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The Effect of External Motivation on Strategy-Selection in Working Memory Updating Tasks

Bachelor's Project Thesis
Artificial Intelligence
Peter Clark, S3316998, p.clark@student.rug.nl
Supervisor: Corné Hoekstra, MSc.

Abstract: Cognitive performance on working memory tasks differs with motivation, however with little direct study on the interaction between reward motivation and working memory tasks in humans. Working memory tasks utilize cognitive executive functions such as inhibition, updating, and shifting. In this experiment, we studied the relationship between external monetary motivation and the cognitive strategies used to complete a series of 3 updating span working memory tasks. Participants used either an active updating strategy (maintaining and updating information in working memory) or a passive receiving strategy (recall of information at end of trial). The 3 updating span tasks included a letter-memory, a keep-track, and a tone-monitoring task. From 23 participants, we discovered significant differences caused by self-reported active strategy usage for the Tone-Monitoring task, and for a model including the interaction between motivation and reported strategy usage for the Letter-Memory task. This study shows that performance-contingent rewards affect WM updating, and open the potential for further research into the nature of motivation and WM components.

1. Introduction

Working memory can be described as a set of mechanisms that are dedicated to holding mental representations for further cognitive processing (Ecker et al, 2010), and it involves the encoding, maintaining, and manipulation of information that facilitates us to complete cognitively demanding complex tasks. In order to effectively use working memory, the contents of working memory need to be updated as new information is presented. Even a simple task like counting sheep in their pen requires updating a number in working memory with every object counted, two numbers if you are counting lambs as well (Garavan, 1998). Updating of working memory was found to be one of three correlated factors, alongside shifting and inhibition, that was able to distinguish differences in executive functions at an individual level (Miyake et al. 2000). It was first studied in 1962 by Yntema & Mueser, in an experimental design in which subjects were presented with a long list of words one by one and asked to recall the last exemplar from a set of categories, called a keep-track task. In a related task used by Morris & Jones (1990), a running span task, participants were asked to recall the last *N* items presented to them from the list. The running span task has been used to study Baddeley's model of executive function (1986). Both of these tasks are complex working memory tasks that require the updating and maintaining of an unknown quantity of serially ordered information. The updating factor of working memory is the only one of the three found by Miyake et al. (2000) that is a significant predictor of fluid intelligence (Friedman et al. 2006).

Cognitive performance on working memory tasks is influenced by a variety of factors such as motivation, task complexity, cognitive and memory resource availability and more. Since working memory tasks deal with focusing on relevant information and disregarding irrelevant information, the active use of cognitive functions like working memory updating play a vital role in successful completion of those tasks. Selecting and following-through with use of cognitive functions is what we refer to as action-selection/strategy-selection. In a neural study done by Krawcyzk (2007), the effects of reward motivation in working memory tasks suggest that a high-level of active cognitive control is utilized. Cognitive control is heavily reliant on selection of relevant information alongside inhibition of irrelevant information, and dependent on availability of cognitive and memory resources.

Subjects in the working memory tasks described above seem to keep track of the required information by actively updating that set of information as new items are presented to them (Bunting et al, 2006; Hockey, 1973; Morris \& Jones, 1990). Hockey (1973) hypothesized that there are two cognitive strategies to completing these running span tasks: An active strategy of updating as described above, or a passive strategy of observation and recall. Active updating is a highly cognitively demanding task and applied only when necessary (Chatham et al., 2011; Juvina & Taatgen, 2007). Participants reported a slow-paced running span task associated with active updating use was more challenging to complete than a fast-paced running span task associated with passive recall (Bunting et al, 2006). Here, pace refers to speed of stimulus presentation. The use of active updating in these tasks is linked to distinct activity in the dorsolateral prefrontal cortex, activity not seen with the use of passive recall (Miyake et al., 2000). This means that different parts of the brain are used when participants report using working memory updating to complete a task compared to the passive recall strategy.

