

Desirable Difficulties: The Relationship Between Perceived Mental Effort and Perceived
Effectiveness and the Effect of Monitoring Accuracy

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Abstract

Students try to avoid effortful studying by choosing methods that give a feeling of fluency. This is misleading since they give a feeling of effectiveness but are less effective. Methods that require higher mental effort are more effective since they give better long-term results. However, high experienced effort leads to a lower feeling of effectiveness. Therefore, the relationship between perceived mental effort and perceived effectiveness was examined. How well someone monitors their learning can influence this relationship. Thereupon, it was examined if monitoring accuracy has a moderating effect on the relationship between mental effort and effectiveness. To further investigate the field of desirable difficulties, blocked and interleaved studying were examined. Interleaving is more effective than blocked practice. With a regression analysis evidence was found for the negative influence of mental effort on perceived effectiveness when studying interleaved. This means that students who have higher mental effort experience lower effectiveness. Monitoring accuracy has not been found to be a moderator but does directly influence perceived effectiveness for interleaved practice. So, students that monitor studying better think interleaving is effective. No significant results were found for blocked practice, possibly due to greater influences of other cues for indicating effectiveness.

Keywords: perceived mental effort, perceived effectiveness, monitoring accuracy, self-regulated learning, judgements of learning, desirable difficulties.

Desirable Difficulties: The Relationship Between Perceived Mental Effort and Perceived Effectiveness and the Effect of Monitoring Accuracy on this Relationship

In today's education the importance of self-studying is rising rapidly. Students are asked to be more self-managing and self-disciplined (Jerald, 2009; Voogt & Roblin 2010). With the uprise of the internet and technology, students have countless information sources available. Therefore, additional skills are needed in education. For example, students in higher education are expected to have high sufficient self-regulation skills (Bjork et al., 2013; Wirth et al., 2020). In other words, students need to be able to regulate their learning towards their learning goals.

Students' ability to regulate learning is of great importance, especially with the recent shift in educational practice in mind. Part of regulating learning is choosing the right learning strategy (Bjork & Bjork, 2011; Zimmerman, 2000). However, students seem to inaccurately choose their studying methods. For example, they often study with suboptimal strategies, even when they are aware of the need for more effective one's (Bjork & Bjork, 2011). An explanation for this is that more effective learning strategies are often more effortful to maintain and often do not result in an immediate feeling of effective learning. For instance, interleaved practice is known to be more effortful, but also more effective than blocked practice (Kirk-Johnson et al., 2019; De Groep, 2021). With blocked practice, students study materials grouped together and with interleaved practice the materials are mixed-up (Kirk-Johnson et al., 2019). Hence, to experience the effectiveness of interleaved practice, students need to be able to accurately monitor their invested effort in relation to their learning and their used learning strategies. However, not much is known about how students' monitoring of their invested effort relates to their perceptions of effectiveness of their used learning strategies. The present study aimed to gain more insight into this by investigating whether students use their perceived effort during a particular study session as a cue for perceived

effectiveness of their used learning strategy. In addition, it was tested whether students' monitoring accuracy of their learning moderated this relationship between perceived effort and perceived effectiveness.

Desirable Difficulties

When studying, one can use different study strategies, like restudying, retrieval practice, testing, blocked and interleaved practice (Bjork & Bjork, 2011). Some of the mentioned strategies are more desirable than others. These are called *desirable difficulties* and lead to higher learning outcomes and retention in the long run (Bjork & Bjork, 2020; Bjork & Kroll, 2015; Kirk-Johnson et al., 2019). An important aspect of desirable difficulties is to vary the learning conditions instead of keeping them constant and predictable (Sungkhassetee et al., 2011; Weissgerber & Reinhard, 2017).

Within this study, two learning strategies were compared, namely *blocked studying* and *interleaved studying* (Kirk-Johnson et al., 2019). Blocked studying involves studying exemplars grouped together by category and is not difficult since the learning conditions remain constant during studying (Kirk-Johnson et al., 2019). An example of blocked studying is studying paintings categorised by artist (De Groep, 2021). First, one would study all paintings of one artist before moving to the next artist. Bjork & Bjork (2011, p. 59) say "Interleaving the practice of separate topics or tasks is an excellent way to introduce spacing and other learning dynamics". Interleaved studying is seen as a desirable difficulty and involves studying exemplars of multiple categories mixed (Kirk-Johnson et al., 2019). When using interleaved practice in the previous example, one would study the paintings from different artists in a mixed-up sequence (De Groep, 2021). This research method using paintings was also used in the study of De Groep.

Often, students have the perception that studying with blocked practice is more effective (De Bruin et al., 2020). An experience of fluent learning may be interpreted as

productive and effective. This experience occurs mainly with blocked practice. Contrarily, interleaving has better long-term effects on transfer and retention than blocked practice (Bjork & Bjork, 2011).

Judgements of Learning

As seen above, students misinterpret fluent learning as productive and effective and therefore misjudge their own learning (De Bruin et al., 2020). Within research about desirable difficulties, these judgements of learning (JOL) should be considered (Baars et al., 2020). Koriat (1997) described judgements of learning as: “Judgements made by participants at the end of learning trial regarding the likelihood of remembering the acquired information on a subsequent memory test” (p. 349). Students commonly overestimate or underestimate their studying (Blissett et al., 2018). They use several available cues for making judgements, like fluency or invested time (De Bruin et al., 2020). When a student makes a judgement of learning, the invested amount of effort is used as a cue. When learning occurs effortlessly, often students may misinterpret this as a good sign (De Bruin et al., 2020). When a student restudies, the content will feel familiar and they misinterpret the content as properly learned. But when testing the content, they will find out that they do not possess the knowledge properly. When using a more effortful method, like testing or interleaving, their judgement of learning will be lower compared to using a less effortful method. This misinterpretation is called the *fluency bias* (De Bruin et al., 2020).

Perceived Effectiveness

When studying, most students try to avoid as much effort as possible and they try to find the easiest way to reach their goals (Kirk-Johnson et al., 2019). For this process, a cue that should be considered is *perceived effectiveness* (Kirk-Johnson et al., 2019). If students think a study method may lead them to their goals more easily, they may have more intention to use that method (de Bruin et al., 2020). In that case, students will think of a study strategy

as effective. Learning can be considered effective when a student can accurately recall the learned material (Kirk-Johnson et al., 2019).

When students have experienced that a studying strategy has been effective, they may choose the strategy again (Kirk-Johnson et al., 2019). Therefore, it is important to help students make the right decisions and inform them about the benefits of using these desirable difficulties (Händel et al., 2020). Studies have focused on giving students an explanation of the effectiveness of desirable difficulties to help them make more effective decisions for learning (Kirk-Johnson et al., 2019; De Groep, 2021).

Perceived Mental Effort

Recently, the role of perceived mental effort as a cue for perceived effectiveness has become more important within the scientific community. *Perceived mental effort* can be described as the experienced level of difficulty during study (Kirk-Johnson et al., 2019). Mental effort is seen as the human centered dimension of cognitive load (Scheiter et al., 2020). Paas and van Merriënboer (1994, p. 354) state that “mental effort refers to the amount of capacity or resources that is actually allocated to accommodate the task demands”. High actual mental effort is found to lead to high learning gains (De Groep, 2021). Perceived mental effort is often used as a cue for monitoring (Baars et al., 2020). However, learners may misinterpret their required effort of using a particular strategy and come to the wrong conclusion, which is called the *misinterpreted effort hypothesis* (Kirk-Johnson, et al., 2019). Therefore, one’s perceived mental effort is often misleading for judging the effectiveness of learning (De Groep, 2021).

