, correct after errors and general correct responses are differently sensitive to feedback reflected in reaction time and accuracy differences.

4.1.2 Accuracy

4.1.2.1 Internal and external feedback on error:

We found that external feedback given on all errors did not change performance accuracy compared to internal feedback on errors (Figure 12A).

4.1.2.2 Internal and external feedback on correct after errors (CAE)

At the time when making a correct response after errors, external feedback did have an effect on performance accuracy compared to no external feedback. It seemed that during this time point participants were more sensitive to external feedback since performance was reduced for the main effect contrast where feedback was present in this particular phase compare do all sequences where internal feedback (no external feedback) was presented here (Figure 12 B).

4.1.2.3 Internal and external feedback on general correct (GC) response

General correct responses (correct following corrects) generated performance reductions when external feedback was given on all, compared to when external feedback was given on only 20% of the correct responses.

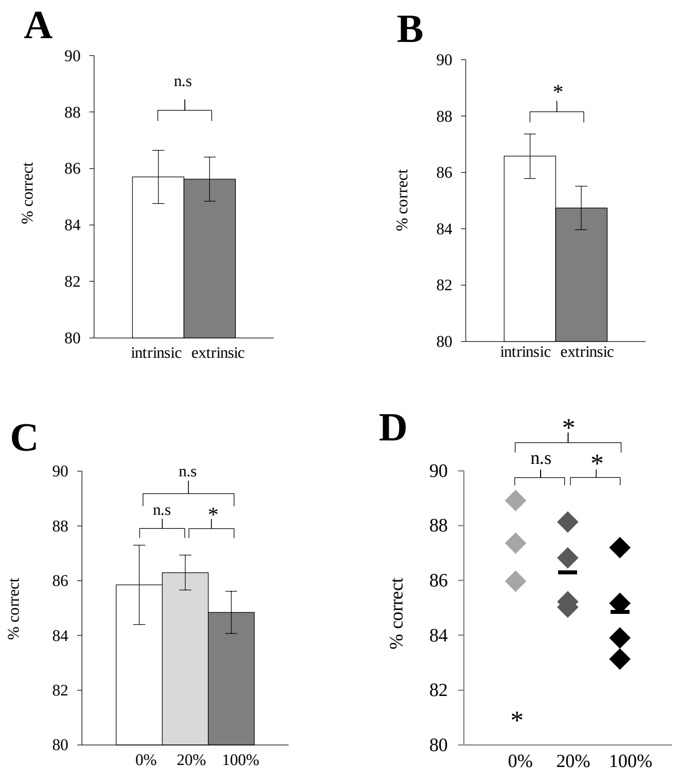


Figure 12 ABCD. Accuracy in % correct responses. A) Accuracy on sequences without and with external feedback on errors. B) Accuracy on sequences without and with external feedback on correct after errors. C) Accuracy on sequences without external feedback on general correct responses (0%), with external feedback on random 20% of the general correct responses (20%) and on all general correct responses (100%). D) Accuracy where the 12 sequences where sequence [010] is displayed as a star ($p<0.05$).

4.1.2.4 *Amount of external feedback on general correct response*

We noted that there was a sequence [010; 81% correct responses] where external feedback was given on 0% of the general corrects but sounds on CAE, which is displayed as a star in the more detailed Figure 12D. This combination seemed to be particularly disturbing. When looking at groups of sequences illustrated in figure 1D we see that there was a significant difference in receiving sound on all general correct responses (100%) compared to receiving no sound on general correct responses (0%) when [010] is excluded, ($p<0.05$). There was also a difference receiving sound on all general correct responses (100%) to receiving sounds on 20% of the general correct responses ($p<0.05$). This illustrates that sequences with a lot of external feedback (sound) are the less beneficial sequences for accuracy, regardless of if external feedback on errors or CAE is presented or not (if removing the outlier sequence [010]).

4.1.3 Interactions accuracy

There was a significant interaction between errors (E) and general corrects (GC) where external feedback on errors, together with sound on all general corrects (GC) [102] [112], resulted in reduced performance compared to the other sequences (E) and (GC) combinations, $F(2, 164) = 71.8$, $p < 0.0001$. The interaction analysis between corrects after errors (CAE) and general corrects (GC) also revealed a significant effect $F(2, 164) = 75.2$, $p < 0.0001$. Performance was significantly improved when no external feedback was presented on CAE in combination with either no external feedback on GC or when there was external feedback on only 20% of the corrects following corrects [100] [000] [101].

4.1.4 Reaction time

4.1.4.1 *Internal and external feedback on error*

We did not find any RT differences after errors depending on external or internal feedback (Figure 13A).

4.1.4.2 *Internal and external feedback on correct after errors (CAE)*

We did not find any RT differences on CAE-correct depending on external or internal feedback (Figure 13B).

4.1.4.3 *General correct responses and amount:*

We found RT differences between internal and external feedback where external feedback on all correct responses were quicker compared to internal feedback (Figure 13C).

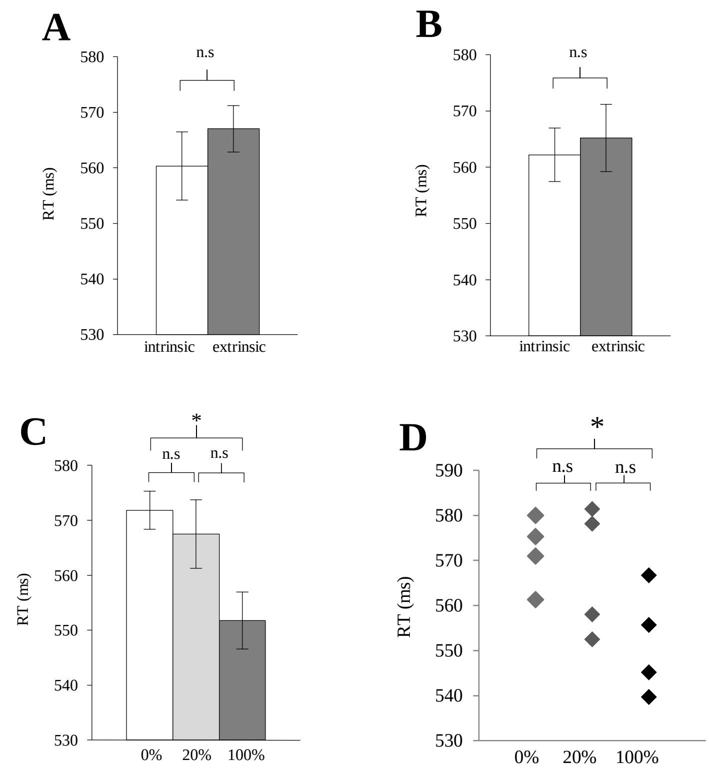


Figure 13 ABC. Reaction time A) RT when given sound or silence on errors. B) RT when giving sound or silence on correct after errors. C) RT when no sound 0%, 20% sound or 100% sound was given on general correct responses we find a significant difference between 0 % and 100% sound. D) All individual sequences shown, with significant difference in RT between 0% and 100% sound on general correct responses ($p<0.05$).

When looking at the individual sequences displayed in the figure above we can see that there is only a difference in RT between 0 and 100% external feedback (sound) on general corrects ($p<0.05$). For the sequences shown in 13D [011] and [111] are slower in RT than the sequences [001] and [101]. This suggests that in the absence of external feedback on the correct response after an error, participants had an overall quicker RT.

4.1.5 Interactions RT

The interaction analysis regarding RT showed that external feedback on CAE and GC revealed a significant effect $F(2, 164) = 3.3$, ($p < 0.05$), meaning that RT was significantly faster in the conditions where external feedback was received on CAE together with external feedback on all GC, that is, the [012] and [112].