The nature of the relationship between motivation, performance and active use of cognitive functions like working memory updating is not known. Motivation in cognitive psychology and neuroscience refers to the combination of intrinsic and external motivation. In other words, the forces that influence motivation occur both within and externally to the individual (Kozlowski, 2012, p.457). A common salient form of external motivation is a performance-contingent reward. Performance-contingent rewards are directly tied to the participants performance in a certain task. These types of rewards are often used in the real world to encourage increased performance. In educational systems, grades, gold stars and praise is given to students (Covington & Müeller, 2001), while organizations may use financial rewards to encourage and motivate employees (Garbers & Konradt, 2014). Positive effects from external rewards have been found for creative performance (Eisenberger & Aselage, 2009). Some researchers believe that rewards produce detrimental effects on performance, known as the undermining effect of extrinsic rewards on intrinsic motivation (Deci, Koestner, & Ryan, 1999) or the over-justification effect; attribution of motivation to the reward rather than the task (Lepper et al, 1973).

While the effects of motivation as a whole have been positively linked in recent meta-analyses (Garber & Konradt, 2014; Cerasoli, Nicklin, & Ford, 2014) to qualitative and quantitative performance, the effects on performance of specifically performance-contingent rewards is unresolved (Hendijani, 2016). It may be the case that performance-contingent rewards are positively linked to performance, or that they are negatively linked through behavior controlling effects, such as the over-justification effect in occasions where the rewards are absent when previously present (Ross, 1975). Reward salience is a cognitive process that assigns the '*desire*' or '*want*' attribute to a stimulus (Puglisi & Ventura, 2012). Too much reward, leading to raised reward salience, and participants could experience the *choking under pressure* phenomenon (Ariely et al. 2009). Too little reward and participants may feel that it's not worth the effort or may feel slighted, leading to significantly decreased performance (Ross, 1975; Gneezy & Rustichini, 2000). Discovering the right type and nature of external reward motivation has a lot of potential for improving efficiency and performance in schools, hospitals and more.

Both motivation and the use of active updating affect the level of cognitive resources devoted to solving a problem. The introduction of monetary rewards affect overall performance in tasks of sufficient difficulty to test the capabilities of participant's ability to effectively use an active updating strategy. In this experiment, we report data from a series of three running span working memory tasks to study the relationship between performance on these tasks, motivation through presence of performance-contingent rewards, and self-reported strategy use. We explore the overall relationship by deconstructing it into a few component research questions, and modelling the results of each:

1) What is the effect of performance-contingent rewards on task performance?

With this first question, we are looking at the effects of having performance-contingent rewards present versus not, across the keep-track and running span tasks. It is our hypothesis (**H1**) that the presence of performance-contingent rewards will improve task performance for all tasks.

2) Is the presence of performance-contingent rewards a predictor of strategy use?

For this question we are looking at how the presence of rewards affected participants ability to successfully use their chosen strategy to complete the task, and whether the presence of rewards is enough to predict participant strategy usage per task. It is our hypothesis (**H2**) that the presence of performance-contingent rewards will be able to predict the strategy a participant ends up using to complete the tasks.

3) Is self-reported active updating strategy use a predictor of task performance?

Looking at performance by task and whether an active updating strategy was used will help examine the difficulty of the tasks, and the rate of successful usage for each strategy types. Task difficulty is correlated to cognitive resource use or mental effort, and will be looked at in the discussion. For this question, it is our hypothesis (**H3**) that active strategy use will be a predictor for improved task performance for all tasks. This question will further help us understand the difficulty of the tasks and how experiment design may have affected our results.

4) What is the interaction between performance on task, presence of performance contingent rewards, and strategy usage?

Lastly, we will examine the interactions between the aspects of our experiment. It is our hypothesis (**H4**) that there will be a significant positive effect on performance for motivation and active strategy usage. If the model is found to have significant effects, but no interaction effects, this would indicate that both motivation and strategy usage have an independent effect on performance. We will investigate this by using a more complex model, and backwards fitting if necessary. Through this experiment we hope to further the state of research about the nature of external motivation and its effects on cognitive performance.