Two recent studies have focussed on this relationship between mental effort and perceived effectiveness, namely Kirk-Johnson and colleagues (2019) and De Groep (2021). In the study of Kirk-Johnson and colleagues (2019) the focus was on comparing study strategies, including blocked and interleaved practice, and the relationship between perceived effort, the

chosen study strategy and self-regulation. They found that, across learning materials, learning strategy, subject population and study location, perceived effectiveness is negatively influenced by mental effort. The study of De Groep (2021) also focused on the comparison between blocked and interleaved practice. De Groep found too that for blocked practice, the perceived mental effort was lower than for interleaving. As predicted, it was also found that blocked practice gave lower learning outcomes than interleaved practice. In line with Kirk-Johnson and colleagues (2019), De Groep found that perceived effort leads to a lower perceived effectiveness (2021).

Monitoring Accuracy

When measuring perceived effectiveness of a study strategy, it is important to investigate how well students can monitor their own learning (Van Der Pol et al., 2019). Monitoring can be described as comparing set standards with learning outcomes and intend to find knowledge gaps (Händel et al., 2020). If students are properly able to assess how well they have studied, their judgements of learning are accurate. Next to that, having good monitoring skills will lead to better self-regulation and learning outcomes (Dunlosky et al., 2005; Thiede et al., 2003). Information from monitoring can be used in decision making in further learning (Baars et al., 2013). However, the information from monitoring one's own learning, often does not lead to an accurate mental model (Bjork & Bjork, 2011). This may be since students aren't taught how to accurately measure their monitoring (Kirk-Johnson et al., 2019).

When students have a high perceived effort, they often feel like their perceived effectiveness is low (De Groep, 2021). This may be caused by an inaccurate monitoring of one's own studying. Therefore, it is of great importance to provide guidance to students to help them monitor accurately (Händel et al., 2020). Students who experience high mental effort, might interpret their studying as ineffective and therefore their monitoring may be

inaccurate. When looking back at the misinterpreted effort hypothesis, one could conclude that misinterpreting one's invested effort may lead to inaccurate monitoring. Therefore, their judgements of learning may be based on wrong information.

Current study

To summarise, perceived mental effort, monitoring accuracy and perceived effectiveness are intertwined. This study continued with the work of Kirk-Johnson and colleagues (2019) and De Groep (2021) and examined the relationship between mental effort, monitoring accuracy and perceived effectiveness. One's perceived mental effort may have a direct influence on one's perceived effectiveness, but when looking at this relationship, monitoring accuracy could be considered.

De Groep (2021) and Kirk-Johnson et al. (2019) showed that a higher perceived mental effort leads to a lower perceived effectiveness by students. Since students use perceived mental effort as a cue during monitoring, it could be relevant to also consider monitoring accuracy as a moderator on the relationship between mental effort and perceived effectiveness. The relationship might differ depending on students' monitoring accuracy. For example, for a student who has poor monitoring skills, it seems plausible that this student misinterprets their high mental effort as poor learning (i.e., negative relationship between mental effort and perceived effectiveness). On the other hand, for a student who has good monitoring skills, it could be that this student does not interpret their high mental effort as a cue for poor learning (i.e., no relationship between mental effort and perceived effectiveness). Therefore, it is of importance to look at the nature of this relationship and that is why monitoring accuracy as a moderator will be examined.

In contrast to the study of Kirk-Johnson et al. (2019) and De Groep (2021), the focus of this research was not on behavioural choices in studying or behavioural interventions. Both Kirk-Johnson and colleagues (2019) as De Groep (2021) focussed less directly on the

relationship between perceived mental effort and perceived effectiveness, but more on how to influence it to help students make choices towards desirable difficulties. In the current study, the relationship between perceived mental effort and perceived effectiveness was examined more in depth, including looking into the possibility of the presence of a moderating factor. So where other research focussed on how to change the outcomes and choices, the goal of this research was to investigate why these outcomes happen.

Within this study, four research questions were examined. The first two questions are: “Does perceived mental effort after blocked practice predict students’ perceived effectiveness of that strategy?” and “Does perceived mental effort after interleaved practice predict students’ perceived effectiveness of that strategy?”. In other words, the difference between those research questions is the used study strategy. In Figure 1 these two questions are displayed graphically using linear relationships. It is to be expected that for blocked practice this relationship will not be found, and for interleaved practice it will be found. This is in line with the findings of De Groep (2021).

Figure 1

Linear Relation between Perceived Mental Effort and Perceived Effectiveness

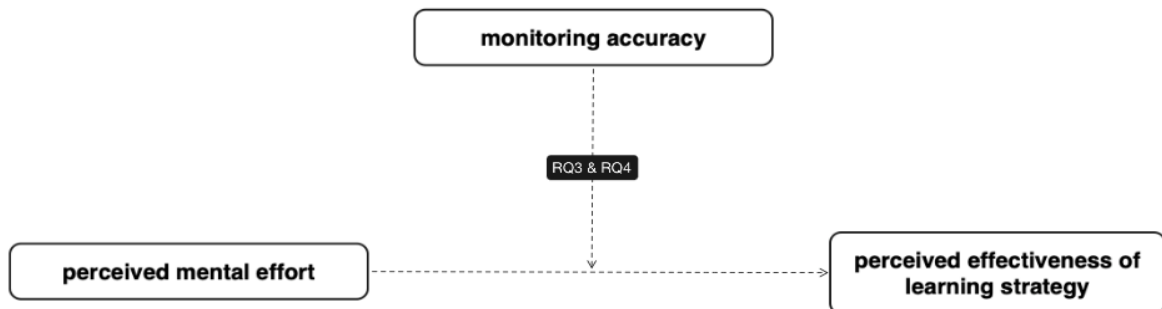


For examining the moderating effect of monitoring accuracy, the following two questions have been formulated, namely “Does monitoring accuracy moderate the relationship between perceived mental effort after blocked studying and perceived effectiveness of that strategy?” and “Does monitoring accuracy moderate the relationship between perceived mental effort after interleaved studying and the perceived effectiveness of that strategy?”. Again, the difference here is in the used study strategy. In Figure 2 this is

displayed graphically. In line with De Groep (2021), the hypothesis is to find this relationship for interleaved practice but not for blocked practice.

Figure 2

Moderation Effect of Monitoring Accuracy



This research has a lot to offer to the scientific field of desirable difficulties. First, in both Kirk-Johnson and colleagues (2019) study and the study of De Groep (2021), students had to use blocked studying as well as interleaved studying. In this research, students will be assigned to either blocked or interleaved practice. This may affect the self-reports, since it is less likely that boredom or practice effects occur (Field, 2009). Not having the possible influence of these effects may differ the current data from the data from De Groep (2021). Second, looking into monitoring accuracy as a moderating factor may give better insight in the relationship between mental effort and perceived effectiveness. Therefore, this research can add new insights into the field.

Method

Research Design

To test the hypotheses, an experiment has been conducted that generated quantitative data. The purpose of this experiment was to create insight about the relationship between perceived mental effort and perceived effectiveness and the role of monitoring accuracy. In advance of conducting the experiment, an application has been submitted and approved by the FERB-committee. For this approval, the ethical aspects of this study were examined and

found sufficient. No sensitive questions were asked nor was the amount of time used for the experiment excessive.