4.1.6 Mutual information

We quantified how much information one variable (sounds), gives about another variable (the outcome being correct or incorrect). If we receive external feedback (sound) on errors, we will be sure that we made an error when we hear a sound. This means that we have high mutual information between feedback sound and outcome. In study I, we first calculated the mutual information of our two fictive sequences (see paper I for details of this calculation) with the following result: Sequence: ([100] 20% errors, auditory feedback on all errors) gives MI = 0.722; there is no uncertainty in the outcome after hearing the feedback. This is because feedback was always provided after an error e.g. upon hearing a sound we can be sure we made an error. Sequence 2: ([001], (20% errors, no feedback on errors, auditory feedback on 20% of correct responses) gives lower MI = 0.057. That is, Sequence 2 feedback provides less information about outcome than does Sequence 1.

We then evaluated if reaction time was influenced by MI. In particular we investigated if external information on an error, sequence [100], would be more informative, higher MI (reducing uncertainty about the outcome) to a participant than external feedback on a random correct responses [001], and thus influencing RT. We predicted from hypothetical sequences MI would be around 0.7 bits for the sequence [100] meaning that we would reduce uncertainty that we have made a mistake after hearing the feedback while we would not be as certain when hearing the feedback on random correct responses. However we found the opposite relationship between the two sequences where in fact a sound on errors did not reduce uncertainty about the outcome more than before receiving the feedback, MI for [001] 0.49 bits and MI in [100] 0.62 and these sequences differed significantly from each other p<0.001(figure 14A). MI for these sequences did not correlate with RT. We also wanted to test if mutual information correlated with RT for the sequences with external feedback on all correct responses. We found that mutual information was quite high when sound was given on all correct responses, thus reducing uncertainty about the outcomes (Fig 14B). MI was 0.68 bits on [012] and 0.58 bits on [102] (Fig 14B). The MI in these sequences correlated with RT showing that the higher the mutual information (participants extracting more information that this is a correct response), the quicker they responded (Fig 15AB).

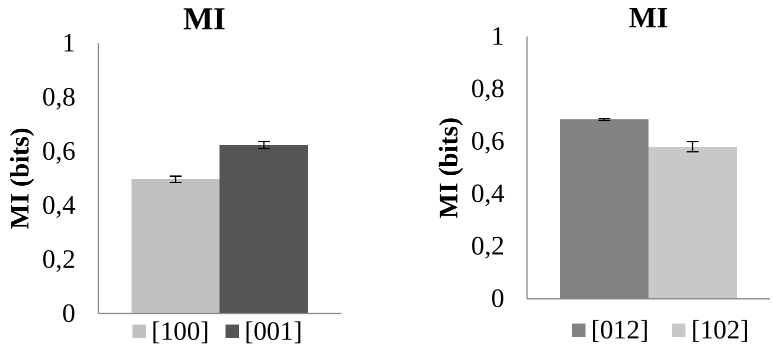


Figure 14AB) Mutual information (MI). A) MI for the two sequences with about the same amount of feedback but placed differently. Sequence [100] with feedback on all errors and sequence [001] with feedback on 20% or random correct responses. B) Mutual information (MI) for these two sequences describes that there is a quite high reduction in uncertainty when hearing the sound on all correct responses especially for the sequence [012].

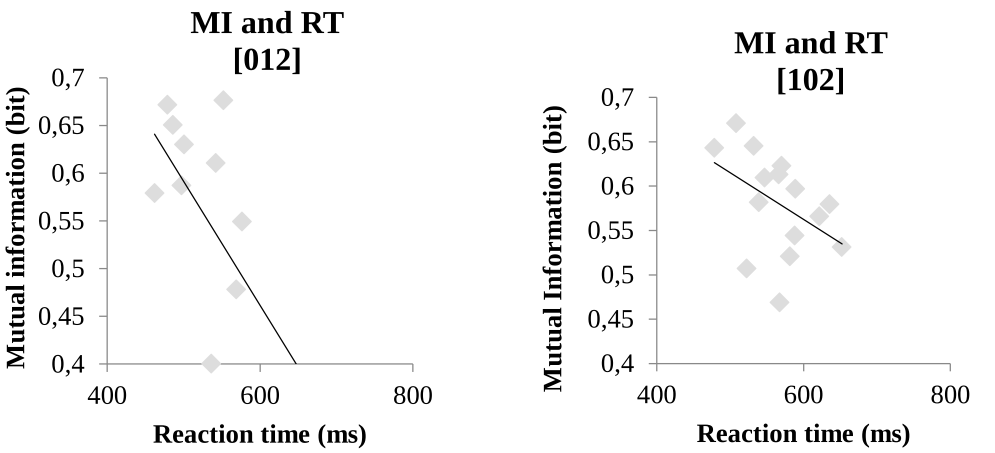


Figure 15AB) Mutual information and RT. A) There was a correlation between RT and MI in the sequence where sound was given on all correct responses [012] (*p*<0.05), the higher MI (extracting information from the sound reducing uncertainty about the outcome) the quicker the participants respond (lower RT). B) There was a correlation between RT and MI in the sequence where sound was given on correct responses and errors [102] (p<0.05) the higher MI (extracting information from the sound reducing uncertainty about the outcome) the quicker the participants respond.

4.1.7 Short discussion

We found that external feedback on general correct responses reduced reaction time and accuracy. The combination with feedback on both errors and correct responses [102] [112] was not beneficial for performance since it reduced performance accuracy found in the interaction analysis. We also found that on the first correct response after an error was a phase particularly sensitive to external feedback since accuracy was reduced when external feedback was presented at this point. RT and accuracy was not influenced by error-feedback; sequences with feedback on errors and without feedback on errors did not differ in overall performance or RT. This supports the argument that internal error monitoring is sufficient in a 2-back task where performance is approximately 80%.

Analysing mutual information we found that MI was higher for [001] than for [100]. One theory of why the reduction in uncertainty was not as big as we expected in [100] may have been because participants were able to ignore the actual error feedback thus relying mostly on their own internal feedback system. The model calculating MI is based on the notion that the participants do not know at all if they have made an error or correct response, but it is possible that this is not often the case, and that instead participants rely a lot on their own internal feedback system.

When comparing MI of the sequence with sound on errors to the sequence with 20% sound on general corrects, the sound on general correct responses may have been more difficult for the participants to ignore since participants want to attend to correct (positive) feedback. Thus, this may have been why participants extracted more information from this feedback resulting in higher MI. It is possible that feedback on correct responses are harder to ignore, which needs to be to further investigated in future studies.

4.1.8 Limitations and future direction

How we react to external feedback may depend a lot on the individual, which makes it hard to find the optimal feedback type for each task. We did not measure any individual characteristics of the participants in this study, which would have been very interesting. We had a mixed design where participants performed several sequences but not all. It would have been more optimal if all the participants had performed all sequences. In this study, we find that too much feedback was not beneficial and that error-feedback does not have to be externally delivered. However, the study was made in a lab environment and thus we do not know if these effects could transfer in other settings such as for example a classroom setting or in a computer game. Therefore, we continued with analysing the effect of trial-based feedback in study III, where we test children doing WM training in the classroom for 5 weeks.

In this study we did not distinguish between errors made on matches, when a letter had been shown two steps back (30% or trials) compared to errors made on non-matches (70% of trials), which would have been interesting since external feedback may be taken in differently depending on the character of the errors. Furthermore, it would have been interesting to differentiate between errors occurring due to non-presses and error made by actual choice and the effect of feedback and mutual information regarding outcome and feedback here. Since participants were instructed to press after all letters, we did not have many non-presses.