2. Methods

The participants were 23 adults (13 female) aged 18-36 years old, recruited through a group connecting participants to paid experiments. The mean age was 24.6 years old. Participants completed three working memory tasks related to the updating component of executive function. Tasks were presented on a Macbook Pro (1200x800p) screen using tasks coded in the psychology experiment program OpenSesame. OpenSesame is an open-source, graphical experiment builder for the social sciences (Mathôt, 2012). Participants responded using a keyboard and mouse. The three tasks were taken from the updating section in Miyake et al., (2000). The tasks are the *Keep-Track* task, the *Letter-Memory* task and a slightly modified *Tone-Monitoring* task (See *Tone-Monitoring* Below). Subjects were paid 8€ for participation. In the context of our experiment, when referring to motivation we are speaking of performance-contingent monetary rewards per trial. The experiment consisted of two blocks per task type: *Motivated* where the participant can earn 0.2€ extra for each correct trial, and *Unmotivated*, where nothing is gained per correct trial. If a trial was *Motivated* and the participant could earn extra money for getting 100% correct on that trial, they were informed of that before beginning said trial. All timings of stimulus presentation are in line with Postle (2003), to generate task conditions though to generate an *effective updating* process. All 23 participants were able to successfully complete all three tasks in this experiment, for both motivation conditions. Participants were encouraged to answer each task carefully and to the best of their ability, meaning reaction-time was not studied in this task. Each task type had 2 practice trials to familiarize the subject with the task before beginning the data-recorded section of the experiment. The order of the three tasks, and motivation condition was randomized for each participant.

2.1 Keep-Track

The Keep-Track task consisted of a sequence of 13-15 simple nouns randomly selected from one of six semantic categories (see Appendix for full list). The nouns were shown one at a time for 2000ms. Below the presented nouns was listed four categories, randomly selected out of the original six. After all the nouns were presented, participants were asked to remember the last presented word for each of the shown categories, and were provided with blank inputs directly adjacent to the category word. The block size for this task was 7 trials for each motivation condition, for a total of 14 trials.

2.2 Letter-Memory

The Letter-Memory task consisted of a sequence of 7, 9, 11, or 13 randomly selected letters presented one-by-one for 2000ms each. At the end of the trial, participants were asked to list the last four letters that had been presented to them. Subjects were prompted to answer by being presented a blank screen with 4 places for single letter input. The block size for this task was 8 trials per motivation condition, for a total of 16 trials.

2.3 Tone-Monitoring

The Tone-Monitoring task consisted of a series of randomly selected tones, length 10-12, being presented serially for 2000ms each, followed by a 500ms gap. There were three tones potentially able to be played: a *low* tone (500Hz), a *mid* tone (1000Hz), and a *high* tone (2000Hz). Participants were able to familiarize themselves with the tones before the trials began. At the end of the trial, participants were asked how many times the tones of each pitch was played. The block size for this task consisted of 8 trials per motivation condition, for a total of 16 trials. For this experiment, participants used over the ear headphones provided by the experimenter. This task was modified from Miyake et al. (2000), removing a sub-task where participants had to actively respond to elements during the task, rather than solely at the end of each trial.

2.4 Strategy Reports

Before the experiment began, participants were informed of possible cognitive strategies that they could use to complete the tasks. The main strategies types were taken from Botto et al. (2014) and Norris et al. (2019), and reduced to include *Active Updating*, *Passive Recall* and *Other*. Active Updating strategies encompass any cognitive strategy that involved maintaining and updating information in the participant's working memory. Passive Recall involves recalling the information presented to you, but is not immediately accessible in the participant's working memory. Other refers to strategies that do not fall directly into these categories, such as higher-level semantic or visualization strategies; for the purpose of the analysis, these were assumed to fall under an Active Updating strategy. Furthermore, at the beginning, the participants were informed what the use of possible cognitive strategies may entail, or *look-like* for each task type.

Every four trials, participants were asked two questions: "What was their intended strategy to complete the trial?" and "What strategy did they use to actually complete the trial?". At the end of each of the three tasks, participants were asked to rate *(Almost Always, Often, Not so Often, Rarely)* how often they felt like they were successful in following through with their desired strategy, and how often they used the different cognitive strategies. These strategy survey questions were based on those provided by Dunning & Holmes (2014), and Kaur et al. (2019). Examples of what the tasks look like when visually presented to participants can be found in the Appendix (A.1-A.5).

3. Results

3.1 Statistical Analysis

We fitted general linear regression models for each of our targeted research questions and a linear model to study parameter interactions. The modelling and preprocessing was done in RStudio. The effect of motivation on performance was studied with all trials from all participants, while the rest only used trials in which the strategy questions were asked after completion of the trial.