In this experiment, participants used an online learning environment. Within this environment, participants studied 25 paintings from five different artists. The participants were randomly assigned to blocked or interleaved practice. The blocked group studied the paintings ordered by artist and the interleaving group studied the paintings from the five artists mixed per block. This type of design has been chosen to outline the differences between the two strategies. After the study session an intervention was provided to the participants. This intervention, however, is not used in the current research questions. For more information, see Appendix B.

Participants

Participants were recruited using Prolific, an online platform where people get paid to take part in online experiments. Participants received 2.92 euros for a finished participation. The estimated time participants needed to finish the experiment was 20 minutes. In total, 174 participants started the experiment, and 166 Dutch students have finished the experiment. Of the participants, 81 were assigned to blocked practice and 85 to the interleaving condition. The participants gave permission to use their data using an informed consent form. Of the students were 71 females ($M(age) = 23.13$ and $SD = 3.72$), 91 males ($M(age) = 23.10$ and $SD = 5.6$), and 4 defined as other ($M(age) = 19.25$ and $SD = 1.50$). Of the participants, 12 students studied at vocational college, 52 students studied at university of applied sciences level, 94 students studied at an academic university and 8 students defined their level of education as other. In Table 1 the study domains of participants are displayed.

Table 1*Study Domains of Participants*

Domains	Number of participants
Environmental studies	6
Economics and business	30
Exact sciences and IT	23
Behaviour and society	23
Health	18
Arts and culture	8
Education and childrearing	9
Law and management	11
Engineering	15
Languages and communication	6
Other domains	17

Materials

The used instrument was a Dutch online experiment to gather data on perceived mental effort, monitoring accuracy and perceived effectiveness, made via Qualtrics. Participants participated using their own laptop. No mobile phones were allowed to participate in the survey. See appendix C for more information about the questions on demographics and after-test questions. These questions are not discussed in depth here since they were not our direct interest.

Start of experiment

Students were shown an information letter explaining the goal of the experiment and were asked to sign an informed consent form. This form is also displayed in Appendix A.

After this, students were assigned to either blocked practice or interleaved practice. Then, general instructions were displayed, asking them to not listen to music or use their phone. Then information on the assigned strategy was displayed and students were shown a demonstration of three test questions using other painters than used in the test. For measuring participants' prior knowledge 3 paintings were selected and participants had to tell which painting was from which art movement. The drop-down answer options were "Baroque", "Luminism", "Romanticism" or "I don't know". The measuring of prior knowledge could be used for determining whether outliers resulted from prior knowledge.

Learning tasks

For the learning tasks, 25 paintings of five different relatively unknown artists were selected. The used artists were Paul Cezanne, Frederic Edwin Church, John Constable, Jean-Baptiste Corot, and William Turner. The selected paintings were the same for both the blocked and interleaved practice. The paintings were per block shown randomised to the participants. After each block, a question on mental effort and a question on judgement of learning was displayed. The paintings were grouped by painter for the blocked practice group and for the interleaved group each block existed of five paintings by five different artists. Five out of ten artists were selected from the paintings used in the study of De Groep (2021). The selected paintings all displayed landscapes, to have a similar level of difficulty.

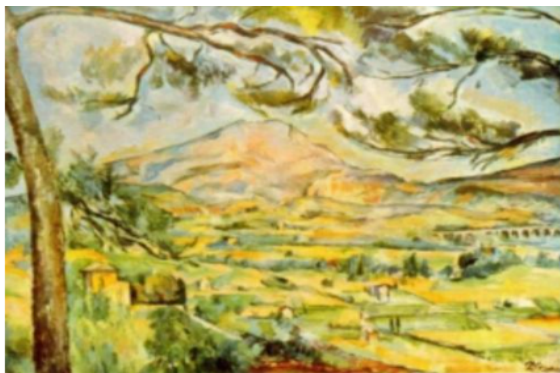
The test

Just before the test, a distracting math question was shown to participants. The question was "Henk buys 50 apples of two different kinds for 14 euros. Henk paid 4 euros for 10 apples of apple A. What is the price of apple B per piece?". The given multiple-choice options were 25 cents, 35 cents, 45 cents and 55 cents. This was followed by a question on perceived effectiveness and a question on their expected test score.

For the test, 10 new paintings of the same artists were selected, two per artist. A drop-down menu displayed the options, which were all artists that were studied during the study session. No difference was made in the test for blocked and interleaved practice. In line with the study sessions, the paintings in the test were all displaying landscapes. In Figure 3, an example of a test question is demonstrated. The painter of this example is Cezanne.

Figure 3

Example of Test Question



Van welke schilder is dit schilderij?

Cezanne

Perceived Mental Effort

For measuring perceived mental effort, a question was asked after each block of paintings. The question used was “How much effort did this cost you?” and was answered on a 9-point Likert scale (1 = *very low effort*; 9 = *very much effort*) (Paas & Van Merriënboer, 1993). The mean of these in total five questions was used to compute the variable *perceived mental effort*. The reliability for perceived mental effort for blocked practice was acceptable (Cronbach's $\alpha = .828$) and for interleaved practice was high (Cronbach's $\alpha = .927$).

Monitoring Accuracy

For measuring monitoring accuracy two factors were compared, namely judgements of learning and learning outcomes. The question for judgements of learning had to map out how well students think they have studied. JOLs were measured during and after the study

sessions. During the study session participants were asked after each block of paintings how well they think they were able to recognise work from the painters. The reliability for JOLs within learning tasks for both blocked practice (Cronbach's $\alpha = .733$) and interleaved practice (Cronbach's $\alpha = .915$) was good. JOLs measured after the study session was asked before starting the test. To create a measurable scale for monitoring accuracy, the JOLs measured after studying have been used. These JOLs were measured using the question “How well do you think you can recognise the work of this/these painter(s)? I expect to point out the right painter in ___ of the 10 paintings.” and was displayed right before the test. When learning outcomes are the same as the judgements of learning, the monitoring of students’ learning process is accurate. However, if a difference between judgements of learning and learning outcomes occurs, this indicates that the monitoring is inaccurate.

For calculating monitoring accuracy absolute accuracy has been used (Bol & Hacker, 2012; Händel et al., 2020). This absolute accuracy is also called *calibration* and it uses an overall score (Bol & Hacker, 2012). This means that an overall estimation of the learning outcome will be compared to the actual learning outcome. The following formula will be used to calculate absolute monitoring accuracy:

$$\text{Monitoring accuracy} = (\text{Judgement of learning} - \text{Test score}).$$

This formula calculates the mean of the differences between both judgements of learning and learning outcomes. Whether the difference is positive or negative was not considered.

Therefore, absolute scores were used ranging from 0 to 10. This means that someone who overestimated their studying by two has the same monitoring accuracy score as someone who underestimated their studying by two. Absolute scores are used since the goal was to measure how well students can monitor their learning and not in which direction their monitoring goes.