In our study, we did not distinguish between errors made by pressing on the wrong button due to a motor error or a faulty memory process. Therefore, we do not know which errors are mistakes where participant thought they made the correct choice and which are slips that happened due to motor error of which participants knew that they pressed incorrectly already before receiving any external feedback. Due to the nature of the task, we believe that there are more slips and this may be why the internal error process seems to work so well in this task. Unfortunately, we did not try to distinguish between these two types. In retrospect, a simpler task such as a Flanker task or Stroop task could have been chosen since in these task errors are almost exclusively slips, however, it is yet not clear if we would have received the same CAE effects which should be further tested.

4.2 RESULTS STUDY II

4.2.1 Brief description of study design

The aim was to investigate if the tendency to drop out from the training program was related to low intrinsic motivation and to having an entity mindset. We recruited 112 children (mean age 13.0 ± 0.6 years old, 58 boys) to perform ≥20 sessions of computerized WM training where each session lasted for approximately 50 minutes.

Prior to the training, the participants answered six selected questions from the Intrinsic Motivation Inventory (IMI) (McAuley et al., 1989). Three Theory Of Intelligence (TOI) questions regarding a participants mindset, were also asked which have been previously been used to measure mindset (Dweck, Chiu, & Hong, 1995). The participants filled in the questions again at the end of the training period. Only the participants who completed a minimum of 20 sessions responded to the questionnaire at the end of the training. Thus, only the questionnaires administered pre-training were used for this study.

Hypothesis of study II: Participants with an incremental mindset and high intrinsic motivation will spend a longer period adhering to the WM training protocol.

4.2.2 Trained sessions and psychometric ratings

The 112 participants, who signed up from three schools in Sweden trained on average 16.4 ±7.7 sessions (table 1) where less than half of them, fifty-three participants (47%, 24 boys, 29 girls) completed the 20 days of WM training. Four participants did not fill in the questionnaires due to technical failure.

	M	SD	N
Trained sessions all	16.4	7.7	112
Trained sessions School 1	18.0	8.7	22
Trained sessions School 2	13.7	6.6	66
Trained sessions School 3	22.3	6.0	24
Motivation Q1	5.2	1.7	108
Motivation Q2	4.5	1.4	108
Motivation Q3	5.6	1.4	108
Motivation Q4	5.4	1.5	108
Motivation Q5	4.4	1.9	108
Motivation Q6	5.5	1.6	108
Motivation Q7	5.7	1.6	108
Motivation average	5.2	1.2	108
Mindset Q1	4.1	1.7	108
Mindset Q2	3.7	1.7	108
Mindset Q3	3.8	1.6	108
Mindset average	3.9	1.3	108

Table 1. Number of trained sessions, motivation scores and mind.-set scores

4.2.3 Mindset

Mindset correlated negatively with amount of trained sessions, *r*(108)=-0.22, p=0.03 (table 1) meaning that the more incremental (low scores) the mindset, the longer they trained. Furthermore, dividing the participants in those who completed and those who did not complete 20 training, there was a significant difference in average mindset scores *t*(107)=6.01, p<0.01 (figure 16). Those who completed the training had lower mindset scores indicating a more incremental mindset, compared to those who did not complete.

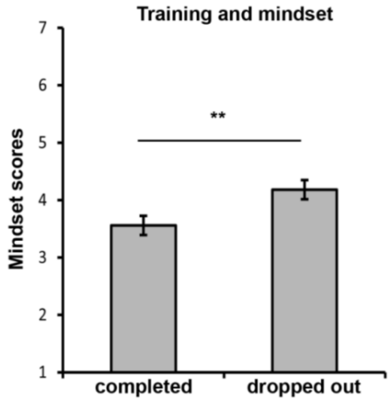


Figure 16. Completion of training and mindset. Lower mindset scores, indicating an incremental mindset was found in the group who completed ≥20 days of WM training compared to those who did not (*p*<0.01).

4.2.4 Motivation

We tested if the number of trained sessions correlated motivation. Motivation scores correlated with amount of trained sessions, *r*(108)=0.23, *p*=0.002 (table 2).

Measures	Duration
Motivation Total	.23*
Q1. I believe the training will be good for me	.27**
Q2. I believe that I will be pretty good at this type of training	-.07
Q3. I will put effort into this when I do the training	.16
Q4. I believe the training will be challenging	-.05
Q5. I believe the training will be fun	.27**
Q6. It is important for me to do well on this training	.19*
Q7. I believe I will go through with all of the training sessions	.21*
TOI Total	-.22*
QI1. You have a certain amount of intelligence and you can't do much to change it.	-.11
QI2. Your intelligence is something that you can't change very much.	-.24*
QI3. You can learn new things, but you can't really change your basic intelligence	-.18

Table 2. Correlation of motivation scores and TOI scores with training duration. All correlations are reported and level of significance are displayed, ** p<0.01, *p<0.05.

Furthermore, dividing the participants in those who completed and those who did not complete 20 training sessions, there was a significant difference in average motivation scores, *t*(107)=4.25, p=0.04. Those who completed the training rated a higher motivation prior to training. However, both the participants who completed the training (trained ≥20 sessions) and those who dropped out (<20 days training) scored above 4, indicating high motivation scores.

4.2.5 Coaches and trained sessions

There was a difference between trained sessions and coaches, $F(2,109)=14.7$, $p=0.001$. The post-hoc analysis showed that School 2 differed significantly from the other schools ($p<0.05$) with fewer trained sessions. Mindset scores did not differ between schools $F(2,105)=1.83$, $p=0.17$. Motivation scores did not differ between schools $F(2,105)=2.50$, $p=0.09$ (table 3).

	Schools (1-3)			
	1	2	3	F
N	22	66	24	
Boys	14	33	11	
Girls	8	33	13	
Training location	Home	School	School	
Trained sessions	17.95 (SD = 8.65)	13.67 (SD = 6.66)	22.29 (SD = 6.03)	14.7***
Mindset	3.49 (SD = 1.65)	4.07 (SD = 1.25)	3.69 (SD = 1.12)	1.83
Motivation	5.05(SD = 2.17)	4.85 (SD = 1.35)	5.56(SD = 0.79)	2.50

Table 3. The schools partaking (gender, location, trained days) and F-scores.

4.2.6 Feedback groups, coaches and training duration

The children were randomized into one of four feedback groups to be part of a larger study but since so many students dropped out, we later added more participants for this purpose (Study III). The feedback groups were; 1) sound on correct responses and positive verbal feedback; 2) sounds on incorrect responses and encouraging verbal feedback; 3) no sound and no verbal feedback; 4) sounds on correct and incorrect responses and both positive and encouraging verbal feedback (see Study III). There were no differences in amount of trained days between the feedback groups, $F(3,108)=1.3$, $p=0.277$, $\eta p^2=0.035$(table 4).

	Group 1	Group 2	Group 3	Group 4	*F*
N	29	30	26	27	
Sessions	15.62(SD=7.9)	18.73(SD=7.5)	15.42(SD=7.8)	15.41 (SD=7.6)	1.3

Table 4. Feedback groups and trained days.

4.2.7 Short discussion

We wanted to investigate if intrinsic motivation and mindset played a role in participant's compliance with a WM training protocol. We found that beliefs regarding one's intelligence, whether it is perceived as a fixed entity or seen as something that can be changed with effort and training (incremental) influenced the number of trained sessions. Our results are in line with previous research where an incremental mindset have been found to increase the time spent on a task (Blackwell et al., 2007; O'Rourke, Haimovitz, Ballweber, Dweck, & Popović, 2014), and we have now shown that this also applies for a WM training program.

We also found that an average score of the subset of the IMI questions which measure subjective enjoyment, effort and competence, correlated with completion of training. Our results show that if the participant believed in their ability and if they thought the training would be of value they were more likely to train for more sessions. That an optimistic view correlated positively with trained sessions is in line with popular theories that people try to match their outcomes with their expectations (Dutton & Brown, 1997) or that expectations of one's own performance influence the performance outcome (Bengtsson & Penny, 2013).