3.2 Motivation & Performance

Looking back at the first research question which can be rephrased as follows, "*Does having external rewards (motivation) improve task performance?*", we look at mean accuracy for each task, aggregated over all participants. These results can be seen in Table 1 below.

	Keep-Track	Tone-Monitoring	Letter-Memory
Motivated	36.23% (±5.7)	66.67% (±5.9)	48.37% (±5.9)
Unmotivated	28.26% (±4.8)	63.04% (±7.4)	49.46% (±3.5)

Table 1: Motivation Condition vs Correct Performance

The three tasks varied in overall difficulty as can be seen by average performance. Tone-Monitoring was the easiest to complete, followed by the Letter-Memory Task, with the Keep-Track task being the most difficult to correctly complete. Separate linear models were run for each task to investigate whether the motivation condition is a significant predictor of performance on task. The results of each of those models are as follows. There were no significant effects found for different motivation conditions of the trials on performance for any task. For the Keep-Track task, ($F(1,274)=2.007$, $p=0.1577$). For Tone-Monitoring, ($F(1,274)=2.004$, $p=0.158$). Lastly, the results for Letter-Memory are, ($F(1,366)=0.043$, $p=0.835$).

3.3 Motivation & Strategy Usage

For our second research question, "*How does having external rewards (motivation) affect self-reported strategy usage?*", we looked at how participant's reported active strategy usage is affected when completing the task in different motivation conditions.

Table 2 below shows the percentage of trials where the participants reported successfully using the Active Updating Strategy to complete the task. The data used for this table consisted of trials after which the two strategy questions were presented to the participant, and is a subset of the data used in 3.2.

	Keep-Track	Tone-Monitoring	Letter-Memory
Motivated	70.59%	92.50%	60.87%
Unmotivated	55.55%	82.35%	59.57%

Table 2: Motivation Condition vs Self-Reported Active Strategy Usage

While the Tone-Monitoring and the Keep-Track tasks both demonstrated noticeable differences (see Table 2) in strategy usage depending on whether a trial was motivated, it was found that there were no significant effects for motivation condition on reported active updating usage. This was confirmed by running separate linear models for each task, results are as follows. For Keep-Track, ($F(1,68)=1.685$, $p=0.198$). For Tone-Monitoring, ($F(1,72)=1.766$, $p=0.188$). For Letter-Memory, ($F(1,91)=0.016$, $p=0.899$).

3.4 Strategy Usage & Performance

For our third research question, "*How does reported strategy usage affect performance per task?*", we looked at how accurate participants were compared to whether or not they reported using active updating to complete the task. The results can be seen in Table 3 below. The data used for this table consisted of trials after which the two strategy questions were presented to the participant, and is a subset of the data used in 3.2.

	Keep-Track	Tone-Monitoring	Letter-Memory
Active Updating	27.27%	70.77%	55.36%
Passive Recall	23.07%	33.33%	35.13%

Table 3: Reported Strategy Usage vs Correct Performance

The most noticeable result is the gap between use of the active strategy and the passive strategy with regards to performance on the Tone-Monitoring task. This is confirmed by running a separate linear model for each task, showing that for the Tone-Monitoring task, there was a significant positive effect on performance ($F(1,72)=5.164$, $p=.026$, $\eta^2=0.0669$), when a participant reported using the active updating strategy. Performance in this task improved overall for participants when they reported using the active strategy. In the Letter-Memory task, there was a borderline significant effect ($F(1,91)=3.723$, $p=.0568$, $\eta^2=0.0393$). In the Keep-Track task, there was no significant effect ($F(1,68)=0.1466$, $p=.703$).

3.5 Interactions

Looking at our final research question, "*What is the interaction between performance on task, external rewards (motivation), and strategy usage?*", a more complex linear model was applied for each task type, including a two-way interaction between reported strategy usage and motivation condition effects. The data used for Tables 4-8 consisted exclusively of trials after which the two strategy questions were presented to the participant, and is a subset of the whole dataset used in 3.2 for Table 1.