Perceived Effectiveness

On three moments within the survey participants were asked about their perceived effectiveness of the used learning strategy. These moments were prior to the study session, after the study session and after the intervention that was not part of this study. For this experiment only the item post study session was used since this is the outcome variable. The used question for blocked practice was “Blocked practice is an effective learning strategy for the current learning task” and was answered on a 9-point Likert scale (1 = *completely disagree*; 9 = *completely agree*) (Paas & Van Merriënboer, 1993). For the interleaved group the question was “interleaved practice is an effective learning strategy for the current learning task”. Questions on perceived effectiveness were presented together with questions on the willingness to use a strategy again. However, this variable is not included in this experiment and therefore will not be discussed further.

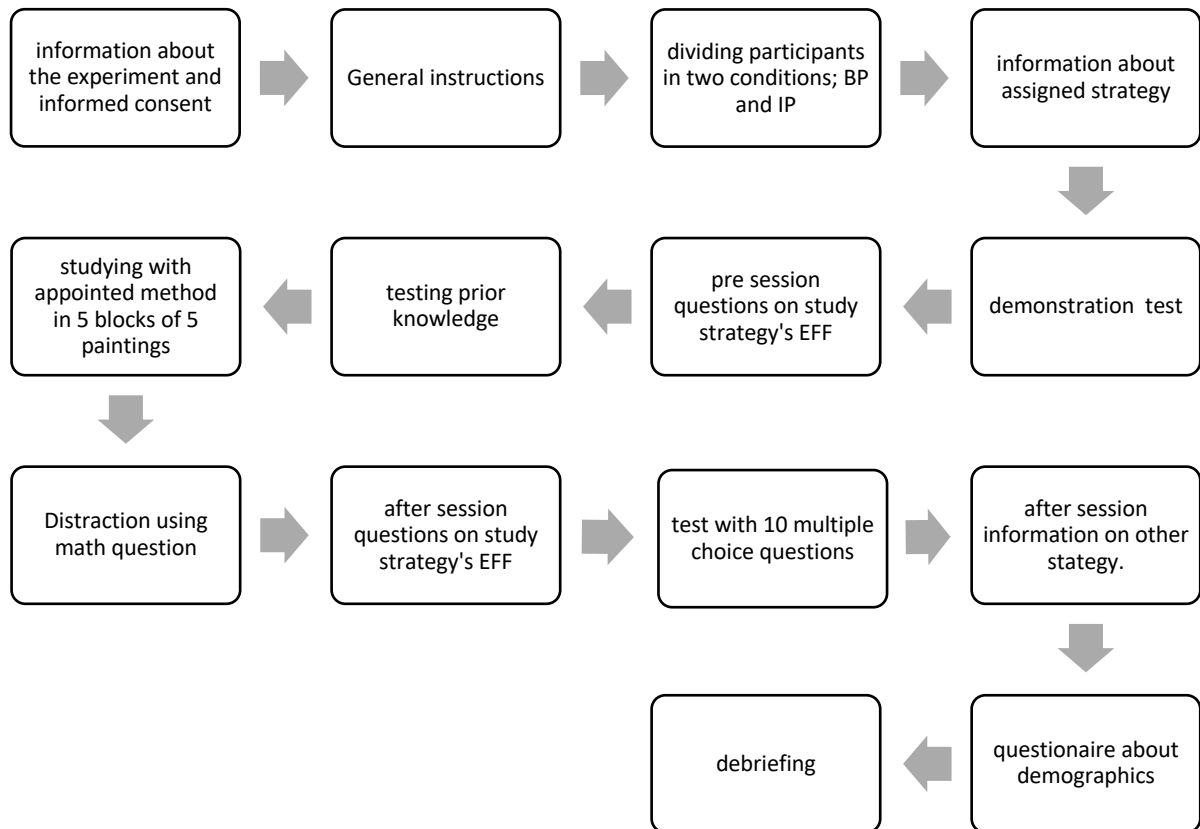
Procedure

When participants entered the online learning experiment via Prolific, they first saw the information page about the study and then signed the informed consent (see Appendix A). Participants were randomly appointed to a learning strategy. This procedure was followed by general instructions, information about the assigned study strategy, a short demonstration, and questions prior to the study session on the participants perceived effort. Then followed a short test of prior knowledge. After studying, the distractor was offered. Prior to the test, participants were asked about their estimated test result (i.e., JOL) and how effective they thought the used strategy was (i.e., perceived effectiveness). Then, the test with the 10 paintings that were displayed in a random order. This was followed by a questionnaire for demographical information. A short debriefing closed the experiment. For a full overview of the used questions in these sections, see Appendix C. The exact procedure of the start, the study sessions, the test, and the information in between those phases is displayed in Figure 4.

In this Figure only information on the flow of this experiment is included, but more data have been gathered.

Figure 4

Outline of the Procedure of the Experiment



Note: BP = Blocked Practice, IP = Interleaved Practice, EFF = perceived effectiveness.

Validity

To ensure the validity of the experiment, researchers from Utrecht University and Maastricht University checked the experiment for absence of errors and correctness of the instrument. Next to that, a trial run has been done, to ensure no errors occurred. To prevent random errors, questions on willingness and effectiveness, and JOLs and mental effort have been counterbalanced. This means that four versions existed of the experiment, differing in the order of WILL and EFF questions, and questions on JOL and ME within the study blocks.

The order of the paintings during the study session and the test questions were randomized for the same reason.

Data Analysis

The data received from Qualtrics were exported into an SPSS file and saved in YODA. To test for normality, histograms and P-P plots have been generated in SPSS. The data are found to be normally distributed. The P-P plot of standardized residual and scatterplot have been examined for homoscedasticity, and it was found to be sufficient. To avoid multicollinearity, *VIF*-scores have been used (Field, 2019). For both groups (blocked and interleaved) those scores have been calculated independently. No high scores ($VIF > 10$) have been found for the simple linear regression, so the assumption of multicollinearity has been checked and is not violated for testing the first two hypotheses. However, the multicollinearity was high for the moderating effects. Therefore, the mean-centered variables have been used for analysing the third and fourth research question. Lastly, the assumption of homoscedasticity is not violated since scatterplots show no specific pattern.

For finding any outliers, boxplots of the used variables have been examined. From this examination, several possible outliers have been detected. When looking at the Mahalanobis distance for those participants, some high values for both distances have been found (Field, 2009). However, the Cook's distance was not high for those participants with high Mahalanobis scores. Therefore, these cases were not considered as problematic. Next to that, other questions answered by the beforenamed respondents, like prior knowledge and explanation questions, were answered in line with their results. Therefore, all cases have been used in the final analysis.

Sample Size

To find a medium effect size, the necessary sample size has been calculated to achieve a medium effect size ($f^2 = 0.15$) (Field, 2009). For finding the sample size the program

*g*power* was used (Buchner et al., 2020). To computing this, a linear multiple regression was used (Fixed model, r2 deviation from zero; $\alpha = 0.05$, Power = 0.8, predictors = 3). The calculated sample size is 77 per group. Since there are two groups, the blocked practice group and the interleaved practice group, the minimum number of participants is 144. The aim was to recruit more than the minimum, so in total 166 participants have been recruited.

Simple and Multiple Linear Regression Analysis

For addressing the research questions a simple linear regression as well as a multiple linear regression analysis has been conducted (Field, 2009). Within these regression analyses, first the focus has been on the relationship between perceived mental effort and perceived effectiveness. Then, monitoring accuracy has been included as well. For this, a new score (monitoring accuracy * perceived mental effort) has been calculated and used. This new, calculated score has been put in the second block during the multiple regression analysis. For completeness, monitoring accuracy as a direct influence, so without it being considered as a moderator, on perceived effectiveness will also be briefly examined.