Our result show that people who think that the training will make them improve and that intelligence can increase with training, are the persons who keep training. Therefore, for coaches and teachers who are to introduce a very demanding task, it is of great importance to make the trainees understand that they can improve through training. In addition, if the trainees are given a clear purpose of the task, their persistence may increase. As a bonus, it seems to help if participants believed the training would be fun.

4.2.8 Limitations and future direction

The present study has the limitation that three schools took part with different coaches. The potential differences in coaching style were unfortunately not analysed due to the lack of information regarding each coach. The different schools did not show differences in average motivation scores before starting the training. The type of response given by the coach when the student struggled with the training may however have influenced the student's motivation to either continue or quit. In line the study by Rattan, Good, and Dweck, (2012) guidelines of how a coach can respond to lack of motivation and how to use feedback should be developed and studied.

4.3 RESULTS STUDY III

4.3.1 Brief description of method

The aim of the study was to investigate the effects of trial-based feedback on WM improvement, effort and motivation. We tested if the effect of feedback on WM improvements was mediated by the effect of effort. In addition, we also evaluated a new measure of effort by correlating this measure with motivation and mindset scores.

In total 177 children (mean age 13.8 ± 1.3, 93 boys) signed up to perform the WM training. We only included the participant who completed ≥20 sessions of training which leaves 133 participants in the WM-training analysis, mean age 13.5 ± 0.9 years, 68 boys. We used four feedback groups (Figure 17), see section 3.3.1 Task Setup, page 20.

Feedback groups	1	2	3	4
Corrects two-tone sounds	Sound	Click	Click	Sound
Errors descending sound	Click	Sound	Click	Sound
Comments regarding corrects	Well done			Well done
Comments regarding errors		That was close		That was close

Figure 17. Feedback groups in study II and III with sounds on correct or errors and feedback comments on correct and errors, or no comments or neutral click sounds.

We used the same motivational questions (McAuley et al., 1989) adapted for this particular WM training as in Study II before and after the training to see if feedback influenced the individuals' intrinsic motivation. For the same purpose, we also used the same three mindset questions as used in Study II.

Hypothesis of study III: Trial-based external feedback will influence WM training improvements, and motivation as measured by intrinsic motivation questions, mindset questions and a newly developed effort score.

4.3.2 Results of feedback effects on WM training

There were differences in maximum WM training scores between the four feedback groups, when controlling for age and start index, $F(3,127)=3.104$, $p=0.04$, $\eta_p^2= .06$. The post-hoc analyses showed that the group receiving both negative and positive feedback (Group 4) had significantly lower max scores than the group who received only positive feedback (Group 1); β =-7.56, p=0.005, two-tailed. Group 4 also had lower max scores than the group who did not receive any feedback at all (Group 3), β =-4.84, p=0.035, (one-tailed). The group who got only error feedback (Group 2) did not differ from Group 4, β =-3.19, p=0.23. This suggests a negative effect of having both positive and negative feedback together. For the different index improvements (max score – start score) see Figure 18.

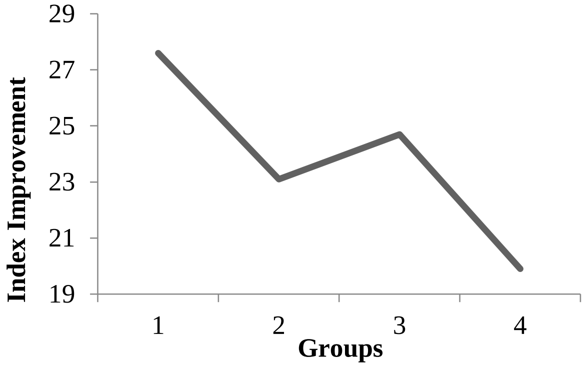


Figure 18. Index improvements (max-start) scores in the four feedback groups.
Group 1; 27.6 ±13.3, Group 2; 23.1 ±7.94, Group 3; 24.7 ± 11.9 and Group 4; 19.9 ±8.64.

4.3.3 Feedback effects on intrinsic motivation

There was a close to significant effect of feedback on motivation scores (before and after training), F(3,127)=2.42, p=0.065, ηp^2=.05. This was explained by a trend of a bigger drop in motivation for Group 4 (feedback on both corrects and errors) compared to Group 2 (feedback on errors) β = 0.43, p=0.07, and Group 3 (no feedback) compared to Group 2 (feedback on errors), β =0.42, p=0.07, illustrated in figure 19.

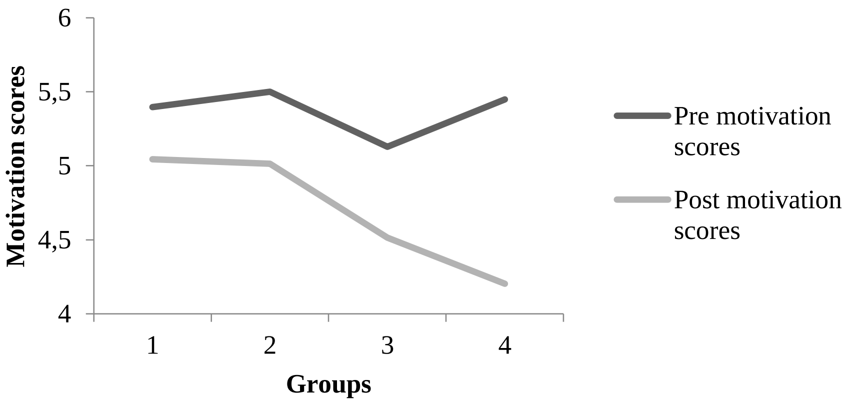


Figure 19. Post-pre motivation scores before training and after training in the four feedback groups

4.3.4 Feedback effects on effort scores

There was a trend of a difference in effort scores between the four feedback groups illustrated in figure 20, $F(3,127)=2.294$, $p=0.08$, $\eta_p^2= .05$. When looking at the post-hoc analyses we found that group 3 showed lower effort scores compared to group 1; β = -7.34, p=0.02; compared to group 2 β =-6.321, p=0.045; and compared to group 4 β =-6.21, p=0.05.

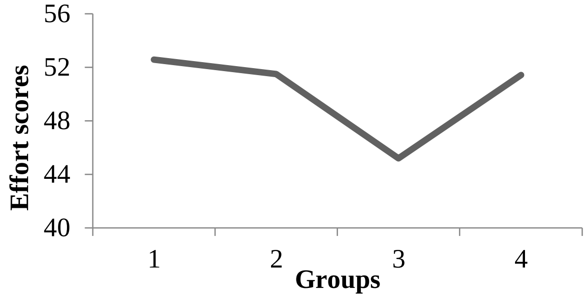


Figure 20. Effort scores in the four feedback groups

4.3.5 Evaluation of effort score

Effort score correlated with; start index, *r*=0.46, *p*<0.001 (figure 21), index improvement *r*=0.235, *p*=0.007 and intrinsic motivation before starting, *r*=0.20, *p*=0.02. Higher start index, higher index improvements and higher motivation was associated with increased effort during the training. We also analysed if all individual questions correlated with effort using Spearman correlations (table 5).

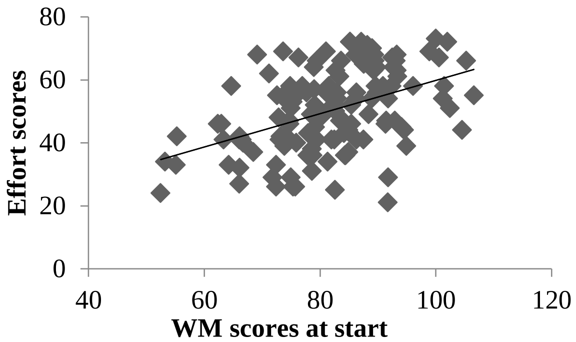


Figure 21. Effort scores and WM scores at start of the training program show significant correlation where the higher the score in the beginning the more effort the child puts in later in the training (r=0.46, p<0.001).

