

# Systematic metacognitive reflection helps people discover far-sighted decision strategies: a process-tracing experiment

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## Abstract

Short-sighted decisions can have devastating consequences, and teaching people to make their decisions in a more far-sighted way is challenging. Previous research found that reflecting on one’s behavior can boost learning from success and failure. Here, we explore the potential benefits of guiding people to reflect on whether and how they thought about what to do (i.e., *systematic metacognitive reflection*). We devised a series of Socratic questions that prompt people to reflect on their decision-making and tested their effectiveness in a process-tracing experiment with a 5-step planning task ( $N = 265$ ). Each participant went through several cycles of making a series of decisions and then either reflecting on how they made those decisions, answering unrelated questions, or moving on to the next decision right away. We found that systematic metacognitive reflection helps people discover adaptive, far-sighted decision strategies faster. Our results suggest that systematic metacognitive reflection is a promising approach to boosting people’s decision-making competence.

Keywords: metacognitive learning, systematic reflection, boosting, planning, decision-making

## 1 Introduction

Consistent with the adage “Failing to plan is planning to fail”, research on judgment and decision-making has found that insufficient foresight is a major source of mistakes that people come to regret (Kinnier & Metha, 1989), such as neglecting their education and

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failing to save for retirement (Bruine de Bruin et al., 2007; Goda et al., 2019; Wang & Sloan, 2018). One way to address this problem, is to increase people's decision-making competence (i.e., boosting; Hertwig & Grüne-Yanoff, 2017) by helping them learn to use more far-sighted decision strategies. Simply telling people about the importance of planning is not enough to achieve this (Larrick, 2004). However, when a person learns such a lesson from experience, it can fundamentally change how they make future decisions (e.g., Heller et al., 2017).

Learning from experience can produce valuable knowledge about the world that can inform future decisions (e.g., "Debt compounds exponentially fast."). Importantly, learning from experience can also improve the process of decision-making itself. For instance, a college freshman who failed to start studying for their first midterm exam on time and received a poor grade on it, might subsequently learn to plan when, where, and how to study for the final exam. As a consequence, the way in which they decide how to spend their time can become more deliberate, more far-sighted, and more proactive. Learning how to decide can involve gaining explicit knowledge about the pros and cons of different ways of decision-making (e.g., "I get better grades when I plan weekly study sessions"), the acquisition of implicit, procedural knowledge about how to make good decisions, or both. Both components of learning how to decide are instances of *metacognitive learning* (Lieder & Griffiths, 2017; Krueger et al., 2017; Jain et al., 2019; He et al., 2021; He & Lieder, 2022) because they involve the acquisition of metacognitive knowledge and (meta)cognitive skills, respectively.

Here, we focus on two important types of metacognitive learning: discovering new decision strategies (He & Lieder, 2022; Jain et al., in press; Siegler & Jenkins, 2014) and learning when to select which decision strategy (Rieskamp & Otto, 2006; Erev & Barron, 2005; Lieder & Griffiths, 2017). While most previous research on metacognition investigated the metacognitive regulation of students' study behavior (Zimmerman, 1990; Panadero, 2017; Veenman et al., 2006) or reasoning and problem-solving (Ackerman & Thompson, 2017; Griffiths et al., 2019), metacognition also plays an important role in strategy discovery (Shrager & Siegler, 1998; Siegler, 1999) and strategy selection (Lieder & Griffiths, 2017).

The term *systematic reflection* (Ellis et al., 2014) refers to a structured procedure in which people i) analyze what they have done, ii) evaluate their performance, iii) determine which behaviors had a positive impact on their performance outcomes and which behaviors had a negative impact, and iv) plan how to improve. The structure of this procedure is often provided by asking a person or group to answer a series of questions. Those questions are generally designed to structure reflection on "knowledge, values, behavior and practice" (Pammer-Schindler & Prilla, 2021). Previous research has found that asking people to systematically reflect on their behavior can boost their subsequent performance (Ellis et al., 2014). For instance, Anseel et al. (2009) found that asking people to reflect on what they did correctly and what they did wrong in a simulated management task significantly increased their subsequent performance on a second instance of the same management task. Moreover, it has been shown that systematic reflection can help people learn from both positive and negative outcomes (Ellis & Davidi, 2005; Ellis et al., 2006). Research in human-computer interaction has shown in many different ways that reflection can be supported by computing technology (Pammer-Schindler & Prilla, 2021), especially

in workplace settings (Renner et al., 2020). Step-by-step guidance through the process of systematic reflection is specifically suitable to implementation of reflection guidance via chatbots (e.g., Kocielnik et al., 2018; Wolfbauer et al., 2020).

Much is known about when and how much systematic reflection on behavior improves subsequent behavior (Ellis et al., 2014), and about helping students reflect on and regulate their study behavior through prompting and learning analytics (e.g., Azevedo, 2005; Azevedo et al., 2012; Bannert et al., 2009; Bannert & Reimann, 2012; Hilliger et al., 2020). However, there is virtually no research on the potential benefits of guiding people to systematically reflect on their decision-making strategies. We refer to the latter as *systematic metacognitive reflection*. Moreover, while we know that systematic reflection on behavior improves behavior, it remains unknown whether systematic metacognitive reflection on decision-making can foster the discovery of adaptive cognitive strategies. Finally, it remains unclear who benefits the most from systematically reflecting on how they reached their decisions, and under which conditions this is most beneficial.

We predicted that systematic metacognitive reflection improves how people make subsequent decisions by fostering metacognitive learning (H1). We hypothesized that those improvements would be driven by people learning to plan more and to use more far-sighted planning strategies (H2). Based on prior work (Sitkin, 1992), we additionally predicted that systematic metacognitive reflection would be especially beneficial after decisions that were made poorly (H3). Moreover, we predicted that reflection would be most beneficial after the first couple of decisions a person makes in a new domain (H4). Finally, because Anseel et al. (2009) found that how much people engage with reflection questions depends on their need for cognition (NFC; Cacioppo et al., 1984), we hypothesized that the effects of systematic metacognitive reflection would be moderated by the person's NFC (H5).

To test these hypotheses, we experimentally investigate the effects of systematic metacognitive reflection on people's planning strategies in a five-step sequential decision-making task. We induce systematic metacognitive reflection by asking participants a series of Socratic questions that guides them to reflect on how they made their decisions. We then measure the effect of metacognitive reflection on how people make subsequent decisions using a recently developed process-tracing method (Jain et al., in press). This approach allowed us to demonstrate that engaging people in systematic metacognitive reflection improves the quality of subsequent decisions by increasing how much they think about what to do and improving what they think about and how they think about it. Specifically, we found that asking participants to reflect on how they reached their decisions enabled them to discover adaptive far-sighted decision strategies. Moreover, we found that systematic metacognitive reflection was especially helpful for people who previously failed to plan, or initially used very short-sighted decision strategies. The Socratic questions we asked to prompt this reflection are only a small step away from a chatbot that fosters systematic metacognitive reflection about real-life decisions. Therefore, our findings could give rise to a cost-effective intervention for improving decision-making in the real world.

## 2 Method

We preregistered this experiment and our data analysis on osf.io. Our preregistration is available at <https://doi.org/10.17605/OSF.IO/M6DFU>. The analysis scripts, the data and the code for the experiment are available at <https://github.com/RationalityEnhancementGroup/ReflectiveLearning>.

### 2.1 Participants

We recruited a total of 265 participants by advertising our study on the online participant recruitment platform Prolific. Participation was restricted to people who had not previously participated in other experiments we ran on Prolific using similar tasks. These sample sizes were chosen to achieve a statistical power of at least 80% for all of our hypotheses, assuming medium-sized effects and a significance level of .05. Participants received a guaranteed payment of £2 for about 20-25 minutes of work and could earn an additional performance-dependent bonus of around £1, which provided an incentive for good task performance. The average wage of the experiment was £7.29. The age of the participants included in the analysis ranged from 18 to 78 years ( $M = 39.9$ ,  $SD = 13.6$ ) and 78% of them were female.

To be included in the analysis, participants had to meet the following pre-registered inclusion criteria. They had to pass the task comprehension quiz in at most 3 attempts. In addition, we excluded participants who reported having previously participated in an experiment using a similar task. Applying these criteria led to the exclusion of eight participants.

### 2.2 Materials

#### 2.2.1 Planning task

Since it is not possible to observe human planning directly, the underlying cognitive process has to be inferred from people's behavior. To this end, we employed the Mouselab Markov Decision Process (Mouselab-MDP) paradigm (Callaway et al., 2017, in press). Mimicking the challenge that achieving important life goals, such as becoming a doctor, often requires planning multiple steps ahead, the Mouselab-MDP paradigm requires participants to plan a series of actions. Which actions are available in each step depends on which actions the participants chooses in the previous steps. As in many challenge real-life decisions, such as choosing a career, which of the initial actions is best primarily depends on the outcomes of later actions. Crucially, the Mouselab-MDP paradigm is designed so that people's information-gathering behavior is highly informative about their planning strategy. In our version of this task, participants were tasked to move a spider from a starting node to one of 18 target nodes. Each possible path consisted of 5 nodes, which contained rewards whose values were initially occluded (see Figure 1). Participants could reveal the value of a reward by clicking on the corresponding node. A fee of \$1 per click incentivized them to only click on a node when they needed its value for their next planning operation. The participant's sequence of clicks (i.e. which nodes the participant inspected on and in which order they clicked on them) is highly informative about which type of planning strategy they

used (e.g., far-sighted vs. near-sighted planning; see Table 2). Once the spider is moved, clicking is no longer possible. The spider uncovers and collects every reward on its way from the start node to a target node. The participants' task is to maximize their game score, which is the sum of the rewards collected by the spider minus the amount spent to uncover the values of the rewards. Rewards are drawn from a Gaussian distribution with mean 0 and standard deviation 1, 2, 4, 8, or 32 for nodes that are 1, 2, 3, 4, and 5 steps away from the start node, respectively. This means that the rewards near the start node vary less than the rewards at the target nodes, making it advantageous to start planning at the target nodes. Participants have to solve 21 instances of this planning task in a row – each time with a different set of hidden rewards.

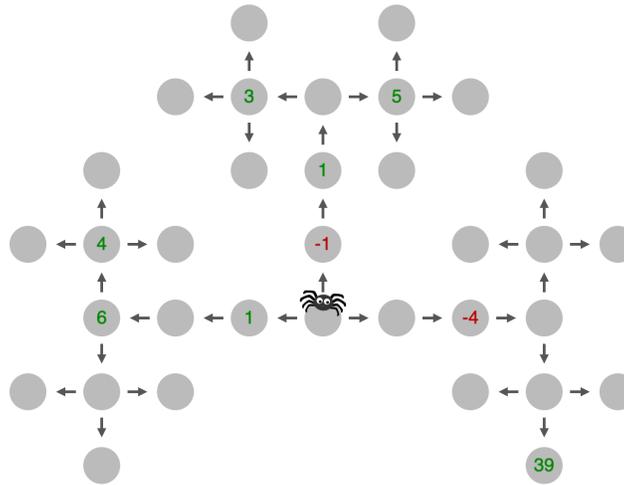


FIGURE 1: Screenshot of the planning task. Participants can reveal rewards for a fee to plan a path to one of the target nodes.

### 2.2.2 Reflection prompts

The reflection prompts started with the instruction “Please reflect about your planning success in the last three rounds by answering a couple of questions”. Participants then received a brief objective feedback on their current performance, displayed for 4 seconds: “Your average score in the last three rounds was X. Your average score in the three rounds before that was Y”. Next, they were asked to answer the questions listed in Table 1 in writing, one question at a time. These questions were designed by adapting the reflection script by Wolfbauer et al. (2020) to foster metacognitive reflection about planning in the task shown in Figure 1. The first three questions guided the participant to describe their planning strategy. The fourth question asked the participant to judge how well they had planned. The following two questions asked the participant to analyze their performance and derive a lesson from it. Next, they were asked to formulate a concrete plan for how to put that lesson into practice in the following trials.