Results

Blocked Versus Interleaved Practice

The data showed that the interleaving is less seen effective than studying blocked. For blocked practice, the mean score on perceived effectiveness was 6.43 ($SD = 1.46$). The mean score for interleaved practice was 5.39 ($SD = 2.06$). This means that blocked practice was perceived as more effective than interleaved practice. Next to that, the standard deviation of blocked practice is lower. This means that the score on perceived effectiveness for blocked practice is more clustered around the mean and has less spread than interleaved practice.

Next to lower perceived effectiveness, participants experienced more mental effort when studying interleaved. The mean score for mental effort for the blocked practice group was 3.73 and ranged from 1 to 6.6 ($SD = 1.24$) and for the interleaved practice group 5.12 and

ranged from 2 to 8 ($SD = 1.37$). This means that the interleaving group experienced, on average, more mental effort than the blocked practice group. The highest scores for mental effort came from participants in the interleaved practice groups.

Participants in the interleaved group did not only have higher mental effort and lower perceived effectiveness, their expectations of their test result were also lower. They also were less able to monitor their studying correctly. The mean of the expected test results from the blocked practice group is 5.74 ($SD = 1.74$) and for the interleaved practice group 5.38 ($SD = 1.88$). This expected test result is used for calculating the judgements of learning. The difference between those groups is only 0.36, but still the JOLs for blocked practice are noticeably higher than for interleaved practice. Based on the JOL scores, monitoring accuracy is measured. The mean score for monitoring accuracy for the blocked practice group is 1.86 ($SD = 1.43$) and for the interleaved practice group 1.99 ($SD = 1.37$). High scores on monitoring accuracy means that participants are worse at monitoring. So these small differences mean that the participants from the blocked practice condition were slightly better at monitoring their own learning and predicting their test score.

Studying interleaved led to higher test scores than blocked practice. The interleaved practice group ($M = 6.87$, $SD = 2.14$) scored as expected higher than the blocked practice group ($M = 6.15$, $SD = 2.13$). With a difference of 0.72, the interleaved practice group had higher test scores. The standard deviation of both groups was nearly the same. So overall, the interleaved practice group scored higher on test scores, and lower on mental effort, perceived effectiveness and expected test results. These differences were in line with the expectations. After explanation of both strategies, 62% of the participants said they would be more willing to use blocked practice in the future and 38% said they would prefer the interleaving strategy. No difference was found between which condition was used for studying during the experiment for future preferences.

Mental Effort and Perceived Effectiveness

For investigating the first two research questions, a linear regression analysis has been conducted. For blocked practice, the relationship between mental effort and perceived effectiveness was statistically non-significant, with 0.1% of the perceived effectiveness could be explained by perceived mental effort ($R^2 = .001$, adjusted $R^2 = -.011$, $F(1, 79) = .097$, $p = .757$). Thus, no support has been found for the relationship between mental effort and perceived effectiveness for blocked practice, nor would mental effort explain much of the score on perceived effectiveness. In other words, in line with what was expected, one’s perceived mental effort when studying blocked cannot explain how effective someone thinks blocked practice is. Students that use blocked studying do not use their low mental effort as a cue for the effectiveness of blocked practice. Table 2 shows the unstandardized (B) and standardized (β) regression coefficients, along with the standard error (SE) and level of significance (p) for the first research question.

Table 2

Mental Effort on Perceived Effectiveness for Blocked Practice

	B	SE	β	p
(Constant)	6.585	.519		.000
ME	-.041	.132	-.035	.757

Note. ME = perceived mental effort.

* $p < .05$. ** $p < .01$.

The second research question focused on the linear relationship between perceived mental effort and perceived effectiveness for interleaved practice. It was hypothesised to find a negative influence here. In this statistically significant model, 9.4% of the score for perceived effectiveness can be explained by perceived mental effort ($R^2 = .094$, adjusted $R^2 =$

.083, $F(1, 83) = 8.644, p = .004^*$). Therefore, support has been found for the second hypothesis. This means that, in contrast to blocked practice, there is a negative relationship between mental effort and perceived effectiveness for interleaved practice. In other words, when a participating student experiences higher mental effort, the lower their perceived effectiveness of their studying using the interleaved method is. When studying interleaved, one of the cues for perceived effectiveness of interleaved practice is perceived mental effort. In Table 3 the unstandardized (B) and standardized (β) regression coefficients are displayed, along with the standard error (SE) and level of significance (p) for the second research question.

Table 3

Mental Effort on Perceived Effectiveness for Interleaved Practice

	B	SE	β	p
(Constant)	7.673	.806		.000
ME	-.447	.152	-.307	.004*

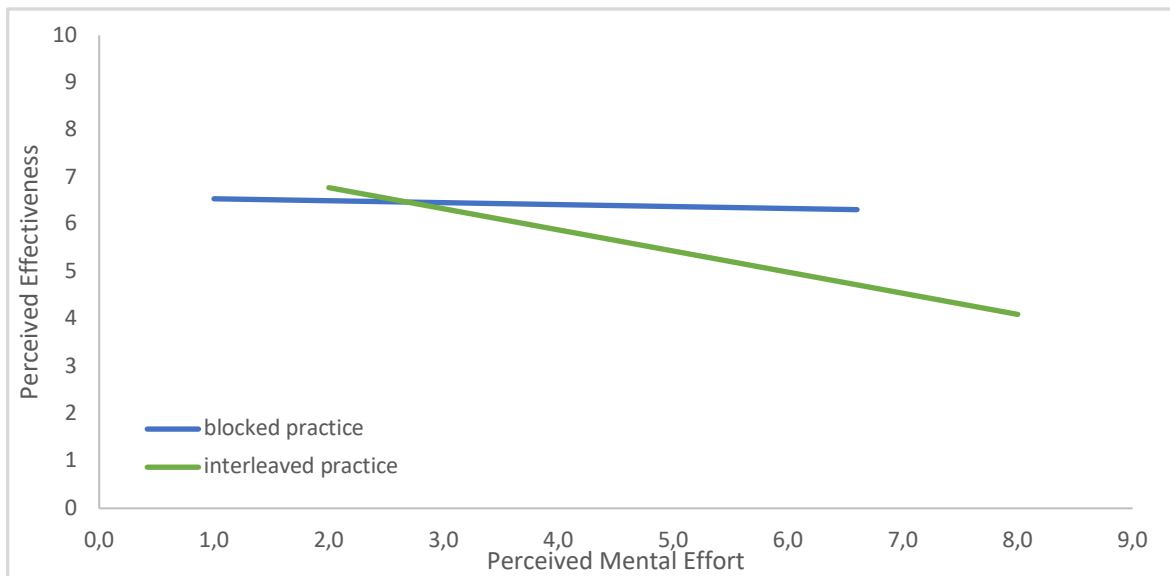
Note ME = perceived mental effort.

* $p < .05$. ** $p < .01$.

The relationship between mental effort and perceived effectiveness is statistically non-significant for blocked practice, while for interleaved practice the relationship is statistically significant. The regression line for both condition is displayed in Figure 5, which shows that the more mental effort someone experiences during interleaved practice, the less effective they think it is. The flat line for blocked practice indicates that mental effort barely has any influence on perceived effectiveness. So, in other words, the more mental effort someone experiences during interleaved practice, the less effective they think it is and mental effort does not matter for those studying blocked.