Measures	Effort scores (r)
Start Index	0.46***
Index improvements (max-start)	0.24***
Motivation Total	0.20*
Motivation Q1; I believe the training will be good for me	0.19*
Motivation Q2; I believe that I will be pretty good at this type of training	0.10
Motivation Q3; I will put effort into the training	0.24**
Motivation Q4; I believe the training will be challenging	0.06
Motivation Q5; I believe the training will be fun	-0.03
Motivation Q6; It is important for me to do well on this training	0.15
Motivation Q7; I believe I will go through with all of the training sessions	0.17*
Mindset Total	-0.15^{+}

***p<0.001, **p<0.01, *p<0.05

Table 5. Correlations between effort scores and start WM index, WM index improvement, motivation and mindset scores before training.

4.3.6 Short discussion

In this study, we found that feedback influenced WM training. The participants in Group 4 got external feedback on both correct responses and errors. This group showed significantly less training improvements compared to Group 1 who received external feedback on correct responses only and compared to Group 3 who did not receive any feedback.

Looking at error feedback, the group receiving external error-feedback only (Group 2) did not differ significantly from the group without feedback (Group 3). This suggests that external error-feedback alone does not have a significant impact on training improvements. Commenting on person's errors does not seem to be particularly helpful for WM improvements, neither in Group 2 (with only error-feedback) nor in Group 4 (with both error and correct feedback). These two groups did not differ in WM max index scores. In study I, we also found that external error information did not differ in accuracy from internal error feedback when looking at accuracy and that the error feedback did not add informative value to the participants. Looking at correct feedback, when given on its own, the WM index training improvements did not differ from when no external feedback is given (group 1 compared to group 3).

When external feedback was given on either corrects or errors alone it did not seem to have as much negative impact as when both error and correct feedback was given. If a person was able to prevent a shift of attention towards a sound as described in Hughes et al., (2013) the individual should be able to perform and improve in a difficult task such as this WM training program. It may be that participants wished to attend to external positive encouragements because of the nature of rewards and by doing so it got harder to neglect external error information, when this was given. Trying to attend to the positive feedback but at the same time trying to ignore the external negative error feedback, may take up more attention from the task.

We conclude that the feedback used today in the WM training program (same as received by group 4) does not seem to be the most suitable for this type of training. This can be of great value for future adjustments in computerized trial to trial tasks to try avoiding feedback that interfere with the participants focus of attention.

The degree of effort that participants put in during training was positively related with high start index score. The participants should not be able to know themselves if they have high or low WM capacity. Yet, as children tend to compare their scores to each other this may lead to that those that have higher WM compared to others know this and therefore this may evoke a sense of mastery in children. This feeling, may lead to putting in more effort into the training. Another theory is that persons WM at start reflects an ability to focus on a task for a long time. This can influence participants with high start WM work to work for a longer time on a difficult level without giving up, receiving higher effort scores.

An average score of all motivation questions correlated with effort scores later in the training. However, individual questions showed differences in correlations with effort. The questions; 'I believe the training will be good for me' (Q1), 'I will put effort into the training' (Q3) and 'I believe I will go through with all of the training sessions' (Q7) all correlated positively with effort scores. This suggests that these questions reflect the motivation to induce effort. Interesting to note is that in study II, Q1, Q5, Q6 and Q7 influenced the participant's number of trained days. This suggests that believing that the training will be good for them is both good for persisting with the whole program and for working on a very difficult level, which demands much effort. The new effort score correlated with motivation questionnaires and can be used as a complementary measure to the subjective measures of motivation.

4.3.7 Limitations and future direction

This study included a subgroup of individuals diagnosed with ADHD. Children with ADHD, who receive high incentives during a task, have been found to deactivate the DFM-network in a similar manner as they do when the dopamine agonist methylphenidate is used. This gives an indication that extrinsic rewards such incentives have a strong effect in persons with ADHD (Liddle et al., 2011). It is therefore possible that testing a large group of children with ADHD would lead to larger distinctions between Group 1 (only positive feedback) and the other groups since people with ADHD may benefit even more from receiving only external rewards as explained by Liddle et al., (2011). This could however not be tested in this study but will be interesting to look at in future studies. Furthermore, it would have been interesting to distinguish between outcome feedback sounds and verbal feedback comments that for future studies can be studied separately.

Depending of the origin of motivation it can be divided as intrinsic and extrinsic. Unfortunately, we did only ask intrinsic motivation questions even though there are extrinsic motivation questionnaires used in for example the study by (Buckworth, Lee, Regan, Schneider, & DiClemente, 2007). If parents promise their children that they will get an ice cream when the homework is done and no ice cream otherwise, the ice-cream works as an extrinsic motivator. This short ‘carrot and stick’ approach (Dickinson, 2001) have come to spread over different disciplines where rewards and bonuses are often given for hard work and is often adopted by parents. Extrinsic rewards have however become a controversial topic since this type of externally driven motivation can also have negative effects. When people perform more simple tasks it has been argued that rewards and punishments can be beneficial, whereas for more complex problems solving where creative solutions and experimenting is a major part, external rewards might be negative for the learning process (Amabile, Hennessey, & Grossman, 1986). This type of external feedback used in this task may not transfer to other types of task which should be taken into consideration.

4.4 RESULTS STUDY IV

4.4.1 Brief description of method

The aim of Study IV was to investigate how positive feedback directed at someone’s trait; being smart or someone’s action; choosing correctly, influence performance improvements, motivation and brain activation during a rule-switching task.

The effect of mindset seems to play a role for improvements and completion of WM training as shown e.g. in Study II and III. Previous long-term studies have looked at how mindsets develop in accordance to feedback exposure during childhood (Gunderson et al., 2013). In the present study, we wanted to investigate if feedback on trait (you are clever) and feedback on action (your choice was correct) could influence task attention on a short-term, instant basis and we investigated the neural processes that underlie this attentional regulation.

Twenty healthy participants (age 24±5.6, 8 females) were scanned with fMRI twice in a within subject design. Two other participants were tested but excluded, one because of performance below chance-level, the other for attending only one session. Participants were neurologically healthy, right-handed, and with Swedish (n=13) or English (n=7) as their mother tongue. They performed the task in their native language. The participants took part in four scanning sessions, two sessions per visit, in a computer based rule-switching task (E. A. Crone et al., 2006). A minimum of one day before starting the experiment the participants filled in burns depression inventory and Rosenberg self-esteem score, and four selected questions regarding intelligence mindset orientation.

At three times during scanning, the participants rated their motivation, stress, and task difficulty by answering three questions asked by the experimenter; How motivated are you to continue with the task?; How stressed do you feel right now?; How difficult did you find the task? Ratings were of 1-10; 1-very calm/unmotivated/easy, 10-very stressed/motivated/difficult. The questions were asked before the cognitive task, after FS, and after NFS (difficulty ratings were not given before the task). After the experiment, the participants wrote down how they experienced the feedback during the different sessions with the questions; What did you think about the test with feedback? What did you think about the test without feedback?

Behavioural data; accuracy (% correct), reaction time (RT), motivation scores, stress scores, and difficulty scores were analysed with repeated measures ANOVAs, and Student's paired t-tests for post-hoc comparisons in SPSS (SPSS Inc, Chicago, USA). All the behavioural analyses were controlled for the order of which the participants received each feedback type (day of testing). In order to test for significance of brain activations, we investigated the main effect of bivalent trials, main effect of condition (task/trait), and interactions between rule (bivalent/univalent) and condition (task/trait). This was done for both the FS and the NFS, locked to the event of seeing the rule symbol as well as at the event of pressing the key i.e. seeing the feedback.