TABLE 1: Reflection prompts that participants in the reflection condition were asked to answer from the first question to the last, grouped by which kind of metacognition they stimulate.

| Level of reflection     | Reflection prompt(s)  |
|-------------------------|---|
| Description             | How many clicks did you make to decide what to do?  |
|                         | Where did you click in order to decide what to do?  |
|                         | Did you use any particular strategy for selecting your clicks? If so, what was it?  |
| Judgment                | How well do you think your current strategy is working? <sup>1</sup>  |
| Evaluation and Learning | Why do you think it worked out that way?  |
|                         | Based on what you have learned in the last rounds, what tip could you give to a person who performs this task for the first time? |
| Planning                | Based on the previous questions, how many clicks do you plan to do in the next rounds?  |
|                         | Based on the previous questions, where do you plan to click in the next rounds?   |
|                         | Which strategy do you want to use to select your clicks in the next rounds?   |

### 2.2.3 Mundane questions

The control prompts started with a brief objective feedback on their current performance, displayed for 4 seconds: “Your average score in the last three rounds was X. Your average score in the three rounds before that was Y”. Next, the participants were asked the following 3 questions: “Please describe your favorite <topic>?”, “What do you like about it?”, and “What do you dislike about it?” Each prompt addressed a different topic, such as food, books, or sports. The control prompts were designed to match the reflection prompts in their writing and time requirements. The mean response time to reflection prompts was 123 seconds ( $SD = 111$ ) and to control prompts it was 150 seconds ( $SD = 97$ ).

### 2.2.4 Questionnaires

We measured how much each participant liked to think using the Need for Cognition (NFC) Scale (Cacioppo et al., 1984). This scale consists of 18 statements related to the satisfaction one gains from thinking (e.g. “I prefer complex to simple problems”) and asks for the degree of approval on a 5-point scale ranging from “extremely uncharacteristic of me” to “extremely characteristic of me”.

In addition, participants in the experimental condition were asked how much effort they had invested into answering the reflection prompts. The answer choices were “minimal

<sup>1</sup>Participants answered this question on a Likert scale with answer choices ranging from “Very Well” to “Very Poor”

effort”, “some effort”, and a “lot of effort”.

## 2.3 Experimental design

Our experiment used a between-subjects design with one experimental group ( $N = 128$ ), one active control group ( $N = 65$ ), and one passive control group ( $N = 64$ ). All groups performed 21 trials of the planning task described above. The three groups differed in whether participants were prompted to engage in systematic metacognitive reflection (reflection condition), prompted to answer the mundane questions described above (active control condition), or not prompted to answer any questions during the planning task at all (passive control condition). The rationale of including the active control condition was to control for the amount of time and mental effort participants had to invest to complete the experiment and the time intervals between subsequent decisions. The rationale for including the passive control condition was to examine whether adding reflection prompts has practically relevant benefits that cannot be explained by the absence of the potential negative effect of interrupting participants’ learning with mundane questions.

## 2.4 Procedure

### 2.4.1 Data collection

After participants gave informed consent and answered the NCS questionnaire, the experiment started with instructions on the planning task. Participants’ understanding of the instructions was tested via a quiz comprising four basic comprehension questions, for example, asking how to learn the value of a node. If a participant answered one or more questions incorrectly, they had to reread the instructions and retake the quiz until they got all answers right. Participants were then informed about the performance-dependent bonus scheme and completed 21 trials of the planning task. After every third trial except for the last one, the experimental group was prompted to reflect on their decision-making, while the active control group was prompted to answer the mundane questions. After completing the 21 trials, participants reported basic demographic information and were asked whether they had participated in an experiment using a similar task before.

### 2.4.2 Data processing and diagnostics

**Measuring engagement** We classified participants’ responses to the reflection prompts according to the participant’s degree of engagement with the question. Each response was categorized as showing either no engagement, low engagement, or high engagement based on the participant’s response time and the length and content of their response. A response was categorized as showing no engagement when its content was meaningless (e.g., “asdf” or “-”). A response was categorized as showing high engagement when it was meaningful and its response time or length were above the fourth quartile of the respective distribution (i.e., longer than 144 seconds or 292 characters). Finally, a response was categorized as showing low engagement when it was meaningful but did not meet the criteria for high engagement or was given too rapidly (i.e., when the response time was below the first quartile

of the response time distribution, i.e., 69 seconds). Whether a response was meaningless or meaningful was determined by two trained raters. The two raters achieved an inter-rater agreement of 99.5% on the first 25% of the responses. Therefore, each of the subsequent responses was categorized by only one rater.

**Inference of planning strategies and strategy types** The computational microscope (Jain et al., in press) is a computational method for inferring the planning strategies participants use in the Mouselab-MDP paradigm from their information-gathering behavior. It performs Bayesian inference to determine which of 89 predefined planning strategies is most likely to have generated the sequence of clicks a participant made on a given trial, taking into account which strategy the participants appears to have used in the adjacent trials. The predefined strategies differ in how much planning they perform, which outcomes they focus on (e.g., immediate outcomes vs. long-term consequences), the order in which different outcomes are inspected (e.g., path-by-path vs. all immediate outcomes first), and in the ways in which the observed outcomes affect whether planning continues (e.g., stop planning upon discovering the highest possible reward) and, if so, how (e.g., if a potential first step yields a positive immediate outcome, then examine its long-term consequences). The set of strategies includes the optimal strategy for this task, which starts by exploring the final outcomes and stops clicking upon finding the maximum value of the reward distribution. The ten strategies our participants used most frequently are described in Table 3. The computational microscope has been empirically validated on the Mouselab-MDP paradigm; it made accurate inferences and was able to detect the effects of feedback on metacognitive learning (Jain et al., in press). We employ the computational microscope to identify possible effects of systematic reflection on the temporal evolution of people’s decision strategies. Building on He & Lieder (2022), we grouped the decision strategies our participants used into the three types defined in Table 2. Of these three strategy types, the far-sighted planning strategies are most adaptive in our task and the near-sighted planning strategies are least adaptive.

TABLE 2: Taxonomy of different types of planning strategies.

| Strategy type           | Description  |
|-------------------------|--|
| Near-sighted strategies | These strategies only consider immediate outcomes or no outcomes at all.             |
| Far-sighted strategies  | These strategies consider final outcomes.  |
| Other strategies        | These are planning strategies that do not fit in any of the two previous categories. |

TABLE 3: The 10 most frequently used decision strategies.

| Strategy   | Used on<br>_% of<br>trials | Strategy<br>type | Expected<br>score |
|--|----------------------------|------------------|-------------------|
| Do not inspect any outcomes (i.e., no planning).   | 29.8                       | Near-sighted     | 0.0               |
| Inspect the final outcomes and stop clicking upon finding the highest possible reward. <sup>2</sup>  | 13.4                       | Far-sighted      | 42.9              |
| For each branch, explore one final outcome and its predecessor.  | 6.1                        | Far-sighted      | 38.0              |
| Inspect all immediate outcomes and then explore paths that start with a positive immediate outcome.  | 5.8                        | Far-sighted      | 25.8              |
| Inspect all final outcomes and then click the predecessor of a positive final outcome and then stop planning.  | 5.5                        | Far-sighted      | 22.9              |
| Plan according to Depth First Search and then stop upon finding the highest possible reward.   | 3.9                        | Other            | 31.8              |
| Inspect all final outcomes and then inspect the immediate outcomes. If you find the highest possible reward while inspecting final outcomes, then it stops clicking.   | 3.8                        | Far-sighted      | 41.0              |
| Inspect the final outcomes. If you find the highest possible reward, then immediately inspect all nodes along the path that leads to the highest possible value, starting from the center of the web. Then stops clicking. | 3.3                        | Far-sighted      | 41.5              |
| Inspect all the final outcomes until you finds the highest possible reward. Then explores the immediate outcome of the path that leads to the highest possible reward.   | 3.1                        | Far-sighted      | 42.5              |
| Inspect immediate outcomes. Once you have uncovered a positive immediate outcome, then inspect the final outcomes in such a way that after exploring a final outcome, you next explore its siblings.                       | 2.2                        | Far-sighted      | 30.7              |

<sup>2</sup>This is the optimal decision strategy for this task.

**Quantifying the goodness of participants' planning** A key characteristic of the experimental task is that the rewards are drawn from distributions with relatively high variances (see section 2.2.1). As a consequence, using the very same planning strategy in multiple trials will most likely lead to different scores. This makes the score a relatively noisy measure for the goodness of planning. To overcome this, the computational microscope (Jain et al., in press) provides an *expected score* for each inferred strategy. The expected score of a strategy is the expected value of the score attained by using the strategy. We estimated it by simulating the application of the strategy to 100,000 different trials of the experimental task and then averaging the attained scores. The expected score can be seen as the expected value of the score distribution of a strategy, whereas the score can be seen as a single draw of it. The expected score thus quantifies the goodness of participant's planning more robustly than the score.

**Computing outcome measures** In each trial, we recorded the participant's *score* in the planning task, the *planning strategy* inferred from the participant's click behavior, the *expected score* of the planning strategy and the *type* of the planning strategy. In addition, we measured the *amount of planning* by the number of clicks the participant made prior to choosing a path. In transitions from one trial to the next, we recorded whether the participant's planning strategy changed (*strategy change*), whether the type of the new strategy was different (*strategy type change*) and whether the amount of planning changed (*clicks change*). In addition, we measured the *numerical difference in expected score* and the *numerical difference in the amount of planning* by subtracting the corresponding value of the previous trial from its counterpart for the new trial.

**Pooling of control conditions** Following our preregistered data analysis plan, we combined the two control conditions into a single control condition upon confirming that they did not differ in any meaningful way. To keep the following text simple, we will refer to the pooled data as "the control condition". The rationale was to increase the statistical power of the comparisons between the experimental condition and the control condition(s). The passive control condition required 12.6 minutes for the experiment on average. The addition of mundane questions in the active control condition increased this duration to 30.4 minutes to match the duration of the reflection condition (30.2 minutes). An ANCOVA, correcting for NCS and the performance in the first three trials, showed that the performance of the two control conditions did not significantly differ in terms of score ( $F(1, 125) = 0.022, p = .883$ ) and expected score ( $F(1, 125) = 0.026, p = .871$ ). The average expected score was 18.8 ( $SD = 18.1$ ) in the passive control condition and 22.9 ( $SD = 18.6$ ) in the active control condition.

### 2.4.3 Data analysis strategy

In the main analysis, we employed linear mixed models (LMM) for numeric dependent variables and generalized LMMs (GLMMs) for binary dependent variables. The exact model formulations and a detailed description of the data analysis are given in our pre-registration (see Section 2). The complete regression results can be found in Appendix A.2. We used the

following packages from the statistical analysis program R: ‘lme4’ for fitting, ‘lmerTest’ to obtain p-values and ‘interactions’ to resolve interaction effects. We standardized all numeric independent variables before fitting the models to stabilize optimization. We evaluated the models after setting the predictor variable *baseline* one standard deviation below average. To control for the false discovery rate, we applied the Benjamini-Hochberg procedure to correct the p-values for multiple comparisons (Benjamini & Hochberg, 1995). Following the best practices outlined by Spiller et al. (2013), we investigated significant interaction effects using the Johnson-Neyman test. This test determines for which values of a moderator variable the main effect is significant.

### 3 Results

As detailed below, our results show that systematic metacognitive reflection boosts people’s decision-making competency by fostering fast metacognitive learning. Moreover, we found that the benefit of metacognitive reflection is greatest when people who use poor decision-making strategies reflect on them for the first time.