Figure 5

Linear Regression Lines for Blocked and Interleaved Practice



Moderating Effect of Monitoring Accuracy

For analysing the data for the third and fourth research question, multiple linear regression analyses have been conducted. Mean centered data have been used for both research questions. The third research question was “Does monitoring accuracy moderate the relationship between perceived mental effort after blocked studying and perceived effectiveness of that strategy?”. The corresponding model is, as expected, statistically non-significant and would in this case explain 0.7% of the score for perceived effectiveness ($R^2 = .007$, adjusted $R^2 = -.032$, $F(3, 77) = .180$, $p = .910$). In other words, no support has been found for the relationship between mental effort, monitoring accuracy and perceived effectiveness for blocked practice. In Table 4, the unstandardized (B) and standardized (β) regression coefficients, the standard error (SE) and level of significance (p), corresponding with the third research question, are displayed.

Table 4

Mental Effort on Perceived Effectiveness with Monitoring Accuracy as Moderator for Blocked Practice

	B	SE	β	p
(Constant)	6.268	.574		.000
ME	.074	.225	.063	.742
MonAcc	-.130	.251	-.127	.608
ME*MonAcc	.067	.102	.179	.516

Note. ME = mental effort, MonAcc = monitoring accuracy, Me*MonAcc = interaction effect.

Variables are centered.

$\wedge p < .10$. * $p < .05$. ** $p < .01$.

Lastly, the moderating effect on the linear relationship between mental effort and perceived effectiveness for interleaved practice is not significant, ($R^2 = .133$, adjusted $R^2 = .101$, $F(3, 81) = 4.131$, $p = .009$). However, the p -value for monitoring accuracy was .062, which is not significant but not very high either. The model with the moderating effect was used to answer the fourth research question, which was “Does monitoring accuracy moderate the relationship between perceived mental effort after interleaved studying and the perceived effectiveness of that strategy?”. This model would explain 13.3% of the score for perceived effectiveness. Only support has been found for mental effort influencing perceived effectiveness. Both monitoring accuracy and the interaction effect are non-significant, but the main effect of monitoring accuracy on perceived effectiveness was marginally significant. Mental effort does have a significant negative effect on perceived effectiveness. In other words, in this model, a student who experiences higher mental effort has a lower score on perceived effectiveness. No relationship between the monitoring accuracy or the interaction

effect and perceived effectiveness has been found. So, monitoring accuracy has no moderating effect on the relationship between mental effort and perceived effectiveness for both blocked and interleaved practice. In Table 5 the unstandardized (B) and standardized (β) regression coefficients, the standard error (SE) and level of significance (p) have been displayed for the fourth model.

Table 5

Mental Effort on Perceived Effectiveness and Monitoring Accuracy as Moderator for Interleaved Practice

	B	SE	β	p
(Constant)	5.366	.213		.000
ME	-.422	.152	-.290	.007**
MonAcc	-.303	.160	-.201	.062 [^]
ME*MonAcc	.040	.126	.034	.751

Note. ME = mental effort, MonAcc = monitoring accuracy, Me*MonAcc = interaction effect.

Variables are centered.

[^] $p < .10$. * $p < .05$. ** $p < .01$.

Since in the fourth model monitoring accuracy has a marginally significant influence on the relationship between mental effort and perceived effectiveness, it was of interest to look at the direct relationship between monitoring accuracy and perceived effectiveness without looking at monitoring accuracy as a moderator. Therefore, for interleaved practice a linear regression has been conducted to test what influence monitoring accuracy has on perceived effectiveness. In this model, 4.9% of perceived effectiveness could be explained by monitoring accuracy ($R^2 = .046$, adjusted $R^2 = .034$, $F(1, 83) = 3.985$, $p = .049$). In other words, people who are better at monitoring their own learning perceive interleaved practice as

more effective. In Table 6 the unstandardized (B) and standardized (β) regression coefficients, the standard error (SE) and level of significance (p) have been displayed.

Table 6

Monitoring Accuracy on Perceived Effectiveness for Blocked Practice

	B	SE	β	p
(Constant)	6.029	.389		.000
MonAcc	-.322	.162	-.214	.049*

Note. MonAcc = Monitoring Accuracy

* $p < .05$. ** $p < .01$.

To conclude, in line with the expectations, both hypotheses for blocked practice to not find an effect for mental effort and a moderating effect of monitoring accuracy have been accepted. The hypothesis to find a negative effect of mental effort on perceived effectiveness for interleaved practice has been accepted too. So, only for interleaved practice perceived mental effort can predict a part of the score for perceived effectiveness. This model, without the moderating effect of monitoring accuracy, predicted 9,4% of perceived effectiveness for interleaved practice. Our hypothesis was to also see a significant result for the model that included the moderating effect of monitoring accuracy on the relationship between mental effort and perceived effectiveness. However, no significant result has been found for the moderating effect. This means that the hypothesis that perceived effectiveness is negatively influenced by mental effort is found to be accepted in the case of interleaved practice only. However, monitoring accuracy does have a statistically significant influence on perceived effectiveness when it is not seen as the moderator on the relationship between mental effort and perceived effectiveness but as a direct effect.

Discussion

The goal of this research was to first examine the relationship between mental effort and perceived effectiveness. The hypothesis was that mental effort would have a negative influence on one's perceived effectiveness of a study strategy. Then, a closer look was taken into monitoring accuracy. It was expected that monitoring accuracy would have a moderating influence on the relationship between mental effort and perceived effectiveness. Two different study strategies in this research, namely blocked and interleaved practice.

Perceived Mental Effort

In line with findings of others, mental effort was higher for interleaved practice and interleaved studying gave higher test results than blocked studying (e.g., Bjork & Bjork, 2011; De Groep, 2021; Kirk-Johnson et al., 2019). In this experiment, no evidence is found for the relationship between mental effort and perceived effectiveness for blocked practice. Thus, mental effort does not predict perceived mental effort of participants when studying with blocked practice. However, for interleaved practice a significant, but small effect is found for mental effort. So, in line what was expected, when studying interleaved, mental effort influences one's perceived mental effort negatively. This means that when students experience higher levels of mental effort during interleaved studying, the lower their score for perceived effectiveness will be. This may be due to that students often interpret high mental effort as poor learning and therefore less effective (Kirk-Johnson et al., 2019). Students see interleaved studying as more difficult and more effortful than blocked practice. Therefore, ease of learning is not considered to be a reliable cue for basing study strategy effectiveness upon, since long-term results are fostered by more difficult strategies (Bjork & Bjork, 2011; De Bruin et al., 2020; De Groep, 2021; Kirk-Johnson et al., 2019).

No evidence has been found for the negative influence of mental effort on perceived effectiveness for blocked practice. De Groep (2021) did not find a significant result for

blocked practice as well. Since more mental effort will be present in interleaved than in blocked studying, it is more likely to be used as a cue for learning in interleaved studying. A possible explanation for the difference between blocked and interleaved is that students studying blocked indicate their perceived effectiveness not based on mental effort, but on other cues. Possible cues for this could be invested time, fluency, beliefs on what is effective or (un)awareness of what does and does not enhance learning (Bjork et al., 2013; De Bruin et al., 2020; De Groep, 2021; Sungkhasettee et al., 2011).