Hypothesis study IV: Trait feedback evokes more focus on one's character (self) which will be reflected in increased paracingulate cortex activation and trait feedback will lead to reduced motivation and performance improvements compared to task feedback.

4.4.2 Accuracy improvements

The accuracy was higher in the no feedback session (NFS) compared to the session with feedback (FS) for both types of feedback, $F(1,18)= 6.24$, $p=0.02$). There was a few % more increase from FS to NFS when task feedback was used compared to trait feedback, $t(19)= 3.55$, p=0.04, one-sided (figure 22).

Accuracy was significantly higher for univalent trials compared to bivalent trials during FS $F(1,18)=31.18$, $p=0.001$, and NFS $F(1,18)=8.796$ $p=0.008$. Participants showed more improvement in the task feedback condition from FS to NFS compared to trait feedback, when looking at only bivalent trials $F(2,18)= 3.907$, $p=0.03$, one-sided but no such difference was found when looking at univalent trials only, $F(2,18)=0.423$, $p=0.26$.

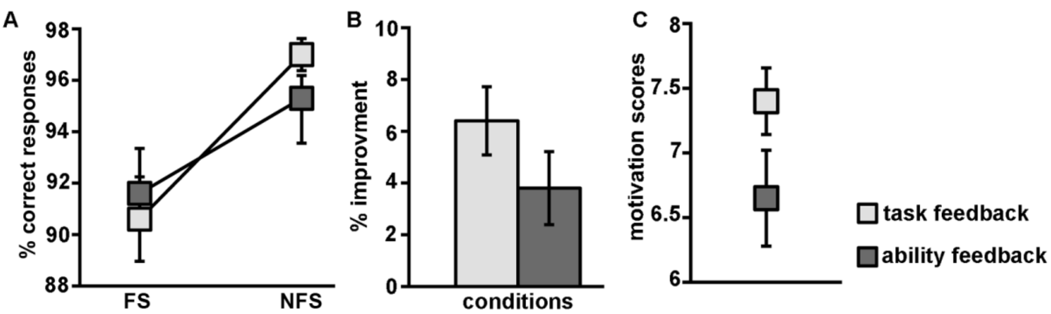


Figure 22. Accuracy, improvement and motivation scores for task and trait feedback

4.4.3 Reaction time

Reaction time was slower when receiving feedback (FS) compared to when feedback was not received (NFS) $F(1,18)=29.3$, $p=0.001$, but no difference depending on the feedback type, $F(1,18)=0.11$, $p=0.73$.

4.4.4 Motivation, stress and difficulty ratings

Feedback affected motivation $F(1.18)=6.2$, $p=0.02$. Participants rated higher motivation to continue the task after task feedback compared to after trait-feedback $F(1,18)=6.2$, p=0.02.

There was an effect of feedback on stress $F(1,18)=14.69$, $p=0.001$, where task-feedback induced less stress than trait-feedback. The first visit induced more stress within the individuals when they got trait feedback compared to the participants who got task feedback on their first visit $F(1,18)=12.1$, $p=0.003$.

We found no difference in difficulty ratings dependent on feedback $F(1,18)=0.22$, $p=0.65$.

4.4.5 Debriefing

Some more negative views were found after trait feedback such as ‘distracting’, ’annoying’, or ‘repetitive’ and some more positive view were found after task feedback such as ‘nice’, ‘motivating’, or ‘it was good’. We found that task feedback was perceived as positive by 75% of the participant whereas, 20% had negative comments, and 5% gave neutral comments. When task feedback had been removed, 70% were positive, 25% negative, and 5% neutral. We found that 30% were positive to trait feedback, 45% were negative and 25% expressed neutral comments. In regard to when trait-feedback had been removed, 60% were positive, 20% negative, and 20% neutral.

4.4.6 Questionnaires

We found a correlation between Burns depression scores and Rosenberg self-esteem scores, $r=0.87$, $p=0.001$, where the lower the self-esteem the more depressed. There was a significant interaction between mindset and feedback when looking at motivation as dependent variable, $F(1,16)=6.040$, $p=0.026$, two-tailed showing that motivation scores in participants with an entity mindset was lower (5.43±3.04) after trait-feedback (FS) than after task feedback (8.14±1.86), $t(18)=2.03$, $p=0.09$, two-tailed. Motivation score in participants with an incremental mindset did not differ between trait feedback (7.25±2.05) compared to task feedback (6.91±2.15), $t(18)=0.87$, $p=0.40$, two-tailed. We found no other effects of the questionnaires on RT, accuracy or motivation.

4.4.7 Brain activations

4.4.7.1 Anticipation of trait versus task feedback

Bilateral caudate nucleus activity was increased for bivalent trials compared to univalent trials at the time when seeing the rule symbol ([12 8 -4], t=7.62, [-14 6 0], $t=7.62$, $p<0.05$ FWE corrected, whole brain). When looking at bivalent compared to univalent rule symbols in the trait condition compared to task condition we found that left anterior caudate nucleus was more activated. Left caudate nucleus activity was increased when analysing a one-way interaction analysis between rule (bivalent > univalent) and condition (trait > task) ([-22 18 -12] $t=5.09$, $p<0.05$ FWE whole brain corrected) and right caudate nucleus was found for the cross over interaction ([24 20 18], $t=5.39$, $p<0.05$, FWE whole brain corrected).

4.4.7.2 Receiving the feedback

At the time of seeing the feedback, there was no activation surviving the conservative statistical threshold of correcting for multiple comparisons in the whole brain. We observe that at the threshold $p<0.001$ uncorrected, there was more activity when seeing the feedback ‘you are clever’ as compared to ‘your choice was correct’ for both bivalent and univalent trials. See table in paper IV.

4.4.7.3 Paracingulate cortex activation in feedback and no feedback session

We had a hypothesis about seeing more activity in paracingulate cortex, the area located between the ACC and the anterior frontal pole e.g. in the anterior medial prefrontal cortex during the trait feedback condition (Amodio & Frith, 2006; Bengtsson et al., 2011; Bengtsson, Lau, & Passingham, 2009). When seeing the rule symbol during in the (FS) trait condition we found a main effect of trait > task feedback activation in the anterior paracingulate cortex 4-mm sphere ([12 52 28], t=2.46, p<0.05 small volume corrected (SVC), ([12 54 26], t=2.59 p<0.06, 6-mm).

Seeing the bivalent rule symbol during the no feedback session (NFS) when previously having seen the trait feedback also evoked increased paracingulate cortex activity in a 6-mm sphere, for the interaction (bivalent > univalent) and condition (trait > task) ([6 50 26], t=2.76, p<0.05, SVC). This was also found in the contrast; trait bivalent rule vs. trait univalent rule ([6 50 28], t=3.08, p<0.05, SVC).

We found that there was a significant positive correlation between BOLD and performance accuracy at the event of seeing the bivalent rule symbol, in the no feedback condition following the condition with the task feedback (16 50 30, t=4.26, p<0.008 Bonferroni corrected).

4.4.8 Short discussion study IV

We found different effects of trait feedback i.e., ‘you are clever’ compared to action/task feedback i.e., ‘your choice was correct’, on motivation, accuracy improvements, stress and brain activations. Trait feedback reduced motivation, increased stress and lead to less accuracy improvements compared to task feedback. During the trait feedback session we found increased caudate activation compared to task feedback during anticipation when having seen the rule symbol. We found increased activation in trait feedback sessions compared to task feedback sessions in paracingulate cortex, in line with our prior hypothesis. We also found increased paracingulum activity in the condition without feedback following the task feedback session.