As illustrated in Figure 2, the expected score of the control condition increased linearly across all trials. By contrast, in the reflection condition, there was a rapid improvement from trials 3-7 that slowed down afterward. According to the LMM summarized in Table 4, the slopes of the expected score differed significantly between those two time periods, producing a kink at trial 7 ( $z = 5.80, p < .001$ ). To meet the linearity assumption of linear models, we analyzed trials 3-7 separately from trials 7-21. Because most of the learning occurred in trials 3-7 we refer to them as the *learning phase*. Relatedly, because people’s performance was stable in the subsequent trials, we refer to trials 7-21 as the *performance phase*.

#### 3.1 H1: Systematic metacognitive reflection boosts performance and learning

##### 3.1.1 Improved performance

Considering all trials, the reflection group outperformed the control group in terms of their expected score ( $M = 24.5, SD = 17.5$  points vs.  $M = 20.9, SD = 18.4$  points) and their score ( $M = 22.8, SD = 30.5$  points vs.  $M = 21.4, SD = 32.2$  points). As summarized in Table 4, these differences were significant in both the learning and performance phase.

##### 3.1.2 Accelerated learning

In the learning phase, the reflection group compared to the control group had a steeper learning curve in their expected score ( $M = 2.6, SD = 4.4$  points/trial vs.  $M = 1.0, SD = 2.7$  points/trial) and their score ( $M = 3.6, SD = 10.2$  points/trial vs.  $M = 1.9, SD = 10.2$  points/trial). This difference in slope was significant for the expected score (see Table 4).

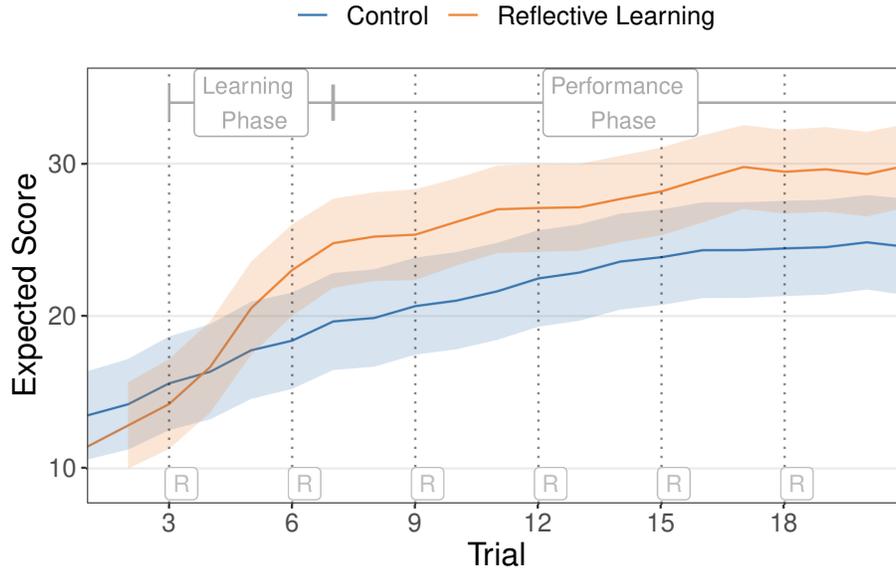


FIGURE 2: Expected score as a function of trial number and condition. In the reflection condition after every third trial a reflection prompt occurred, indicated by the letter R.

TABLE 4: Regression results for the effect of reflection on performance, the amount of planning, and the rate at which they increase with practice (Reflection × Trial Nr).

| Trials | Fixed Effect          | Outcome Variable |       |             |       |              |       |
|--------|-----------------------|------------------|-------|-------------|-------|--------------|-------|
|        |                       | Expected Score   |       | Score       |       | Clicks       |       |
|        |                       | $\beta$          | $p$   | $\beta$     | $p$   | $\beta$      | $p$   |
| 3-7    | Reflection            | <b>7.35</b>      | <.001 | <b>8.51</b> | .015  | <b>2.28</b>  | .001  |
|        | Reflection × Trial Nr | <b>4.71</b>      | <.001 | 2.05        | .475  | <b>1.14</b>  | <.001 |
| 7-21   | Reflection            | <b>12.21</b>     | <.001 | <b>9.96</b> | <.001 | <b>2.6</b>   | .002  |
|        | Reflection × Trial Nr | <b>-0.74</b>     | .021  | 0.28        | .812  | <b>-0.39</b> | .048  |

Note. All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Interaction effects are denoted with a cross (×).

### 3.2 H2: Systematic metacognitive reflection improves *how* and *how much* people plan

Having found that systematic metacognitive reflection improves performance, we now investigate which reflection-induced changes in decision-making are responsible for this improvement. We start by examining the cumulative effect of repeatedly reflecting on different decisions. Then, we zoom in on the immediate effect of a single reflection session.

### 3.2.1 Cumulative effects of reflection on planning

Looking at the cumulative effect of reflection, we found that systematic metacognitive reflection improves both how people plan and how much people plan.

**Reflection improves how people plan** Considering all trials, the reflection group used near-sighted planning strategies in 27.0% of trials and the control group in 39.6% of trials. Consistent with the hypothesis that reflection helped people to improve their planning strategies, we found that the reflection group used significantly fewer near-sighted strategies ( $\beta = -17.89, p = .005$ ) than the control group in the learning phase. In the performance phase, the effect of reflection was moderated by how often participants used near-sighted planning strategies in the first three trials ( $\beta = -34.7, p = < .001$ ), which we will refer to as the *baseline* trials. The Johnson-Neyman test revealed that reflection reduced the use of near-sighted strategies within the group of participants who used these strategies in the majority of the baseline trials.

For far-sighted strategies, we observed the opposite pattern. Considering all trials, the reflection group used far-sighted planning strategies in 60.3% of trials and the control group in 54.2% of trials. Again, the effect of reflection in the performance phase was moderated by the initial use of far-sighted strategies ( $\beta = -13.1, p = < .001$ ). Using the Johnson-Neyman test, we found that reflection increased the use of far-sighted strategies within the group of participants who did not use far-sighted strategies in the baseline trials.

These differences might arise partly because reflection helps people overcome near-sighted planning. Consistent with this hypothesis, an exploratory follow-up analysis showed that participants who used near-sighted strategies in the majority of the baseline trials learned to use far-sighted strategies significantly more often when they were in the reflection condition than when they were in the control condition ( $\beta = 10.9, p = < .001$ ).

**Reflection fosters strategy exploration** Supporting the interpretation that these improvements were achieved through the exploration of alternative decision strategies, we found that reflection caused participants to change their decision strategy more often. That is, compared to the control group, the reflection group more frequently changed their decision strategy (1.8 times vs. 2.5 times), and the type of their decision strategy (0.7 times vs. 1.1 times). Both differences were statistically significant (see Table 5). Accordingly, the average improvement per trial, in terms of the expected score, was significantly higher in the reflection condition than in the control condition (0.92 points per transition vs. 0.55 points per transition; see Table 5).

**Reflection improves how much people plan** The reflection group performed significantly more planning on each trial than the control group ( $M = 6.3, SD = 6.8$  clicks vs.  $M = 4.7, SD = 6.1$  clicks; see Table 4). This is an improvement because the strategy with the highest expected score performs 14.9 clicks on average. The reflection group also learned significantly faster to increase its amount of planning in the learning phase ( $M = 1.0, SD = 1.9$  clicks/trial vs.  $M = 0.4, SD = 1.3$  clicks/trial; see Table 4). In addition, the reflection condition changed their amount of planning significantly more often than the control condition (13.4 times vs. 11.2 times; see Table 5).

TABLE 5: Regression results for the effect of reflection on the frequency and magnitude of changes in performance and the amount of planning from one trial to the next.

|  | Outcome Variable |       |             |      |             |       |                        |       |                  |      |
|--|------------------|-------|-------------|------|-------------|-------|------------------------|-------|------------------|------|
|  | Change of        |       |             |      |             |       | Magnitude of change of |       |                  |      |
|  | Strategy         |       | Type        |      | Clicks      |       | Expected score         |       | Number of clicks |      |
| Fixed Effect                                 | $\beta$          | $p$   | $\beta$     | $p$  | $\beta$     | $p$   | $\beta$                | $p$   | $\beta$          | $p$  |
| Reflection                                   | <b>0.98</b>      | <.001 | <b>0.69</b> | .017 | <b>1.13</b> | <.001 | <b>2.69</b>            | <.001 | -0.1             | .721 |
| Reflection prompt                            | 0.63             | .088  | 0.84        | .088 | <b>0.67</b> | .006  | 0.75                   | .278  | <b>1.31</b>      | .006 |
| Reflection prompt $\times$<br>Previous Value | -0.17            | .484  | -0.23       | .484 | -0.28       | .257  | <b>-0.8</b>            | .045  | -0.26            | .436 |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Previous Value denotes the value of the outcome variable in the previous trial. Interaction effects are denoted with a cross ( $\times$ .)

### 3.2.2 Immediate effects of reflection on planning

We then took a closer look at what happens immediately after a person engages in systematic metacognitive reflection, and how that differs from the changes that occurred in the control condition and in the trials of the reflection condition where no prompt was provided.

**Reflection fosters strategy exploration on the next trial** In the reflection condition, participants changed their planning strategy more often immediately after a reflection prompt than in transitions without a reflection prompt (16.3% vs. 10.7%). The relation between reflection prompts and the number of strategy changes is illustrated in Figure 3. Overall, reflection prompts led to a not statistically significant increase in the proportion of participants who switched to a different planning strategy in the next trial (see Table 5).

**Reflection leads to increased planning on the next trial** Reflection had an immediate effect on how much people planned on the very next trial. That is, the reflection group changed their amount of planning significantly more often after transitions with reflection prompts than after transitions without reflection prompts (72.5% vs. 64.4%; see Table 5). In addition, the average change in the amount of planning was significantly larger after transitions with reflection prompts than after transitions without reflection prompts (+1.2 clicks vs. -0.2 clicks; see Table 5).

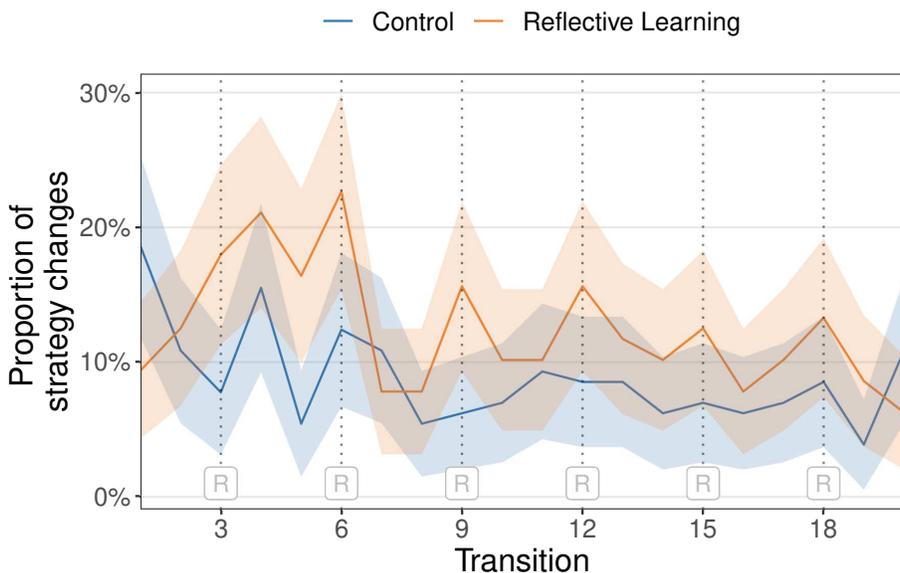


FIGURE 3: The proportion of performed strategy changes as a function of transition number and condition. Participants in the reflection condition reflected on their planning success in every third transition (R).

### 3.3 H3: Reflection is most beneficial when the decision was made poorly

Having found that systematic metacognitive reflection is beneficial for people *on average*, we now examine whether, and if so, how these benefits depend on the person and the situation. Concretely, we examine if the benefit of reflection depends on the person's initial planning skills, their NFC, which strategy they used, and the outcome of their decision.