Monitoring Accuracy

Against the expectations, the influence of monitoring accuracy as moderator is not a significant result. However, in the moderating model for interleaved practice, the effect of mental effort on perceived effectiveness was significant, and the influence of monitoring accuracy on perceived effectiveness was not significant but not very high either. Next to that, monitoring accuracy does influence perceived effectiveness directly. This means that the better one can monitor their learning, the higher their perceived effectiveness is. Although monitoring accuracy did not seem to be a moderator, it can be a cue for perceived effectiveness. Thus, monitoring accuracy does not moderate the relationship between mental effort and perceived effectiveness but does directly influence perceived effectiveness. The nature of the relationship between monitoring accuracy, mental effort and perceived effectiveness is still unclear.

From the presented models it could be stated that both mental effort and monitoring accuracy for interleaved practice do not have a very high effect size. In other words, only a small portion of the variance of perceived effectiveness can be explained by using only mental effort and monitoring accuracy as variables. Therefore, other factors for indicating the scores on perceived effectiveness are possibly present. Sungkhasettee and colleagues (2011) state that people do not appreciate the benefits of studying with more effortful strategies and

that people often think that if someone learns the easy way, it will be easier recalled upon when needed. It is possible that in this case, one's perceived effectiveness depends on how easy something is recalled on a test and not on mental effort.

Limitations and Recommendations

This research focussed on perceptions on mental effort, effectiveness, and their judgements of learning of students in tertiary education. Kirk-Johnson and colleagues (2019) also mention that the pattern of higher mental effort leading to lower perceived effectiveness is found to be the same across different subject populations, as well as learning materials or used research type. It could be said that results from this research are therefore also generalizable to multiple groups of people. However, since monitoring accuracy in settings like this one has not yet been examined much, more research should be done before it is possible to make conclusions and generalise findings.

Since no evidence has been found for the moderating effect of monitoring accuracy, it might be of interest to investigate this further. Although a direct effect was found for monitoring accuracy on perceived effectiveness, the nature of the relationship between monitoring accuracy and mental effort on perceived effectiveness is still unclear, and in future research this could be examined. For example, it might be useful to investigate this in other study strategies. In this research, the focus was on paintings. However, it is possible that the influence of monitoring accuracy is significant in other types of studying, like studying words in another language. Some participants indicated that paintings are less interesting and were not seen as useful, and they might want to study with blocked or interleaved practice in another setting. Due to this disinterest, it is possible that they may have put not as much effort into the studying as they would have done in daily practice, which may influence the results of this research. Therefore, it might be interesting to investigate other fields of studying.

Even though it was not the direction of this experiment, something that might be interesting to investigate would be if overestimating or underestimating learning, creating either negative or positive differences in monitoring accuracy, would be of influence on one's perceived effectiveness. Other research often focussed on perceptions and behavioural choices (i.e., De Groep, 2021; Kirk-Johnson et al., 2019). It is possible that underestimating or overestimating creates different perceptions. For instance, someone who constantly overestimates their learning would often experience disappointment, and someone who always underestimates their learning would probably be pleasantly surprised. This can influence their behavioural choices and could be interesting for the field to research. By taking the direction of monitoring (i.e., over- and underestimating) into consideration, possible differences in perceived effectiveness and strategy choices may be found.

Implications

Current findings on the negative influence of mental effort on perceived effectiveness are in line with existing literature. Therefore, this research contributes to the theoretical foundation on desirable difficulties. This research also attempted to investigate the influence of monitoring accuracy on this relationship. However, no evidence has been found for monitoring accuracy as a moderator but does have a direct influence on perceived effectiveness. It is possible that in a different research setting other outcomes can be found. Therefore, it might be of interest to recreate the same type of research in another setting. For instance, with other learning strategies or other learning materials. This research contributes by strengthening the scientific basis on mental effort and, additionally, it gives input for future research on monitoring accuracy.

As for educational practice, it is advisable for students to study with interleaved practice or other desirable difficulties (Bjork & Bjork, 2011). Studying interleaved will give students better long-term results, even though students might experience more effort. For

teachers, another idea is having students use the two methods and explain the benefits and differences between them (Händel et al., 2020). Informing students of the use of more difficult strategies can help students understand why desirable difficulties are in fact desirable. The knowledge on the beneficial effects of interleaved practice may help students choose this method more often (De Bruin et al., 2020). When doing this, clearly stating the effect of mental effort on perceived effectiveness is necessary since only telling students on the beneficial effects of desirable difficulties is often not enough (Kirk-Johnson et al., 2019). Next to this, enhancing students' capabilities to accurately monitor their own learning will help students to align their perceived effectiveness with the actual effectiveness of a strategy. For instance, (self-)testing and evaluating these could be useful for enhancing monitoring skills (Dunlosky et al., 2005).

To conclude, this research found that, as expected, mental effort has a negative influence on perceived effectiveness. In contradiction to our hypotheses, no evidence is found for the moderating effect of monitoring accuracy but monitoring accuracy has been found to directly influence perceived effectiveness. The nature of the relationship between mental effort, monitoring accuracy and perceived effectiveness has yet not been fully explained. However, it can be said that both monitoring accuracy and mental effort influence how effective someone thinks a strategy is. With the implications of our research bearing in mind, it could be said that when one studies more effortful in a good way, they perceive it as less effective. However, when students are notified of the actual benefits of these desirable difficulties, they might choose to use these more effortful strategies after all.

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Appendix A

Information Letter and Informed Consent

Welkom bij het onderzoek!

Hierbij nodigen we je uit om deel te nemen aan het onderzoek genaamd ‘Cognitieve inspanning tijdens het studeren bewaken en reguleren’. Het doel van dit onderzoek is om inzicht te krijgen in hoe studenten het studeren middels verschillende leerstrategieën ervaren.

Waarom?

Er komen steeds meer mogelijkheden om iets te leren. De lesstof van je studie kun je tegenwoordig online op talloze manieren bestuderen en oefenen (denk bijvoorbeeld aan extra uitleg via online instructiefilmpjes). Sterker nog, niet alleen je studiestof, maar bijna alles kan je online leren en in sommige gevallen zelfs met een erkend diploma tot gevolg. Deze nieuwe vorm van leren vraagt wel wat van je: omdat er tijdens online leren weinig sturing van een docent is, zal je zelf moeten bepalen waar, wanneer en hoe je gaat studeren. Wetenschappelijk is nog weinig bekend over hoe mensen omgaan met deze vrijheid en op basis waarvan zij kiezen hoe te studeren. Met dit onderzoek willen we daar meer inzicht in krijgen. We zijn vooral benieuwd hoe studenten het studeren middels verschillende leerstrategieën ervaren.

Wat houdt deelname in?

Deelname aan dit onderzoek duurt circa 20 minuten. Je zal het werk van verschillende schilders bestuderen. Middels een leerstrategie ga je proberen zoveel mogelijk werk van schilders te leren herkennen aan de hand van hun schilderijen. We stellen je daarnaast een aantal vragen over jouw ervaringen tijdens het leren. Aan het einde toetsen we hoeveel je geleerd hebt.

!! Deelname aan dit onderzoek vereist je volledige aandacht. Je kan alleen via een computer of laptop deelnemen. Deelname vanaf een telefoon of tablet is niet toegestaan. Van jou als deelnemer wordt verwacht dat je alle taken in één onafgebroken sessie maakt, dit betekent dat

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er geen onderbreking mogelijk is.