4.4.8.1 Previous research of anticipation of rewards

The caudate nucleus has previously been found during anticipation and of wanting a reward in several studies on humans (Berridge, 2007; Aharon, Kahneman, & Shizgal, 2001; Hajcak & Simons, 2002; Knutson, Adams, Fong, & Hommer, 2001; O’Doherty, Critchley, Deichmann, & Dolan, 2003). When participants can win or lose money in a task depending on their action, caudate nucleus is activated when they anticipate a reward with uncertainty to whether their action will lead to the desired outcome or not (Tricomi, Delgado, & Fiez, 2004). Tricomi et al., (2004) argued that caudate nucleus is more associated with the anticipations of secondary rewards such as winning money or making a correct response, whereas nucleus accumbens seem more activated by anticipations of primary reward, such as when later getting to drink a juice. They investigated the link between anticipation of positive feedback related to participants’ own actions arguing that the participants’ later action is required to elicit the anticipatory activity of the caudate nucleus.

4.4.8.2 Caudate activity in the current study

In our results of study IV, we found increased activation during anticipation on bivalent rule symbols compared to univalent symbols in the caudate, in line with the results of Tricomi et al., (2004). This activation may reflect that the participant starts to anticipate the upcoming cue symbol with uncertainty. This uncertainty may be related to thoughts about which symbol will be next and what to respond in order to receive the rewarding feedback. In line with this argument, our result showed increased activity in the caudate during bivalent rule symbols in particular due to greater uncertainty of the upcoming symbol.

We found less caudate activity on univalent trials. Univalent trials are easy and have a fixed outcome. Thus, participants are probably more certain when seeing this type of rule symbol. When seeing the next symbol, participants now will know what to press in order to receive the feedback that will follow a correct choice without having to remember the first symbol. If it was a bivalent trial, the participant would on the other hand have to remember the rule symbol in order to connect the two to perform the correct button press. Behavioural data also showed that univalent trials were much easier than bivalent trials.

4.4.8.3 Task and trait feedback

In the sessions where the feedback sentence 'you are clever' was delivered at correct choices, participants had increased caudate activity at the time of seeing the bivalent rule symbols compared to the sessions when 'your choice was correct' was used.

Making associations to intelligence seem to have an enhanced impact on the participants' confidence compared to thoughts regarding making a correct choice. The feedback 'you are clever' relates to a person's character, and as found in the debriefing, some but not all, participants found this feedback to be annoying, disturbing or even ironic in a task like this. When participants were anticipating 'you are clever' they may have felt a higher level of uncertainty regarding their future actions and outcomes and during this session they may possibly have felt that there was more at stake, compared to the session with the feedback; 'your choice was correct'. This may have strengthened their anticipation during the rule symbol. As the behavioural results showed, trait feedback did lead to slightly less improvement and participants were also found to be less motivated to continue after this session.

Furthermore, in the session with the feedback 'you are clever', we found more activity in the brain in general. It may be related to that the trait feedback sentence need to be translated into 'correct' whereas in the task feedback session, participants are given the direct message of choosing correctly which does not need further translation and participants can instead focus their full attention to the task, which is beneficial for full focus on the task.

4.4.8.4 Activity at the time when receiving the feedback

Anticipating feedback have been found to differ from receiving the feedback (Herwig, Kaffenberger, Baumgartner, & Jäncke, 2007; Nitschke, Sarinopoulos, MacKiewicz, Schaefer, & Davidson, 2006; O'Doherty, Deichmann, Critchley, & Dolan, 2002). In a study by O'Doherty et al., (2002), they found midbrain, posterior dorsal amygdala and striatum activations when people expected a taste reward but these areas were not found when receiving the reward itself. In our study, did not find caudate activation increase at the time when receiving the feedback in either task or trait feedback session. This indicates that the reward was expected (Schultz and Dickinson, 2000) possibly already at the time when seeing the first symbol for univalent trials and at the second symbol for bivalent trials.

4.4.8.5 Paracingulate activity during anticipation

We found increased activity in the paracingulate cortex in the trait compared to the task feedback session when seeing the rule symbol. This activity may reflect self-reflection on cleverness such as (Am I smart/stupid?). Interestingly, we also found paracingulate cortex activity in the silent condition following the task feedback session at the time when seeing the rule symbol. This activity correlated with performance accuracy. This internally evoked self-reflection following the task feedback session, can be related to choosing correctly/incorrectly, which seem to have benefitted performance monitoring. On the other hand, paracingulate activity evoked during the session with trait feedback session, may relate to self-reflection about one's intelligence, which was not beneficial performance.

4.4.9 Limitations and future direction

From this study, brain activation patterns together with the behaviour results give us an indication that trait feedback seems less beneficial.

We used subjective measures of stress and difficulty where the participants had to tell the experimenter their ratings. It would have been interesting to also use an objective measures such as cortisol and heart rate to measure their stress level.

This task was easy for the participants. Having a more complex task with different levels of difficulty would have been valuable in order to investigate the effect of feedback depending on task difficulty. In a more difficult task, we could also have studied the reactions to errors depending on the type of praise given in the two conditions. Furthermore, with a larger sample, we could also have looked into the participants' entity or incremental mindset in relation to their mistakes in the trait and task sessions.

5 OVERALL DISCUSSION AND FUTURE DIRECTIONS

The overall aim of this thesis named; Error, Praise, Action and Trait, was to investigate the effects of trial-based feedback and anticipations on performance accuracy and motivation in cognitive-tasks such as WM-tasks and a rule-switching task.

External input can grasp our attention. The disadvantage of attending to feedback is that the feedback itself can use up our attentional resources that could otherwise be spent on the actual task (Kanfer & Ackerman, 1989). When an individual is focusing on a task, activity increases in areas needed for that particular task and a decrease in activity has been found in the posterior cingulate, precuneus and medial prefrontal cortex (MPFC). This network is instead increased when a person is in a resting state (Fransson, 2006; Raichle et al., 2001).

In our studies, we have demonstrated that feedback can be used to direct attention. More specifically, studies I and III illustrate that feedback frequency matters for performance. In study I, we found that too much external trial-based feedback on a WM task was not good for performance accuracy. In study III, in which we tested trial-based feedback on students in a school environment, we replicated the finding from study I. Students were found to improve less in a WM training program when both positive and negative feedback was given, compared to other groups receiving only positive or no feedback. These two studies point in the same direction showing that feedback on all trials, both errors and corrects, hampers performance, see summary figure 23. When external feedback on errors and correct responses is given, it is possible that attention is drawn towards the external input and away from the internal task monitoring, which reduces performance.

One attention grasping mechanism described in previous research is when there is a change of auditory sounds in a sequence (Sörqvist, 2010). This may be the reason why we in studies I and III found that the combination of correct and incorrect sounds were particularly distracting for the individuals' cognitive performance in WM tasks. This effect of distractions by task irrelevant sounds on performance (Sörqvist et al., 2012) is an important issue to take into account when designing tasks using feedback with sounds that aim to be helpful rather than distracting.

The results from study III in particular can be used to try to improve computerized pedagogic tools such the feedback used in WM training software. Moreover, it would be of great interest to use the same setup as in study III, with feedback groups, to test on individuals with ADHD. The effects of positive feedback alone and distractions of positive and negative feedback combined may play an even bigger role, when the attentional control is lower, which needs to be tested.