#### 3.3.1 People who plan poorly benefit more

**Reflection is especially helpful for low performers** We found that the average expected score in the first three trials moderated the effect of reflection on expected score and score (see Table 6). The moderation implies that the effectiveness of reflection decreased with increasing baseline performance, which is consistent with the fact that people who start out with good planning strategies have less room for improvement. The Johnson-Neyman procedure revealed significant main effects of reflection on expected score and score for participants who were in the lower half of the baseline performance range (i.e. who had an average expected score in the first three trials that was below median).

Accordingly, in trials 3 to 7 the learning curves were steeper for participants with lower baseline performance as illustrated in Figure 4. We found that reflection increased the rates at which the expected score and the amount of planning increased with the trial number even more strongly for low-performers (see Table 6). In trials 7 to 21, the effect of baseline performance on the learning rate was significantly smaller in the reflection condition than in the control condition (see Table 6). As illustrated in Figure 4, this suggests that low-

TABLE 6: People’s performance in the baseline trials moderates the effect of reflection on their performance and their amount of planning in the subsequent trials.

| Trials | Fixed Effect                                   | Outcome Variable |       |              |       |              |      |
|--------|--|------------------|-------|--------------|-------|--------------|------|
|        |  | Expected Score   |       | Score        |       | Clicks       |      |
|        |  | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$  |
| 3-7    | Reflection $\times$ Baseline                   | <b>-3.84</b>     | .001  | <b>-7.81</b> | .001  | -0.41        | .416 |
|        | Reflection $\times$ Baseline $\times$ Trial Nr | <b>-2.48</b>     | <.001 | 0.32         | .845  | <b>-0.49</b> | .033 |
| 7-21   | Reflection $\times$ Baseline                   | <b>-6.52</b>     | <.001 | <b>-6.89</b> | <.001 | -0.32        | .606 |
|        | Reflection $\times$ Baseline $\times$ Trial Nr | <b>0.6</b>       | .015  | -0.1         | .904  | <b>0.3</b>   | .039 |

Note. All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. The baseline value was given by the average value of the corresponding outcome variable in the first three trials. Interaction effects are denoted with a cross (×.)

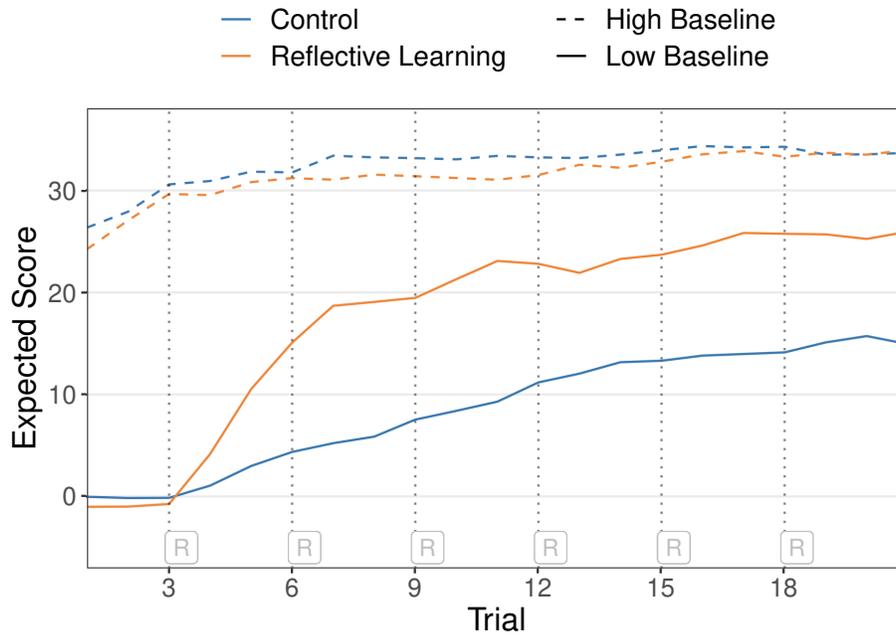


FIGURE 4: Expected score as a function of trial number and condition and baseline performance. Participants in the reflection condition reflected on their planning success after every third trial (R).

performers in the control group still had more room for improvement left after the first seven trials than low-performers in the experimental group.

**Reflection is especially helpful for near-sighted decision-makers** To examine how the effect of reflection depends on the participant’s initial planning strategy, we used the

type of the strategy participants used in the first three trials as a moderator. Using this analysis, we found that the effect of reflection was greater for people who started with near-sighted strategies. When asked to reflect, they experienced greater increases in score ( $\beta = 6.68, p = .002$ ), expected score ( $\beta = 5.77, p = .002$ ), and amount of planning ( $\beta = 1.62, p = .013$ ) in the performance phase than participants who started from other types of planning strategies.

### 3.3.2 Reflecting on bad planning is more beneficial than reflecting on good planning

We now turn to the question of how the immediate effect of reflection depends on how the participant planned on the previous trial and the outcome of their decision.

**The quality of planning on the previous trial moderates the effect of reflection** We investigated whether the expected score of the decision strategy used in the trial preceding a reflection prompt alters the immediate effects of the reflection prompt. We found that the beneficial effect of reflection on the expected score of the strategy used on the next trial was larger when the expected score on the preceding trial was lower (see Table 5).

**Effect of the previous score** We investigated whether the planning success (score) the participant experienced in the trial preceding a reflection prompt altered the immediate effects of the reflection prompt. We found that with decreasing planning success, participants were more likely to change their strategy type ( $\beta = -0.69, p = .039$ ) and to increase their expected score ( $\beta = -1.22, p = .001$ ) immediately after a reflection prompt. This is again consistent with the interpretation that reflecting on poor planning is especially beneficial.

**Reflecting on near-sighted strategies** In an exploratory analysis, we further found that the addition of a reflection prompt led to significantly larger improvements in expected score ( $\beta = 2.25, p = .016$ ) when the participant had used a near-sighted strategy on the previous trial.

## 3.4 H4: Repeated reflection on the same kind of decision has diminishing returns

To test our fourth hypothesis, we investigated whether the effect of reflection changed from the first reflection period (i.e. trials 4-6), to the second reflection period (i.e., trials 7-9), to the third reflection period (i.e., trials 10-12). We limited the analysis to these 3 periods as they capture most of the learning dynamics, as illustrated in Figure 2.

**The frequency of change appears to decrease over time** On average 18.5%, 12.8% and 12.0% of the participants in the reflection group changed their strategy in the first, second and third reflection period, respectively. By contrast, only 9.6%, 9.6%, and 7.5% of the participants in the control group changed their strategy in the first, second and third reflection period, respectively. The decrease was not significantly larger in the reflection condition than in the control group ( $\beta = -0.17, p = .24$ ). The two groups significantly differed in the

first and third reflection period ( $\chi^2(1, 257) = 12.0, p = .001$ ;  $\chi^2(1, 257) = 3.92, p = .048$ ) but not in the second period ( $\chi^2(1, 257) = 1.68, p = .2$ ).

**The amount of improvement decreases over time** We found a significant decrease in the effect of reflection on how rapidly the expected score increased from the 3<sup>rd</sup> to the 12<sup>th</sup> trial ( $\beta = -0.87, p = .003$ ). The first reflection prompt was the most effective. On average, the reflection group improved by 2.9, 0.8 and 0.6 points/trial in the first, second and third reflection period respectively. By contrast, the control group improved by only 0.9, 0.8 and 0.6 points/trial in the first, second and third reflection period respectively. The two groups significantly differed in the first reflection period ( $W = 7092, p = .021$ ) but not in the following ones (all  $p > .68$ ).

**Engagement does *not* decrease over time** One possible reason why improvement decreased over time could be that participants became increasingly more disengaged over the course of the experiment. However, we found that the level of engagement stayed constant over time ( $r(772) = -.05, p = .129$ ). Moreover, we found that our participants' engagement was encouragingly high. In the reflection condition, 55.5% of participants reported having invested a lot of effort into answering the prompts, and 44.5% of participants reported having invested some effort into answering them. The median response length to a reflection prompt was 188 characters ( $M = 236$ ), and the median response time was 97 seconds ( $M = 123$ ). According to our categorization of participants' answers to the reflection questions, 1.3% of the responses showed no engagement, 63.8% of the responses showed low engagement, and 34.9% of the responses showed high engagement.

### 3.5 H5: Need for cognition does *not* moderate the effect of systematic metacognitive reflection

We did *not* find that NFC moderates the effect of reflection on the expected score ( $\beta = 0.63, p = .737$ ). Nor did we find that NFC moderated the effect of reflection on how quickly the expected score increased with practice ( $\beta = 0.25, p = .555$ ). This indicates that the reflection prompts were effective regardless of the strength of the participant's NFC. Furthermore, we found that NFC was uncorrelated with the amount of planning that participants performed in the first three trials ( $r(255) = .02, p = .802$ .) and with the baseline performance ( $r(255) = .09, p = .132$ ).

Based on Anseel et al. (2009), we had hypothesized that people with higher NFC would engage more deeply in the reflection, and that higher engagement would yield more learning. Contrary to our prediction, we found that higher NFC was not correlated with higher engagement in answering the reflection questions ( $r(126) = .07, p = .422$ ). Moreover, whether participants answered the reflection prompts with high engagement or not did not affect the frequency of strategy changes (18.3% vs. 15.2%;  $\beta = 0.18, p = .551$ ) or the increase in the amount of planning ( $M = 1.4, SD = 6.9$  vs.  $M = 1.1, SD = 6.0$ ;  $\beta = 0.58, p = .449$ ). However, for participants' expected score, we found a significant interaction of high engagement with previous performance ( $\beta = -1.52, p = .043$ ). The Johnson-Neyman procedure revealed that high engagement, compared to no engagement

and low engagement, promoted significantly larger improvements in expected score for participants whose previous performance was below the 30<sup>th</sup> percentile. Thus, when people reflect on poor planning, higher engagement leads to a larger improvement in their expected score.

## 4 Discussion

This article introduced a new approach to improving human decision-making, namely prompting people to engage in systematic metacognitive reflection. Unlike the forms of systematic reflection that have been studied previously (Ellis et al., 2014), our Socratic questions direct people's attention to the mental processes that generated their decisions. It does so in a very granular, step-by-step manner that walks people through the metacognitive operations necessary to discover far-sighted decision strategies. Moreover, using a new process-tracing method to measure the reflection-induced changes in people's planning strategies allowed us to rigorously characterize the effects of systematic (metacognitive) reflection in more detail than was previously possible.

We found that systematic metacognitive reflection led to rapid improvements in decision-making. Participants who were prompted to systematically reflect on their decision-making changed their decision strategy more often, improved faster, performed better, and adopted more adaptive, far-sighted decision strategies than participants who practiced decision-making without systematic metacognitive reflection.

In our experiment, reflecting on instances of poor decision-making was especially beneficial. Systematic metacognitive reflection helped many of our participants to overcome poor decision strategies by learning to plan more and becoming more far-sighted. In other words, systematic metacognitive reflection was most effective for the people who most needed to improve. This is good news, given that prior work suggested that reflection only benefits people who already have considerable domain knowledge (Renner et al., 2020; Kirschner et al., 2006). Whether this difference is due to the generality of the decision strategies, we asked our participants to reflect on, or due to the simplicity of our planning task remains to be seen.

Unlike Anseel et al. (2009), we did not find that people with a lower need for cognition (NFC) reflected less. This might be because our reflection prompts were more numerous and more detailed than those by Anseel et al. (2009). We required our participants to provide written responses to nine Socratic questions that i) explicitly directed their attention to the most relevant aspects of their decision strategy, and ii) guided them through the process of metacognitive learning, from describing how they reached their decisions to planning how to implement the lesson they learned from the outcomes of their decisions (see Table 1). This detailed guidance might have succeeded to engage people with a low NFC in crucial steps of reflection that they might have skipped if we had asked only four questions, as Anseel et al. (2009) did.