Vertrouwelijkheid en gegevensverwerking

Omdat we geen namen of IP-adressen opslaan, verzamelen we geen persoonlijke gegevens.

De opgeslagen gegevens zijn op geen enkele wijze terug te leiden tot individuen. De computer waarop de verzamelde gegevens worden opgeslagen is beschermd door een beveiligingscode en alleen de betrokken onderzoekers hebben toegang tot deze gegevens. Je gegevens worden minimaal 10 jaar bewaard. Dit is in overeenstemming met de richtlijnen van de Vereniging van Universiteiten in Nederland (VSNU). Raadpleeg de website van de Autoriteit Persoonsgegevens: <https://autoriteitpersoonsgegevens.nl/nl/onderwerpen/avg-europese-privacywetgeving>, voor meer informatie over privacy.

Vrijwillige deelname

Deelname aan dit onderzoek is vrijwillig. Je kunt je deelname aan het onderzoek op elk moment beëindigen, zonder enige uitleg en zonder enige negatieve gevolgen. Als je je deelname beëindigt, zullen we de tot dan toe verzamelde gegevens gebruiken, tenzij je ons expliciet anders informeert.

Onafhankelijke contactpersoon en klachtenfunctionaris

Als je vragen of opmerkingen hebt over het onderzoek, neem dan contact op met dr. Eva Janssen via e.m.janssen@uu.nl Als je een officiële klacht hebt over het onderzoek, dan kun je een e-mail sturen naar de klachtenfunctionaris via klachtenfunctionaris-fetcsocwet@uu.nl.

Als je na het lezen van deze informatie instemt met het gebruik van je anonieme gegevens voor onderzoek, vragen we je vriendelijk om daar hieronder digitaal toestemming voor te geven.

Mede namens het onderzoeksteam,

Met vriendelijke groet,

Roosmarijn Knopper (r.l.knopper@uu.nl)

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Toestemmingsverklaring

Ik verklaar hierbij dat ik de informatie over het onderzoek ‘Cognitieve inspanning tijdens het studeren bewaken en reguleren’ heb gelezen. Ik weet dat ik mijn deelname op elk moment kan beëindigen en ik ga ermee akkoord deel te nemen aan het onderzoek.

- Ja ik ga akkoord en wil nu beginnen aan mijn deelname
- Nee ik ga niet akkoord en ik beëindig hierbij mijn deelname

Datum: _____

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Appendix B

Example of the Intervention

Reflectie

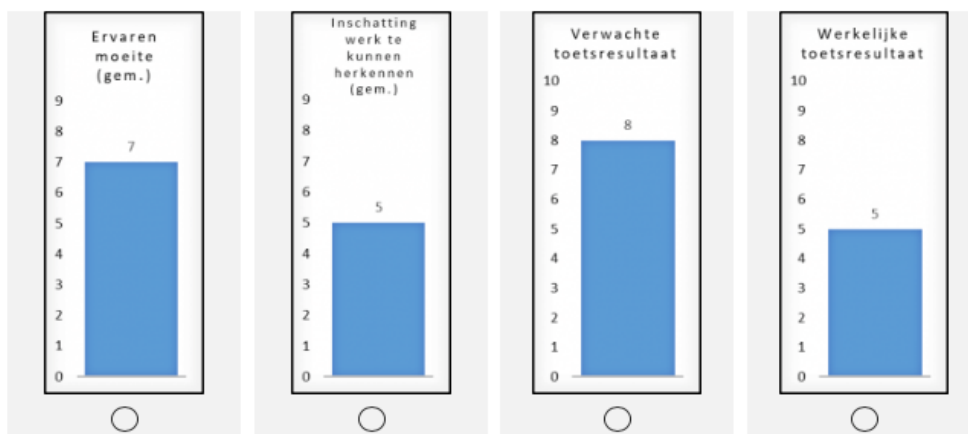
Neem de tijd om te reflecteren op de gemixte leerstrategie die je zojuist hebt toegepast.

Om je daarbij te helpen zie je hieronder een overzicht van hoe jij **zelf hebt aangegeven** het leren te hebben ervaren en wat jouw werkelijke leeropbrengst is.

Voor beide gebruikte leerstrategieën zie je een terugkoppeling met (van links naar rechts):

1. gemiddeld genomen hoeveel **moeite het je kostte** om het werk van schilders te leren herkennen (tijdens het leren).
2. gemiddeld genomen hoe **goed jij dacht** het werk van de schilders te kunnen herkennen (tijdens het leren).
3. het aantal schilderijen waarvan jij **verwachtte** de juiste schilder te kunnen herkennen op de toets.
4. het aantal schilderijen dat jij **daadwerkelijk** correct herkende op de toets.

Jouw resultaten voor gemixt leren



Beschrijf kort wat je kunt opmaken uit de resultaten hierboven.

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Appendix C

Questionnaire on Demographical Information and Effectiveness and Willingness for Using Strategy Again.

Demographics

- Wat is je geslacht? (vrouw/man/anders)
- Wat is je leeftijd in jaren?
- Wat is het niveau van je huidige opleiding? (MBO niveau 2, MBO niveau 3, MBO niveau 4, HBO bachelor, HBO master, WO bachelor, WO master)
- Wat is je huidige studierichting? (Aarde en Milieu, Economie en Bedrijf, Exact en Informatica, Gedrag en Maatschappij, Gezondheid, Kunst en Cultuur, Onderwijs en Opvoeding, Recht en Bestuur, Taal en Communicatie, Techniek, Anders.

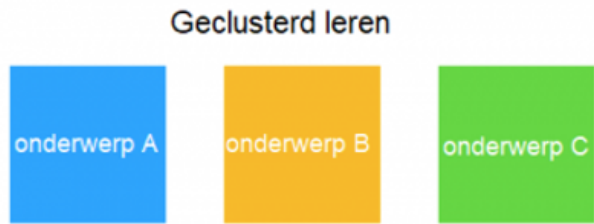
After Study Session

In dit onderzoek heb gemixt leren gebruikt om schilders te leren herkennen aan de hand van hun schilderijen: je bestudeerde de schilderijen van verschillende schilders door elkaar, gemixt dus. Schematisch ziet dat er zo uit:



Zoals aan het begin aangegeven, bestaan er meerdere manieren om hetzelfde te leren. Een andere manier was bijvoorbeeld **geclusterd leren** geweest. Als je geclusterd leert, bestudeer je één onderwerp voordat je doorgaat naar het volgende onderwerp. Toegepast op de huidige leertaak betekent **geclusterd leren** dat je eerst een cluster schilderijen van één schilder bestudeert en vervolgens doorgaat met het bestuderen van een cluster schilderijen van een nieuwe schilder etc. Schematisch ziet dat er zo uit:

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Welke van de twee leerstrategieën is volgens jou het meest effectief voor de huidige leertaak (namelijk, het werk van schilders leren herkennen aan de hand van hun schilderijen)?

- Geclusterd leren
- Gemixt leren

Kun je deze keuze kort toelichten? _____

Welke van de twee leerstrategieën zou je willen gebruiken voor leertaken die vergelijkbaar zijn met de huidige leertaak (namelijk, het werk van schilders leren herkennen aan de hand van hun schilderijen)?

- Geclusterd leren
- Gemixt leren

Kun je deze keuze kort toelichten? _____