The will to perform well and the fear of failure can become a hindrance in everyday life. For example, people who have a self-esteem based on results e.g. a performance-based self-esteem, burnouts are common (Dahlin et al., 2007). Moreover, ascribing one's own value to accomplishments have been linked to increase drop-outs from schools (Vallerand, Fortier, & Guay, 1997). In Study II of this thesis, performed in schools, we investigated factors influencing persistence and dropouts from a demanding WM training program. We found that students' motivation and way of thinking about intelligence influenced the number of trained sessions. A growth mindset, high beliefs about the usefulness of the task and a student's strong belief of being able to complete the training were factors that correlated positively with trained sessions. This is in line with previous work (Blackwell et al., 2007; Mueller & Dweck, 1998) where students with a growth mindset showed increased motivation. The results also fit well with Bandura's (1993) description of self-efficacy and of the importance of having a goal and a purpose for a task, as explained by Ryan & Deci (2000). It is of great educational value to better understand the effects of prior expectations before starting a task or program, since these expectations have great impact on improvements and persistence.

We found a correlation with low self-esteem and depression scores in study IV. However, a high view of oneself does not have to influence performance or effort in a positive direction (Baumeister et al., 2003). This is of importance to study further since the relation between self-view and performance is complex. For example, in Study III we did not find correlations between a person's strong belief of being good at an upcoming task and more effort when the task started. Starting a challenging training program with the belief that the task will be easy and that one will do well was not beneficial when looking at the effort measure. One explanation of this may be that these high expectations on performance were not met in the training. If the task presented a greater challenge than expected, it is possible that the individuals were influenced by fixed thoughts, such as; 'I'm no good at this task'. These kinds of thoughts may have influenced the individual's effort and the urge to give up which would be of interest to test in future experiments.

In study III we took the concept of effort and motivation one step further by analysing a new measure, effort score. The effort scores correlated positively with high intrinsic motivation (figure 23) indicating that this measure of effort can be used as a complement to the questionnaires, which should be further evaluated in future studies to better understand the aspects of effort.

Kluger & DeNisi, (1996) suggested that feedback is not always beneficial for improving achievements. In the thorough review by Hattie & Timperley, (2007), on the educational aspects of feedback, they discuss why feedback is not always beneficial. They argue that person related feedback such as "you are fantastic" or 'you are an idiot' do not consist of information that informs the participant about the task and how to change strategy to improve and therefore this type of feedback does not enhance self-efficacy. A focus on oneself rather than the task may lead to assigning the performance outcome to one's character rather than to the actions. There are studies suggesting that associations to things unrelated to the task influence where our attention is directed (Guinote, 2007). If feedback involves something self-related it may therefore direct attention to oneself instead of to the task (Butler, 1987; Hattie & Timperley, 2007). Interestingly, the processing efficiency theory by Eysenck and

Calvo (1992) depict that anxiety can take up peoples' attention but can also work a drive to increase effort in order to perform well.

Actions can be changed but one's characteristics are viewed as fixed, as described by Dweck, (1986). Inspired by the work of Dweck and colleagues, especially the study by Gunderson et al., (2013), on long-term effect of action and trait feedback, we decided to use the two types of positive feedback or praise in an imaging study. Our results in study IV imply that action and trait feedback also had short-term effects, reflected in different brain activations and behavioural measures. When feedback related to an action rather than a trait, it seems to be better for both motivation and improvements.

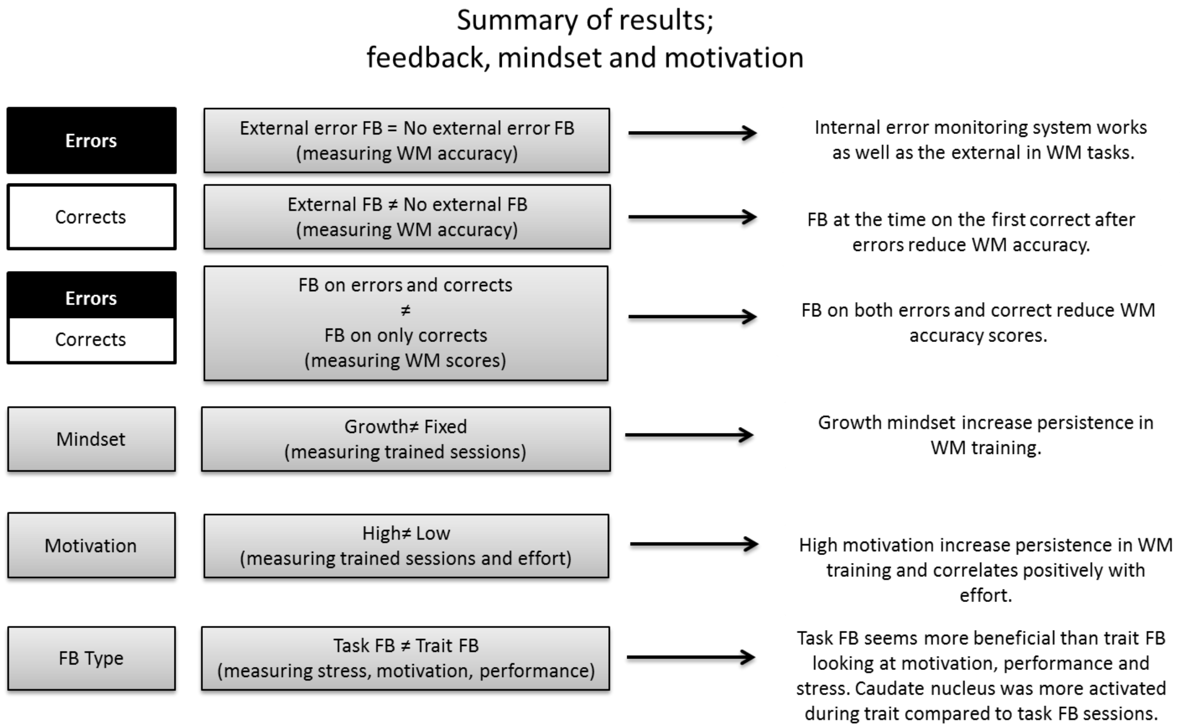


Figure 23. Summary of some of the major results of the studies included in the thesis regarding feedback (FB), mindset and motivation on working memory (WM) accuracy.

Another important aspect that has been addressed in this thesis is how to adjust the difficulty level in a task. The level of difficulty has also been described to influence the level of which feedback sounds work as distractions (Halin et al., 2014). It would be of interest to study these effects also in a more difficult task, which would give the opportunity to also look at errors. Furthermore, for future studies, with a larger sample, and a more difficult task, we can investigate the effects of trait and task feedback on errors and if these reactions differ among people with a growth or fixed mindset.

One aspect that was only touched upon in study III was the student-teacher relationship and how this influences motivation and performance. A teacher's expectations on their students has been shown to influence students' performance (Rosenthal & Jacobson, 1968). Furthermore, the way of teaching can have a lot of impact on the students' motivation (Rattan et al., 2012; Reeve, J., Boilt E., Cai, 1999). In study III, we found that the impact of coaching was a factor influencing training compliance but we did not have enough information regarding the coaching to understand the effects. For future studies, it would be of interest to standardize the coach protocols and use coach evaluations to better understand the role of coaches for persistence in WM training program.

The research done on how we react to setbacks and mistakes relates to the clinical condition of having a hyperactive error-monitoring system found in people diagnosed with OCD (Fitzgerald et al., 2005; Huyser, Veltman, Wolters, de Haan, & Boer, 2011). Moreover, this strong reaction to mistakes is also found in students who score high on conscientiousness (Fitzgerald et al., 2005; Hajcak & Simons, 2002). It would for future studies be interesting to analyse how expectations play a role in handling mistakes and if we can via feedback and expectations influence these reactions, so that these reactions do not impede daily life.

In the future, I hope to find more studies on how feedback and expectations can influence training and motivation. This way we can develop computerized learning games and teaching strategies that can be put into practice to increase individuals own will to learn and improve.

Don't be disappointed with yourself

for not knowing things

before you learned about them

but give yourself and others

the feedback needed

in order to learn

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