In our experiment, reflecting once was enough to significantly improve decision-making. This suggests that our reflection prompts might enable people to rapidly improve their decision-making with minimal effort. In our experiment, subsequent reflection sessions led to increasingly less improvement. Therefore, future work should investigate how enhanced

metacognitive learning can be sustained over an extended period of time.

The main limitation of the present work is that it investigated metacognitive reflection in a single artificial task and used Socratic questions that are somewhat specific to that task. Therefore, future work should investigate whether our findings generalize to other, more naturalistic, and less structured scenarios. Ultimately, the real question is whether the principles of systematic metacognitive reflection instantiated by our reflection prompts are also effective in the real world. If this were true, then the principles of effective metacognitive reflection identified in this article could be applied to develop interventions that help people and organizations leverage their real-life experience to learn how to make better decisions. By guiding the user to reflect on how they arrived at their best and their worst decisions, such chatbots could help people gain valuable insights into what might be the most effective ways to make different types of decisions and how to avoid catastrophic mistakes.

While we found that a particular form of systematic metacognitive reflection was effective, many more questions remain. For instance, since we only tested a single series of reflection prompts, it remains unclear how much each step in the reflection process contributes to the effect of our intervention. Moreover, systematic reflection can be performed in many ways. Therefore, testing the effectiveness of our reflection prompts against alternative reflection prompts that foster other forms of reflection, such as comparison, explanation, and counterfactual reasoning is an important avenue for future research. Furthermore, future research should investigate to which extent the effectiveness of reflection depends on directing people's attention to specific crucial aspects of their decision-making. More fundamentally, the cognitive mechanisms through which reflection boosts metacognitive learning are still unknown. Future research on these mechanisms will lay a more solid foundation for designing interventions that boost metacognitive learning.

Overall, our findings suggest that systematic metacognitive reflection on how decisions were reached is a promising approach to improving human decision-making. This makes developing (digital) tools and interventions for fostering systematic metacognitive reflection in the real-world (e.g., reflective learning chatbots) an important direction for future research. Fostering systematic metacognitive reflection could thereby become a valuable complement to conventional forms of systematic reflection that are already being applied to foster learning and improvement within organizations (Ellis et al., 2014; Daudelin, 1996). Integrating these two forms of reflection and comparing their individual and combined effects is an interesting direction for future research. Moreover, systematic metacognitive reflection could also be highly beneficial to individuals seeking to improve their own thinking and decision-making. Furthermore, prompts for fostering systematic metacognitive reflection could also be used to develop educational interventions for helping students learn how to make better study choices (Bannert et al., 2009; Azevedo, 2005) and better decisions in real life (Heller et al., 2017; Wilson & Jan, 1993; Ryan & Ryan, 2013; Hertwig & Grüne-Yanoff, 2017).

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## Appendix

### A.1 Analyzing the adaptiveness of planning

#### A.1.1 Methods

As described in our pre-registration, we categorized planning strategies into adaptive, moderately adaptive, and adaptive strategies based on their expected score. The following section reports our pre-registered analysis of how people’s use (mal)adaptive strategies.

**Clustering planning strategies** To quantify in which range of the goodness spectrum a strategy is situated, we grouped the strategies into adaptive, moderately adaptive, and maladaptive strategies. To achieve this, we applied the k-means clustering algorithm (Bishop, 2006) with  $k = 3$  clusters to the expected scores of those planning strategies that had been used at least once. The maladaptive cluster contains 12 strategies and has an expected score of 0.1 points (*adaptiveness level 0*); the moderately adaptive cluster contains 28 strategies and has an expected score of 27.7 points (*adaptiveness level 1*); and the adaptive cluster contains 25 strategies and has an expected score of 39.2 points (*adaptiveness level 2*). The adaptiveness level describes the ordering of the clusters with respect to their average expected score.

**Measuring planning adaptiveness** In each trial, we recorded whether the participant used an adaptive, moderately adaptive, or maladaptive strategy. We refer to this variable as the *adaptiveness* of the planning strategy. In transitions from one trial to the next, we recorded whether the participant changed to a strategy that had a different level of adaptiveness than the previous strategy (*change in adaptiveness*). In addition, we measured the *numerical difference in the adaptiveness levels* by subtracting the adaptiveness level of the previous trial from the adaptiveness level for the new trial.

## A.1.2 Results

**Reflection led to an increased use of adaptive strategies** Considering all trials, the reflection group outperformed the control group in terms of their use of adaptive strategies (42.0% vs. 36.1%), and their use of maladaptive strategies (30.3% vs. 41.4%). This difference was significant in the performance phase (see Table 7). In the learning phase, the reflection group compared to the control group had a steeper learning curve in their use of adaptive strategies (5.9 %/trial vs. 1.9 %/trial), and their use of maladaptive strategies (−6.8 %/trial vs. −2.5 %/trial).

TABLE 7: Reflection increased the adaptiveness of participants' planning strategies.

| Trials | Fixed Effect          | Outcome Variable |       |              |      |             |       |
|--------|-----------------------|------------------|-------|--------------|------|-------------|-------|
|        |                       | Adaptive         |       | Moderate     |      | Maladaptive |       |
|        |                       | $\beta$          | $p$   | $\beta$      | $p$  | $\beta$     | $p$   |
| 3-7    | Reflection            | 3.39             | .499  | 1.39         | .568 | -5.63       | .3    |
|        | Reflection × Trial Nr | 1.85             | .475  | 0.01         | .993 | 3.02        | .475  |
| 7-21   | Reflection            | <b>7.57</b>      | <.001 | 1.71         | .12  | <b>-31</b>  | <.001 |
|        | Reflection × Trial Nr | <b>-0.79</b>     | .017  | <b>-0.61</b> | .017 | <b>1.64</b> | .017  |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Interaction effects are denoted with a cross (×).

**Reflection led to more changes in adaptiveness** We found that, compared to the control group, the reflection group changed the adaptiveness of their planning strategy significantly more frequently (1.4 times vs. 0.8;  $\beta = 0.87, p = .002$ ). Moreover, the average improvement in adaptiveness per trial was significantly higher in the reflection condition than in the control condition (0.05 adaptiveness levels per transition vs. 0.03 adaptiveness levels per transition;  $\beta = 0.14, p = < .001$ ).

**Reflection is especially helpful for low performers** As already described for score and expected score (see Section 3.3.1), we found that the average expected score in the first three trials moderated the effect of reflection on the use of adaptive ( $\beta = -4.12, p = < .001$ ) and maladaptive strategies ( $\beta = 40.07, p = < .001$ ). The moderation implies that

TABLE 8: The use of maladaptive strategies in the baseline trials moderates the effect of reflection on participants' performance and their amount of planning.

| Trials | Fixed Effect   | Outcome Variable |       |             |      |             |      |
|--------|--|------------------|-------|-------------|------|-------------|------|
|        |  | Expected Score   |       | Score       |      | Clicks      |      |
|        |  | $\beta$          | $p$   | $\beta$     | $p$  | $\beta$     | $p$  |
|        | Reflection $\times$ Trial Nr                               | <b>2.27</b>      | <.001 | 2.45        | .186 | <b>0.69</b> | .002 |
|        | Reflection $\times$ Trial Nr $\times$ Adaptive baseline    | -0.35            | .502  | -2.28       | .334 | 0.32        | .234 |
| 3-7    | Reflection $\times$ Trial Nr $\times$ Maladaptive baseline | <b>2.09</b>      | <.001 | -2.19       | .502 | 0.23        | .363 |
|        | Reflection   | <b>5.76</b>      | .002  | 3.49        | .076 | <b>2.03</b> | .001 |
|        | Reflection $\times$ Adaptive baseline                      | -0.75            | .704  | 1.2         | .704 | -0.55       | .451 |
| 7-21   | Reflection $\times$ Maladaptive Baseline                   | <b>4.76</b>      | .028  | <b>6.41</b> | .011 | 1.1         | .124 |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross ( $\times$ ).

the effectiveness of reflection decreased with increasing baseline performance, which is consistent with the fact that people who start out with good planning strategies have less room for improvement. The Johnson-Neyman procedure revealed significant main effects of reflection on the use of adaptive and maladaptive strategies for participants who had an average expected score in the first three trials that was below median.

To understand in more detail how reflection helps participants starting from different levels of initial performance, we investigated whether the effect of reflection on learning is moderated by the adaptiveness of the planning strategies participants used in the first three trials (see Table 8). We found that participants who started with maladaptive strategies benefited the most from reflection. For this group, reflection had a larger effect on the increase in expected score and score than for participants who started with (moderately) adaptive strategies (see Table 8). This group also had a higher learning rate for the expected score. Whether participants started with adaptive versus moderately adaptive strategies did not alter the effect of reflection on learning.

**Reflecting on maladaptive strategies is more beneficial than reflecting on adaptive strategies** We found that the effect of reflection on changes in the quality of planning was moderated by the adaptiveness of the previous planning strategy. If the previous strategy was maladaptive, being in the reflection condition led to significant improvements in planning quality, and this effect was even stronger when a reflection prompt occurred (see Table 9). By contrast, if the previous strategy was adaptive, then being in the reflection condition led to a statistically significant decline in planning quality. However, this effect was smaller than the beneficial effect of reflection following maladaptive strategies, and this effect was not amplified in the trials immediately following a reflection prompt (see Table 9). Moreover, we observed an almost statistically significant tendency for participants in the reflection group to be more likely to change their planning strategy if the previous strategy

TABLE 9: The adaptiveness of the strategy used on the previous trial moderates the effect of reflection on whether and how much the participant's performance and amount of planning change on the next trial.

| Fixed Effect                             | Outcome Variable |      |         |      |              |      |             |       |                        |      |                    |      |                  |      |
|--|------------------|------|---------|------|--------------|------|-------------|-------|------------------------|------|--------------------|------|------------------|------|
|  | Change of        |      |         |      |              |      |             |       | Magnitude of change of |      |                    |      |                  |      |
|  | Strategy         |      | Type    |      | Adaptiveness |      | Clicks      |       | Expected score         |      | Adaptiveness Level |      | Number of clicks |      |
|  | $\beta$          | $p$  | $\beta$ | $p$  | $\beta$      | $p$  | $\beta$     | $p$   | $\beta$                | $p$  | $\beta$            | $p$  | $\beta$          | $p$  |
| Reflection                               | 0.24             | .659 | -0.1    | .807 | 0.48         | .48  | -0.37       | .227  | 0.93                   | .155 | 0.04               | .155 | -0.48            | .227 |
| Reflection × Previous Maladaptive        | 0.97             | .059 | 1       | .068 | 0.6          | .195 | <b>1.87</b> | <.001 | <b>2.52</b>            | .001 | <b>0.12</b>        | .001 | 0.53             | .308 |
| Reflection × Previous adaptive           | -0.26            | .484 | 0.55    | .484 | -0.55        | .484 | 0.26        | .794  | <b>-1.56</b>           | .042 | <b>-0.07</b>       | .042 | 0.13             | .794 |
| Reflection prompt                        | -0.07            | .922 | 0.05    | .922 | -0.1         | .922 | 0.55        | .084  | -0.86                  | .467 | -0.02              | .568 | 1.35             | .084 |
| Reflection prompt × Previous Maladaptive | 0.99             | .238 | 1.03    | .238 | 0.64         | .342 | 0.18        | .885  | 2.05                   | .062 | 0.06               | .215 | -0.13            | .885 |
| Reflection prompt × Previous Adaptive    | 0.62             | .358 | 0.95    | .376 | 1.16         | .356 | -0.57       | .415  | 0.22                   | .812 | -0.03              | .812 | -0.65            | .448 |

*Note.* All  $p$ -values were corrected for multiple comparisons. Significant predictors are marked in bold. Interaction effects are denoted with a cross (×).

was maladaptive (see Table 9). Lastly, we found that participants in the reflection condition changed their amount of planning even more when the previous strategy was maladaptive (see Table 9).