Table 4 below shows the results of the model for the Letter-Memory task. The models (shown in Tables 4-8) all used the same format with the following variable values used for all tasks: task performance can be seen in the *Estimate* column in Tables 4-8 (0 for incorrect, 1 for correct). The *intercept* row details the results for when the trials were *Unmotivated* and participants used the *Passive Recall* strategy. Reported use of the Active strategy is seen in the *ActiveStrategy* row, and when the trial is motivated by reward in the *Motivation* row. For example, below in Table 4, the effect of *ActiveStrategy Use* on performance means that we see the effect when the participants used an active strategy to complete a trial that is in the unmotivated condition. This is the case for Tables 4-8.

Model: Task Performance ~ Active Strategy Usage * Motivation Condition

Measure	Estimate (β)	Standard Error (SE)	t-Value (t)
Intercept	0.6316	0.1053	5.997
ActiveStrategy	-0.1673	0.1365	-1.226
Motivation	-0.5760	0.1510	-3.815
ActiveStrategy : Motivation	0.7546	0.1946	3.878

Table 4: Effects on Performance from Active Strategy Usage and Motivation in **Letter-Memory** Task (2-Way Interaction)

In this model including the interaction effects, there is a significant negative effect caused on correct performance by a trial being motivated by external reward. ($\beta = -0.5760$, $t = -3.815$, $p < .0001$). This can be interpreted as there being a decrease in performance when the trial was in the motivated condition versus the unmotivated condition. There was also a significant positive difference caused by the interaction of motivation condition of the trial and reported strategy usage for that trial ($\beta = 0.7546$, $t = 3.878$, $p < .0001$). This suggests an interaction effect, resulting in performance improvement when the participant reported use of active updating strategy when the trial condition is motivated as compared to otherwise. A trial being motivated has a negative effect on performance except when the trial is motivated and the participant reported successful usage of the active updating strategy.

Table 5 below shows the complex linear model for the Tone-Monitoring task.

Model: Task Performance ~ Active Strategy Usage * Motivation Condition			
Measure	Estimate (β)	Standard Error (SE)	t-Value (t)
Intercept	0.1667	0.1884	0.885
ActiveStrategy	0.5119	0.2076	2.466
Motivation	0.500	0.3263	1.532
ActiveStrategy : Motivation	-0.4488	0.3461	-1.297

Table 5: Effects on Performance from Active Strategy Usage and Motivation in **Tone-Monitoring** Task (2-Way Interaction)

There is a significant positive effect caused by the reported use of active updating strategy on correct performance (β = 0.5119, t = 2.466, p = .0161). This means that participant's reported use of active updating during the trial had a positive effect on task performance. There were no significant differences for motivation condition and no significant interaction effects. Because of this, we will attempt to backwards fit the model by first removing the interaction effects. The results of the model without the interaction between motivation and active strategy use can be seen below in Table 6.

Model: Task Performance ~ Active Strategy Usage + Motivation Condition			
Measure	Estimate (β)	Standard Error (SE)	t-Value (t)
Intercept	0.2996	0.1588	1.887
ActiveStrategy	0.3505	0.1669	2.100
Motivation	0.1012	0.1095	0.924

Table 6: Effects on Performance from Active Strategy Usage and Motivation in **Tone-Monitoring** Task

After removing the non-significant interaction effect from the model for the Tone-Monitoring task, we can see that reported use of the Active Updating strategy still has a significant positive effect on task performance (β = 0.3505, t = 2.100, p = .0393). In this stripped back model, there are no significant effect from whether or not trials were motivated. A Chi-Squared difference test was performed to compare the goodness-of-fit for the models in Table 5 and 6 for Tone-Monitoring. The results are (X^2 (1) = 0.538, p = .1947) meaning that there is no significant difference in variance explained between the complex and simpler model. We can accept the simpler model, the one without the interaction effect (see Table 6), as the preferred model for the Tone-Monitoring task.

Table 7 below shows the complex model with interaction effects for the Keep-Track task.