**The frequency of change appears to decrease over time** On average, the reflection group improved by 0.14, 0.04 and 0.04 adaptiveness levels per trial in the first, second and third reflection period respectively. By contrast, the control group improved by only 0.04, 0.04 and 0.03 adaptiveness levels per trial in the first, second and third reflection period respectively. The two groups significantly differed in the first reflection period ( $W = 6658, p = < .001$ ) but not in the following ones (all  $p > .68$ ).

**The amount of improvement appears to decrease over time** On average, 11.8%, 6.8% and 7.3% of the participants in the reflection group changed their level of adaptiveness in the first, second and third reflection period, respectively. By contrast, only 5.4%, 4.4%, and 3.4% of the participants in the control group changed their level of adaptiveness in the first, second and third reflection period, respectively. The two groups significantly differed in the first and third reflection period ( $\chi^2(1, 257) = 9.0, p = .003$ ;  $\chi^2(1, 257) = 5.2, p = .046$ ) but not in the second period ( $\chi^2(1, 257) = 1.64, p = .2$ ).

## A.2 Complete model results

In this section, we provide the complete results of all of our regression analyses. Tables 10-13 report the results concerning the participants' performance, the amount of planning, the adaptiveness of people's strategies, and the use of different strategy types. Tables 14-15 describe the moderation of the effect of reflection by of the adaptiveness of the strategies the participant used in the baseline trials. Tables 16-17 describe the moderation of the effect of reflection by the type of planning strategies participants used in the baseline trials.

Tables 18-21 list the results concerning whether and how much the participant's performance and amount of planning changed from one trial to the next. Table 19 describes the moderation of the effect of reflection by the participant's score on the previous trial. Table 20 describes the moderation of the effect of reflection by level of adaptiveness of the strategy the participant used on the previous trial. Table 21 describes the moderation of the effect of reflection by the type of the strategy the participant used on the previous trial. Lastly, Table 22 describes the moderation of the effect of reflection by how deeply the participant engaged with the reflection questions.

TABLE 10: Regression results concerning participants' performance, amount of planning, and adaptiveness in the learning phase.

| Trial | Fixed Effect                                   | Outcome Variable |       |              |       |              |       |              |       |              |       |              |       |
|-------|--|------------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|
|       |  | Expected score   |       | Score        |       | Clicks       |       | Adaptive     |       | Moderate     |       | Maladaptive  |       |
|       |  | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   |
|       | Reflection                                     | <b>7.35</b>      | <.001 | <b>8.51</b>  | .015  | <b>2.28</b>  | .001  | 3.39         | .499  | 1.39         | .568  | -5.63        | .3    |
|       | Baseline                                       | <b>15.17</b>     | <.001 | <b>12.52</b> | <.001 | <b>3.51</b>  | <.001 | <b>13.62</b> | <.001 | <b>11.04</b> | <.001 | <b>-34.2</b> | <.001 |
|       | Trial Nr                                       | <b>2.32</b>      | <.001 | 1.3          | .439  | <b>0.69</b>  | .002  | <b>6.89</b>  | <.001 | <b>4.74</b>  | <.001 | <b>-15.3</b> | <.001 |
|       | NFC  | 0.51             | .88   | 0.61         | .88   | 0.01         | .981  | 0.71         | .88   | 0.96         | .88   | 0.38         | .88   |
|       | Reflection $\times$ Baseline                   | <b>-3.84</b>     | .001  | <b>-7.81</b> | .001  | -0.41        | .416  | <b>-7.96</b> | .001  | 0.32         | .826  | -9.33        | .333  |
|       | Reflection $\times$ NFC                        | 1.71             | .619  | 1.3          | .692  | 0.24         | .616  | 2.72         | .619  | 1.06         | .692  | -0.34        | .882  |
|       | Baseline $\times$ NFC                          | -0.75            | .497  | -0.95        | .647  | 0.19         | .504  | -1.26        | .497  | -0.32        | .647  | 1.65         | .647  |
| 3-7   | Trial Nr $\times$ Reflection                   | <b>4.71</b>      | <.001 | 2.05         | .475  | <b>1.14</b>  | <.001 | 1.85         | .475  | 0.01         | .993  | 3.02         | .475  |
|       | Trial Nr $\times$ Baseline                     | <b>-0.83</b>     | .006  | 0.85         | .457  | -0.22        | .112  | <b>-3.2</b>  | <.001 | <b>-2.92</b> | <.001 | <b>6.24</b>  | <.001 |
|       | Trial Nr $\times$ NFC                          | 0.08             | .817  | -3.23        | .12   | 0.21         | .278  | -1.6         | .325  | -0.98        | .325  | -0.49        | .74   |
|       | Trial Nr $\times$ Reflection $\times$ Baseline | <b>-2.48</b>     | <.001 | 0.32         | .845  | <b>-0.49</b> | .033  | -0.45        | .788  | -0.72        | .652  | 2.12         | .652  |
|       | Trial Nr $\times$ Reflection $\times$ NFC      | 0.25             | .555  | 2.41         | .147  | 0.24         | .266  | -0.98        | .162  | -0.26        | .742  | -            | -     |
|       | Trial Nr $\times$ Baseline $\times$ NFC        | -0.06            | .788  | 0.74         | .384  | -0.24        | .071  | <b>0.99</b>  | .049  | 0.3          | .456  | -            | -     |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross ( $\times$ ). For the dependent variables expected score, score, the use of adaptive strategies and the use of maladaptive strategies the predictor *Baseline* was given by the average expected score in the first three trials. For the dependent variables number of clicks and the use of moderately adaptive strategies the predictor *Baseline* was given by the average of the dependent variable in the first three trials.

TABLE 11: Regression results concerning participants' performance, amount of planning, and adaptiveness in the performance phase.

| Trial | Fixed Effect                                   | Outcome Variable |       |              |       |              |       |              |       |              |       |              |       |
|-------|--|------------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|
|       |  | Expected score   |       | Score        |       | Clicks       |       | Adaptive     |       | Moderate     |       | Maladaptive  |       |
|       |  | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   |
|       | Reflection                                     | <b>12.21</b>     | <.001 | <b>9.96</b>  | <.001 | <b>2.6</b>   | .002  | <b>7.57</b>  | <.001 | 1.71         | .12   | <b>-31</b>   | <.001 |
|       | Baseline                                       | <b>11.87</b>     | <.001 | <b>10.28</b> | <.001 | <b>2.1</b>   | <.001 | <b>7.89</b>  | <.001 | <b>5.63</b>  | <.001 | <b>-40.5</b> | <.001 |
|       | Trial Nr                                       | <b>3.07</b>      | <.001 | <b>2.8</b>   | .001  | <b>0.95</b>  | <.001 | <b>2.04</b>  | <.001 | <b>0.77</b>  | <.001 | <b>-3.59</b> | <.001 |
|       | NFC  | 0.36             | .816  | 1.95         | .816  | -0.08        | .87   | -0.19        | .816  | -0.14        | .816  | 0.53         | .816  |
|       | Reflection $\times$ Baseline                   | <b>-6.52</b>     | <.001 | <b>-6.89</b> | <.001 | -0.32        | .606  | <b>-4.12</b> | <.001 | -2.3         | .087  | <b>40.07</b> | <.001 |
|       | Reflection $\times$ NFC                        | 0.63             | .737  | -1.2         | .737  | 0.08         | .895  | 1.89         | .423  | 0.37         | .737  | -0.45        | .737  |
|       | Baseline $\times$ NFC                          | -0.25            | .885  | -0.9         | .885  | 0.18         | .617  | 0.18         | .885  | -0.12        | .885  | 0.15         | .885  |
| 7-21  | Trial Nr $\times$ Reflection                   | <b>-0.74</b>     | .021  | 0.28         | .812  | <b>-0.39</b> | .048  | <b>-0.79</b> | .017  | <b>-0.61</b> | .017  | <b>1.64</b>  | .017  |
|       | Trial Nr $\times$ Baseline                     | <b>-1.29</b>     | <.001 | -0.55        | .344  | <b>-0.56</b> | <.001 | <b>-0.89</b> | <.001 | <b>-0.75</b> | <.001 | <b>5.58</b>  | .008  |
|       | Trial Nr $\times$ NFC                          | 0.25             | .231  | 1.18         | .231  | 0.05         | .695  | 0.28         | .231  | -0.15        | .231  | -0.42        | .231  |
|       | Trial Nr $\times$ Reflection $\times$ Baseline | <b>0.6</b>       | .015  | -0.1         | .904  | <b>0.3</b>   | .039  | <b>0.88</b>  | <.001 | 0.12         | .65   | -4.3         | .059  |
|       | Trial Nr $\times$ Reflection $\times$ NFC      | -0.15            | .892  | -0.31        | .892  | <b>-0.55</b> | <.001 | -0.01        | .973  | -0.06        | .892  | 0.75         | .269  |
|       | Trial Nr $\times$ Baseline $\times$ NFC        | -0.08            | .841  | -0.17        | .859  | 0.16         | .056  | -0.13        | .401  | 0.01         | .944  | -0.49        | .401  |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross ( $\times$ ). For the dependent variables expected score, score, the use of adaptive strategies and the use of maladaptive strategies the predictor *Baseline* was given by the average expected score in the first three trials. For the dependent variables number of clicks and the use of moderately adaptive strategies the predictor *Baseline* was given by the average of the dependent variable in the first three trials.

TABLE 12: Regression results concerning the use of different strategy types in the learning phase.

| Trial | Fixed Effect                                   | Outcome Variable |       |              |       |              |      |
|-------|--|------------------|-------|--------------|-------|--------------|------|
|       |  | Near-sighted     |       | Far-sighted  |       | Other        |      |
|       |  | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$  |
|       | Reflection                                     | <b>-17.9</b>     | .005  | 1.5          | .549  | <b>3.04</b>  | .033 |
|       | Baseline                                       | <b>34.5</b>      | <.001 | <b>22.67</b> | <.001 | <b>2.8</b>   | .006 |
|       | Trial Nr                                       | <b>-8.61</b>     | <.001 | <b>5.4</b>   | <.001 | <b>1.58</b>  | .008 |
|       | NFC  | 1.77             | .519  | -0.2         | .852  | -0.9         | .519 |
|       | Reflection $\times$ Baseline                   | 9.86             | .381  | -0.48        | .894  | 1.42         | .421 |
|       | Reflection $\times$ NFC                        | -0.95            | .626  | 2.9          | .292  | 1.38         | .292 |
|       | Baseline $\times$ NFC                          | -6.12            | .092  | 0.19         | .907  | 1.02         | .15  |
| 3-7   | Trial Nr $\times$ Reflection                   | <b>8.31</b>      | .001  | -1.72        | .144  | -1.34        | .073 |
|       | Trial Nr $\times$ Baseline                     | <b>-4.05</b>     | .005  | <b>-4.7</b>  | <.001 | <b>-1.56</b> | .006 |
|       | Trial Nr $\times$ NFC                          | <b>3.57</b>      | .003  | 0.15         | .818  | 0.59         | .241 |
|       | Trial Nr $\times$ Reflection $\times$ Baseline | -4.49            | .088  | -1.53        | .271  | 0.2          | .747 |
|       | Trial Nr $\times$ Reflection $\times$ NFC      | -                | -     | <b>-2.12</b> | .023  | -0.83        | .103 |
|       | Trial Nr $\times$ Baseline $\times$ NFC        | -                | -     | -0.33        | .473  | <b>-0.58</b> | .034 |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross ( $\times$ ). The predictor *Baseline* is the number of trials in which the participant used the corresponding strategy type in the first three trials.

TABLE 13: Regression results concerning the use of different strategy types in the performance phase.

| Trial | Fixed Effect                                   | Outcome Variable |       |              |       |              |       |
|-------|--|------------------|-------|--------------|-------|--------------|-------|
|       |  | Near-sighted     |       | Far-sighted  |       | Other        |       |
|       |  | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$   |
|       | Reflection                                     | <b>-25.4</b>     | <.001 | <b>11.55</b> | <.001 | 1.13         | .275  |
|       | Baseline                                       | <b>35.51</b>     | <.001 | <b>14.69</b> | <.001 | 0.61         | .474  |
|       | Trial Nr                                       | <b>-3.28</b>     | <.001 | <b>1.19</b>  | <.001 | <b>0.68</b>  | .004  |
|       | NFC  | 0.53             | .867  | -0.15        | .867  | -0.55        | .867  |
|       | Reflection $\times$ Baseline                   | <b>-34.7</b>     | <.001 | <b>-13.1</b> | <.001 | 0.96         | .466  |
|       | Reflection $\times$ NFC                        | -0.56            | .685  | 0.78         | .685  | 0.46         | .685  |
|       | Baseline $\times$ NFC                          | -0.16            | .89   | -0.15        | .89   | -0.77        | .572  |
| 7-21  | Trial Nr $\times$ Reflection                   | <b>1.52</b>      | .009  | -0.39        | .225  | -0.37        | .225  |
|       | Trial Nr $\times$ Baseline                     | <b>-2.71</b>     | .018  | <b>-1.49</b> | <.001 | <b>-0.81</b> | .014  |
|       | Trial Nr $\times$ NFC                          | -0.57            | .268  | 0.01         | .967  | 0.28         | .268  |
|       | Trial Nr $\times$ Reflection $\times$ Baseline | 2.17             | .108  | <b>0.92</b>  | .018  | 0.41         | .218  |
|       | Trial Nr $\times$ Reflection $\times$ NFC      | 0.77             | .414  | 0.11         | .71   | -0.28        | .518  |
|       | Trial Nr $\times$ Baseline $\times$ NFC        | -0.1             | .67   | -0.32        | .063  | <b>-0.56</b> | <.001 |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross ( $\times$ ). The predictor *Baseline* is the number of trials in which the participant used the corresponding strategy type in the first three trials.

TABLE 14: Regression results of the performance, the amount of planning and the adaptiveness in the learning phase moderated by the use of adaptive and maladaptive strategies in the baseline.

| Trial | Fixed Effect   | Outcome Variable |       |              |       |              |       |              |       |              |       |             |     |
|-------|--|------------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|-------------|-----|
|       |  | Expected score   |       | Score        |       | Clicks       |       | Adaptive     |       | Moderate     |       | Maladaptive |     |
|       |  | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$     | $p$ |
|       | Reflection   | <b>3.4</b>       | .012  | 1.24         | .758  | <b>1.41</b>  | .017  | -0.47        | .852  | 1.39         | .758  | -           | -   |
|       | Trial Nr   | <b>1.5</b>       | <.001 | 2.02         | .084  | <b>0.48</b>  | .002  | <b>2.56</b>  | <.001 | <b>1.77</b>  | .004  | -           | -   |
|       | NFC  | -0.22            | .829  | -0.32        | .829  | -0.06        | .872  | -0.82        | .829  | 0.68         | .829  | -           | -   |
|       | Adaptive Baseline  | <b>4.16</b>      | <.001 | <b>3.92</b>  | .021  | 0.36         | .431  | <b>11.33</b> | <.001 | <b>-8.66</b> | <.001 | -           | -   |
|       | Maladaptive Baseline                                       | <b>-12.2</b>     | <.001 | <b>-9.76</b> | <.001 | <b>-2.65</b> | <.001 | -1.51        | .242  | <b>-12.4</b> | <.001 | -           | -   |
|       | Reflection $\times$ NFC                                    | 2.08             | .275  | 1.18         | .589  | 0.4          | .502  | 1.45         | .582  | 1.17         | .582  | -           | -   |
|       | Reflection $\times$ Adaptive Baseline                      | -0.38            | .777  | 1.36         | .777  | -0.22        | .755  | 3.27         | .777  | -1.88        | .777  | -           | -   |
| 3-7   | Reflection $\times$ Maladaptive Baseline                   | 2.64             | .093  | <b>7.43</b>  | .014  | <b>1.93</b>  | .005  | 0.63         | .83   | -0.36        | .83   | -           | -   |
|       | Trial Nr $\times$ Reflection                               | <b>2.27</b>      | <.001 | 2.45         | .186  | <b>0.69</b>  | .002  | 1.64         | .186  | -0.74        | .315  | -           | -   |
|       | Trial Nr $\times$ NFC                                      | 0.01             | .969  | -2.36        | .152  | -0.03        | .842  | 0.61         | .361  | -0.67        | .361  | -           | -   |
|       | Trial Nr $\times$ Adaptive Baseline                        | -0.44            | .191  | 2.18         | .122  | -0.34        | .05   | <b>-1.98</b> | .002  | <b>2.1</b>   | .003  | -           | -   |
|       | Trial Nr $\times$ Maladaptive Baseline                     | 0.49             | .382  | 0.99         | .495  | -0.22        | .253  | 0.68         | .412  | <b>3.29</b>  | <.001 | -           | -   |
|       | Trial Nr $\times$ Reflection $\times$ NFC                  | 0.18             | .693  | 2.21         | .616  | 0.32         | .154  | -1.12        | .616  | -0.32        | .693  | -           | -   |
|       | Trial Nr $\times$ Reflection $\times$ Adaptive Baseline    | -0.35            | .502  | -2.28        | .334  | 0.32         | .234  | -1.13        | .334  | 1.11         | .334  | -           | -   |
|       | Trial Nr $\times$ Reflection $\times$ Maladaptive Baseline | <b>2.09</b>      | <.001 | -2.19        | .502  | 0.23         | .363  | -0.04        | .97   | 0.86         | .502  | -           | -   |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross ( $\times$ ). The predictor Adaptive Baseline is the number of times the participant used adaptive strategies in the first three trials. The predictor Maladaptive Baseline is the number of times the participant used maladaptive strategies in the first three trials.

TABLE 15: Moderation of the effects of reflection and trial number on performance, the amount of planning, and the adaptiveness in the performance phase by the use of adaptive and maladaptive strategies in the baseline trials.

| Trial | Fixed Effect                                 | Outcome Variable |       |              |       |              |       |              |       |              |       |             |     |
|-------|--|------------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|-------------|-----|
|       |  | Expected score   |       | Score        |       | Clicks       |       | Adaptive     |       | Moderate     |       | Maladaptive |     |
|       |  | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$     | $p$ |
|       | Reflection                                   | <b>5.76</b>      | .002  | 3.49         | .076  | <b>2.03</b>  | .001  | <b>4.51</b>  | .014  | -0.58        | .565  | -           | -   |
|       | Trial Nr                                     | <b>1.75</b>      | <.001 | <b>2.32</b>  | <.001 | <b>0.34</b>  | <.001 | <b>1.12</b>  | <.001 | 0.04         | .79   | -           | -   |
|       | NFC  | 0.14             | .899  | 1.03         | .899  | -0.13        | .762  | 0.25         | .899  | -0.15        | .899  | -           | -   |
|       | Adaptive baseline                            | <b>3.57</b>      | .008  | <b>2.96</b>  | .038  | 0.5          | .297  | <b>8.2</b>   | <.001 | <b>-4.88</b> | <.001 | -           | -   |
|       | Maladaptive Baseline                         | <b>-9.28</b>     | <.001 | <b>-8.32</b> | <.001 | <b>-1.79</b> | <.001 | -0.92        | .262  | <b>-6.06</b> | <.001 | -           | -   |
| 7-21  | Reflection × NFC                             | 0.66             | .692  | -1.25        | .692  | 0.24         | .701  | 1.15         | .692  | 0.38         | .692  | -           | -   |
|       | Reflection × Adaptive baseline               | -0.75            | .704  | 1.2          | .704  | -0.55        | .451  | -3.12        | .39   | 1.67         | .39   | -           | -   |
|       | Reflection × Maladaptive Baseline            | <b>4.76</b>      | .028  | <b>6.41</b>  | .011  | 1.1          | .124  | 0.02         | .992  | 2.45         | .118  | -           | -   |
|       | Trial Nr × Reflection                        | -0.17            | .881  | -0.02        | .98   | -0.01        | .932  | -0.01        | .98   | <b>-0.48</b> | .022  | -           | -   |
|       | Trial Nr × NFC                               | 0.17             | .358  | 0.95         | .316  | <b>0.23</b>  | .018  | -0.02        | .91   | -0.16        | .316  | -           | -   |
|       | Trial Nr × Adaptive baseline                 | <b>-0.38</b>     | .033  | -0.95        | .146  | 0.09         | .4    | <b>-1.02</b> | <.001 | <b>0.87</b>  | <.001 | -           | -   |
|       | Trial Nr × Maladaptive Baseline              | <b>1.02</b>      | <.001 | -0.31        | .671  | <b>0.44</b>  | <.001 | 0.17         | .459  | <b>0.79</b>  | <.001 | -           | -   |
|       | Trial Nr × Reflection × NFC                  | -0.11            | .879  | -0.13        | .879  | <b>-0.61</b> | <.001 | 0.3          | .542  | -0.05        | .879  | -           | -   |
|       | Trial Nr × Reflection × Adaptive baseline    | -0.23            | .6    | -0.18        | .859  | 0.03         | .859  | 0.2          | .6    | -0.25        | .6    | -           | -   |
|       | Trial Nr × Reflection × Maladaptive Baseline | <b>-0.62</b>     | .042  | 0.26         | .791  | -0.15        | .369  | <b>-0.54</b> | .042  | -0.09        | .791  | -           | -   |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross (×). The predictor Adaptive Baseline is the number of times the participant used adaptive strategies in the first three trials. The predictor Maladaptive Baseline is the number of times the participant used maladaptive strategies in the first three trials.

TABLE 16: Moderation of the effects of reflection and trial number on performance, the amount of planning, and the adaptiveness in the learning phase by the use of adaptive and maladaptive strategies in the baseline trials.

| Trial | Fixed Effect  | Outcome Variable |       |              |       |              |       |              |       |              |       |             |     |
|-------|---|------------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|-------------|-----|
|       |   | Expected score   |       | Score        |       | Clicks       |       | Adaptive     |       | Moderate     |       | Maladaptive |     |
|       |   | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$     | $p$ |
|       | Reflection  | 2.3              | .086  | -0.32        | .884  | <b>1.15</b>  | .047  | <b>-8.03</b> | <.001 | 3.15         | .061  | -           | -   |
|       | Trial Nr  | <b>1.54</b>      | <.001 | 2.27         | .053  | <b>0.48</b>  | .002  | <b>1.9</b>   | <.001 | <b>1.31</b>  | .004  | -           | -   |
|       | NFC   | -0.42            | .815  | -0.65        | .815  | -0.1         | .798  | -0.59        | .815  | 0.18         | .815  | -           | -   |
|       | Other Baseline  | -2.11            | .15   | -0.58        | .78   | -0.26        | .636  | <b>-5.74</b> | <.001 | 1.47         | .328  | -           | -   |
|       | Near-Sighted Baseline                                       | <b>-15.5</b>     | <.001 | <b>-13.0</b> | <.001 | <b>-2.95</b> | <.001 | <b>-11.6</b> | <.001 | <b>-3.77</b> | <.001 | -           | -   |
|       | Reflection $\times$ NFC                                     | 2.37             | .228  | 1.89         | .522  | 0.34         | .557  | 1.59         | .522  | -0.43        | .678  | -           | -   |
|       | Reflection $\times$ Other Baseline                          | -1.02            | .664  | -0.17        | .947  | 1.2          | .073  | 1.69         | .664  | -1           | .664  | -           | -   |
| 3-7   | Reflection $\times$ Near-Sighted Baseline                   | <b>4.2</b>       | .002  | <b>8.12</b>  | .001  | <b>2.16</b>  | <.001 | <b>8.02</b>  | <.001 | -1.28        | .432  | -           | -   |
|       | Trial Nr $\times$ Reflection                                | <b>2.27</b>      | <.001 | 2.16         | .193  | <b>0.71</b>  | .001  | <b>2.5</b>   | .012  | -0.77        | .154  | -           | -   |
|       | Trial Nr $\times$ NFC                                       | -0.09            | .766  | -2.39        | .148  | -0.06        | .676  | 0.08         | .766  | -0.17        | .766  | -           | -   |
|       | Trial Nr $\times$ Other Baseline                            | 0.86             | .163  | -0.38        | .813  | 0.3          | .16   | 0.41         | .227  | 0.3          | .227  | -           | -   |
|       | Trial Nr $\times$ Near-Sighted Baseline                     | 0.6              | .087  | -0.53        | .666  | -0.05        | .742  | <b>1.32</b>  | .023  | <b>1.52</b>  | .003  | -           | -   |
|       | Trial Nr $\times$ Reflection $\times$ NFC                   | 0.26             | .557  | 2.18         | .255  | 0.35         | .112  | -0.89        | .254  | 0.53         | .254  | -           | -   |
|       | Trial Nr $\times$ Reflection $\times$ Other Baseline        | 0.21             | .896  | 0.59         | .896  | -0.4         | .116  | <b>2.33</b>  | .02   | 0.04         | .896  | -           | -   |
|       | Trial Nr $\times$ Reflection $\times$ Near-Sighted Baseline | <b>2.07</b>      | <.001 | -0.21        | .935  | -0.09        | .706  | 0.96         | .437  | -0.04        | .935  | -           | -   |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross ( $\times$ ). The predictor Other Baseline was given by the frequency the participant used a strategy of an undefined strategy type in the first three trials. The predictor Near-Sighted Baseline is the number of times the participant used a Near-Sighted strategy in the first three trials.