Model: Task Performance ~ Active Strategy Usage * Motivation Condition			
Measure	Estimate (β)	Standard Error (SE)	t-Value (t)
Intercept	0.1875	0.1111	1.687
ActiveStrategy	0.1625	0.1491	1.090
Motivation	0.1125	0.1792	0.628
Strategy : Motivation	-0.2542	0.2241	-1.134

Table 7: Effects on Performance from Active Strategy Usage and Motivation in **Keep-Track** Task (2-Way Interaction)

There was no significant difference in performance discovered for the Keep-Track in either motivation condition, reported strategy usage, or the interaction of them. Because of this, we will backwards fit the model removing the interaction effects. This can be seen below in Table 8.

Model: Task Performance ~ Active Strategy Usage + Motivation Condition			
Measure	Estimate (β)	Standard Error (SE)	t-Value (t)
Intercept	0.2500	0.0967	2.585
ActiveStrategy	0.0500	0.1116	0.448
Motivation	-0.0500	0.1078	-0.464

Table 8: Effects on Performance from Active Strategy Usage and Motivation in **Keep-Track** Task

After removing the non-significant interaction effects from the model for the Keep-Track task, it remained the case that there were no significant effects on performance from both, whether the trial was motivated by external rewards and from whether participants reported using an active strategy. A Chi-Squared model comparison test was run comparing the models in Tables 7 & 8 for the Keep-Track task. The results are ($X^2(1) = -0.25$, $p = .2609$), indicating that both models fit equally well statistically, but to prefer the simpler model from Table 8 (Werner & Schermelleh-Engel, 2010). Overall, there were no significant effects discernable when considering the Keep-Track task.

4. Discussion

The current study investigated the effects of extrinsic motivation in the form of performance-contingent rewards on tasks designed for use of the updating component of working memory.

This experiment highlighted a few important findings. For the first component research question, we hypothesized (**H1**) that presence of performance-contingent rewards will lead to improved performance, and this was not the case. The effect of rewards was found to not be statistically significant for any of the tasks. These findings are not in line with Hendijani et al. (2016) where it was found that performance-contingent rewards positively influence performance. There are a few reasons why this is the case, most importantly that for this hypothesis we were only looking at rewards versus performance, and not including an analysis for active updating strategy use. Further limitations of these results are given later in the discussion. However, this does not definitively conclude that motivation has no effect on performance.

Looking at our second research question and hypothesis (**H2**), we found it was the case that no significant effects were found between the presence of rewards and the reported strategy use for each of the tasks. This proves our hypothesis incorrect, as we expected the presence of rewards to motivate the participant enough to display a significant difference in the use of active updating strategy to complete the task. This intuitively goes against findings from Krawcyzk (2007) who highlights an increase in the use of active cognitive control with motivation, and Miyake et al. (2000) who highlights increased cognitive control with use of an active updating strategy for WM tasks. It may be the case that external rewards alone, when not considering performance, is not enough of a predictor for a participant's strategy use for any of the three WM tasks.

For our third component research question, we hypothesized (**H3**) that a reported active updating strategy use would have a positive effect on performance. We found that there was a significant positive effect on performance in the Tone-Monitoring task, and a close to significant positive effect on performance in the Letter-Memory task. This is in line with the findings from Miyake et al. (2000) and Friedman et al. (2006) that active updating strategy usage in updating WM tasks leads to an increase in performance, however it was not the case for all tasks. Specifically, the Keep-Track task showed no effect of active strategy use on performance.

Lastly, for (**H4**), we hypothesized that there would exist significant effects from the complex model containing interaction effects. It was found that for the Letter-Memory task, external reward (motivation) and the interaction between external reward and reported active strategy use both caused significant differences. The presence of external rewards elicited a negative effect on performance, while when a trial was motivated and the participant reported using an active strategy, there was a significant positive effect on performance. These findings seem counter-intuitive, but are supported by previous research. Hendijani et al. (2006) demonstrated that the effect of performance-contingent rewards is still unresolved, and competing theories about the direction (Ross, 1975; Hendijani et al., 2006) of motivation's effect have not agreed upon a conclusion. This was the only task in which motivation was found to have a significant effect on performance. Likewise, it was the only task where the interaction of active strategy use and motivation had a significant effect on performance.

For the Tone-Monitoring task, reported strategy use was found to cause a significant positive effect on performance. This remained the case when we reduced the model complexity by removing the interaction effect (see Table 6). This is in line with the findings from Miyake et al. (2000), where the use of active updating leads to improved performance in updating WM tasks. No other significant effects were found for the Tone-Monitoring task.

For the Keep-Track task, there were no significant effects found for motivation, active strategy use, or the interaction of the two. This remained the case when the model complexity was reduced by removing the interaction effect. This result was unexpected considering background literature. In the most difficult updating WM task (by average performance) of the three given to participants, it was expected that there would be a significant positive effect caused by active updating use (Miyake et al. 2000) and a significant effect (positive or negative) caused by external rewards (Hendijani et al., 2006). As the Keep-Track task showed no significant effects of either motivation or self-reported active strategy use whether in isolation or when interacting, research into the relationship of task complexity and how external motivation affects performance on those tasks would provide valuable insights into whether these results come from the nature of the task, or from the nature of the relationship of motivation and performance.

Participants were most capable of following through with their intending mental strategy of using active updating in the Tone-Monitoring task. Out of 23 responses, 13 responded saying they were *always able* to follow through, with 5 saying *often*, 3 saying *not so often*, and 2 saying *rarely* able. The Keep-Track task proved the most difficult for participants to follow through with their intended cognitive strategy. 1 reported to *always be able* to follow through, with 9 responding *often*, 11 *not so often*, and 2 *rarely*. This alludes to the difficulty of the task. Tone-Monitoring being completable using the active updating strategy more often than either of the other tasks. Demonstrating a 28.26-36.23% overall accuracy, the Keep-Track task was the most difficult.

This experiment was carried out to further the research in the study of motivation, and the functioning of working memory, specifically looking at performance-contingent rewards, as whether it always has a positive or negative effect on task performance is currently unresolved (Hendijani et al. 2006; Ross, 1975). The results from our experiment unfortunately did not provide results that would clearly indicate which direction the effect of motivation has on performance, leaving the debate very much open. As this experiment was just focused on the Updating component of working memory, similar experiments can be done for the other components highlighted by Miyake et al. (2000), inhibition and shifting.

There are some limitations with this study however. For one, the performance-contingent reward was set at 0.20€ per correct trial, which is a low-moderate reward as described by Hendijani et al. (2016). There is potential for this reward to be considered negligible or too small, and for participants to have the same or worse performance in the reward condition (Gneezy & Rustichini, 2000). Future studies can investigate this by varying the level of reward given from performance. This would help better understand the nature of the effect of performance-contingent rewards, such as if there is an upper or lower limit at which performance difference is negligible.

This experiment was also conducted in an academic setting, and the tasks used are ones not explicitly encountered in professional or day-to-day life. Real-life tasks utilizing updating component of working memory have similar elements as the tasks chosen for this experiment. As the experiment was around an hour long, and the tasks could be considered tedious, there is potential for participants to experience fatigue and have their performance suffer as a result.

Reward salience is another potential confounding factor. As previous studies have suggested, reward salience can have a significant negative effect on motivation and performance (Ross, 1975). The reward was given in a non-salient, non-controlling manner. Participants received their earnings in a direct bank transfer after the conclusion of the experiment.

Individual differences can cause a large amount of variability in performance in the presence of rewards. Covington & Müeller (2001) demonstrated that success-oriented individuals, rewards and motivation are additive, but for failure avoiders, rewards and motivation produced no or a detrimental effect on performance. Future studies could look at this effect by surveying motivational dispositions of individuals alongside tasks with performance-contingent rewards.

The number of participants was also low (N=23), which limits how extrapolatable the results coming out of this experiment are. More participants allow for more manipulation of the experiment parameters, such as with reward salience and varying the amount given to participants as a reward.

This study exclusively looked at the effect of performance-contingent rewards and WM updating tasks, which limits how generalizable the results are to the study of motivation as a whole.

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A. Appendix

A.1. Motivated Trial Screen

For each correct answer, you will earn 0.2 EUR extra.

When you are ready to begin, press any key.

A.2. Keep-Track Task Presentation

UNCLE

animal fruit country

A.3. Letter-Memory Presentation

Y

A.4 Letter-Memory Answer Screen

SY..

A.5 Tone-Monitoring Answer Screen

How many times did the low tone sound?

Low = _

Mid = _

High = _