TABLE 17: Moderation of the effects of reflection and trial number on the performance, the amount of planning and the adaptiveness in the performance phase by the strategy type used in the baseline trials.

| Trial | Fixed Effect                                  | Outcome Variable |       |              |       |              |       |              |       |              |       |              |       |
|-------|---|------------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|--------------|-------|
|       |   | Expected score   |       | Score        |       | Clicks       |       | Adaptive     |       | Moderate     |       | Maladaptive  |       |
|       |   | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   |
|       | Reflection                                    | <b>4.88</b>      | .019  | 2.29         | .354  | <b>1.81</b>  | .003  | 1.87         | .311  | 0.59         | .607  | 3.4          | .422  |
|       | Trial Nr                                      | <b>1.7</b>       | <.001 | <b>2.2</b>   | <.001 | <b>0.34</b>  | <.001 | <b>1.25</b>  | <.001 | 0.16         | .233  | 0.96         | .632  |
|       | NFC   | 0                | .998  | 0.82         | .998  | -0.17        | .683  | 0.13         | .998  | -0.24        | .998  | 0.69         | .998  |
|       | Other Baseline                                | -1.94            | .28   | -1.14        | .516  | -0.22        | .7    | <b>-5.05</b> | <.001 | 2.31         | .109  | <b>13.01</b> | <.001 |
|       | Near-Sighted Baseline                         | <b>-12.2</b>     | <.001 | <b>-10.9</b> | <.001 | <b>-2.24</b> | <.001 | <b>-10.1</b> | <.001 | -0.99        | .117  | <b>33.4</b>  | <.001 |
| 7-21  | Reflection × NFC                              | 0.93             | .841  | -0.78        | .841  | 0.18         | .766  | 0.71         | .841  | 0.08         | .928  | -0.95        | .841  |
|       | Reflection × Other Baseline                   | 0.25             | .942  | 0.94         | .942  | 1.04         | .139  | 0.12         | .942  | -1.23        | .942  | <b>-12.5</b> | <.001 |
|       | Reflection × Near-Sighted Baseline            | <b>5.77</b>      | .002  | <b>6.68</b>  | .002  | <b>1.62</b>  | .013  | 1.9          | .173  | -0.28        | .828  | <b>-32.3</b> | <.001 |
|       | Trial Nr × Reflection                         | -0.06            | .897  | 0.38         | .897  | -0.03        | .838  | 0.03         | .897  | <b>-0.78</b> | <.001 | -1.75        | .897  |
|       | Trial Nr × NFC                                | 0.19             | .355  | 0.96         | .355  | <b>0.23</b>  | .018  | 0            | .987  | -0.07        | .676  | -0.45        | .355  |
|       | Trial Nr × Other Baseline                     | 0.31             | .226  | 0.1          | .898  | -0.05        | .707  | 0.36         | .066  | -0.3         | .066  | -1.44        | .522  |
|       | Trial Nr × Near-Sighted Baseline              | <b>1.43</b>      | <.001 | 0.28         | .655  | <b>0.34</b>  | .001  | <b>1.07</b>  | <.001 | 0.22         | .129  | -4.3         | .136  |
|       | Trial Nr × Reflection × NFC                   | -0.18            | .674  | -0.18        | .832  | <b>-0.59</b> | <.001 | 0.18         | .674  | -0.08        | .75   | 0.42         | .674  |
|       | Trial Nr × Reflection × Other Baseline        | -0.07            | .797  | -1           | .507  | 0.16         | .314  | <b>-0.43</b> | .045  | <b>0.47</b>  | .023  | 1.2          | .626  |
|       | Trial Nr × Reflection × Near-Sighted Baseline | <b>-0.99</b>     | <.001 | -0.35        | .698  | 0.12         | .436  | <b>-1.28</b> | <.001 | <b>0.56</b>  | .004  | 3.32         | .273  |

Note. All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Missing results (-) indicate that the (simplified) model did not converge. Interaction effects are denoted with a cross (×). The predictor Other Baseline was given by the frequency the participant used a strategy of an undefined strategy type in the first three trials. The predictor Near-Sighted Baseline was given by the frequency the participant used a near-sighted strategy in the first three trials.

TABLE 18: Regression results concerning whether and how much the participant's performance and amount of planning change.

| Fixed Effect                                       | Outcome Variable |       |              |       |              |       |              |       |                        |       |                    |       |                  |      |
|--|------------------|-------|--------------|-------|--------------|-------|--------------|-------|------------------------|-------|--------------------|-------|------------------|------|
|  | Change of        |       |              |       |              |       |              |       | Magnitude of Change of |       |                    |       |                  |      |
|  | Strategy         |       | Type         |       | Adaptiveness |       | Clicks       |       | Expected Score         |       | Adaptiveness Level |       | Number of Clicks |      |
|  | $\beta$          | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$                | $p$   | $\beta$            | $p$   | $\beta$          | $p$  |
| Reflection   | <b>0.98</b>      | <.001 | <b>0.69</b>  | .017  | <b>0.87</b>  | .002  | <b>1.13</b>  | <.001 | <b>2.69</b>            | <.001 | <b>0.14</b>        | <.001 | -0.1             | .721 |
| Prompt   | -0.15            | .858  | -0.29        | .858  | -0.05        | .874  | 0.07         | .676  | -0.07                  | .826  | 0                  | .826  | 0.39             | .423 |
| NFC  | -0.03            | .816  | -0.05        | .816  | -0.05        | .816  | 0.16         | .572  | 0.07                   | .88   | 0                  | .88   | 0.04             | .773 |
| Previous Value                                     | 0.11             | .385  | <b>-0.64</b> | <.001 | <b>-0.69</b> | <.001 | <b>1.57</b>  | <.001 | <b>-2.1</b>            | <.001 | <b>-0.12</b>       | <.001 | -0.03            | .812 |
| Prompt $\times$ NFC                                | 0.1              | .556  | -0.32        | .556  | 0.14         | .556  | -0.1         | .841  | 0.33                   | .175  | 0.02               | .073  | 0                | .989 |
| Prompt $\times$ Previous Value                     | 0.19             | .42   | 0.32         | .42   | 0.06         | .823  | 0.09         | .829  | 0.07                   | .779  | 0                  | .779  | -0.05            | .829 |
| Reflection $\times$ NCS                            | 0.13             | .51   | 0.41         | .315  | 0.17         | .51   | 0.18         | .662  | 0.23                   | .557  | 0.01               | .557  | -0.09            | .662 |
| Reflection $\times$ Prompt                         | 0.63             | .088  | 0.84         | .088  | 0.19         | .607  | <b>0.67</b>  | .006  | 0.75                   | .278  | 0.02               | .359  | <b>1.31</b>      | .006 |
| Reflection $\times$ Previous Value                 | <b>-0.5</b>      | .006  | -0.31        | .173  | -0.41        | .131  | <b>-0.77</b> | <.001 | <b>-1.64</b>           | <.001 | <b>-0.08</b>       | <.001 | -0.15            | .439 |
| Reflection $\times$ Prompt $\times$ NFC            | -0.09            | .671  | 0.24         | .671  | -0.26        | .671  | -0.02        | .909  | -0.41                  | .261  | -0.02              | .261  | 0.17             | .909 |
| Reflection $\times$ Prompt $\times$ Previous Value | -0.17            | .484  | -0.23        | .484  | 0.39         | .484  | -0.28        | .257  | <b>-0.8</b>            | .045  | <b>-0.03</b>       | .045  | -0.26            | .436 |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Interaction effects are denoted with a cross ( $\times$ ). Previous Value is the expected score in the previous trial. For the dependent variables Change of Adaptiveness and Magnitude of Change of Adaptiveness Level, Previous Value is the Adaptiveness Level of the strategy the participant used on the preceding trial.

TABLE 19: Regression results concerning whether and how much the participant's performance and amount of planning changed and their moderation by the participant's score in previous trial.

| Fixed Effect                         | Outcome Variable |      |              |      |              |      |             |       |                        |      |                    |      |                  |       |
|--------------------------------------|------------------|------|--------------|------|--------------|------|-------------|-------|------------------------|------|--------------------|------|------------------|-------|
|                                      | Change of        |      |              |      |              |      |             |       | Magnitude of change of |      |                    |      |                  |       |
|                                      | Strategy         |      | Type         |      | Adaptiveness |      | Clicks      |       | Expected score         |      | Adaptiveness Level |      | Number of clicks |       |
|                                      | $\beta$          | $p$  | $\beta$      | $p$  | $\beta$      | $p$  | $\beta$     | $p$   | $\beta$                | $p$  | $\beta$            | $p$  | $\beta$          | $p$   |
| Reflection                           | 0.48             | .154 | 0.02         | .986 | 0            | .986 | <b>0.78</b> | .011  | 0                      | .997 | 0                  | .997 | <b>-0.8</b>      | .007  |
| Prompt                               | -0.21            | .556 | -0.4         | .556 | -0.18        | .556 | 0.02        | .884  | -0.07                  | .862 | 0                  | .862 | 0.46             | .288  |
| NFC                                  | -0.02            | .88  | -0.08        | .88  | -0.07        | .88  | 0.31        | .236  | -0.1                   | .507 | -0.01              | .507 | -0.03            | .844  |
| Previous Score                       | 0                | .997 | <b>-0.34</b> | .029 | <b>-0.32</b> | .029 | <b>0.28</b> | <.001 | -0.22                  | .322 | -0.01              | .335 | <b>0.76</b>      | <.001 |
| Prompt × NFC                         | 0.09             | .586 | -0.32        | .571 | 0.16         | .586 | -0.09       | .887  | 0.36                   | .171 | 0.03               | .078 | 0                | .984  |
| Prompt × Previous Score              | 0.24             | .251 | 0.39         | .251 | 0.25         | .264 | 0.04        | .752  | 0.16                   | .586 | 0.01               | .586 | -0.08            | .752  |
| Reflection × NCS                     | 0.1              | .592 | 0.38         | .335 | 0.15         | .592 | 0.07        | .795  | 0.15                   | .509 | 0.01               | .509 | -0.07            | .795  |
| Reflection × Prompt                  | <b>0.84</b>      | .012 | <b>1.35</b>  | .006 | <b>1.07</b>  | .01  | <b>0.67</b> | .005  | <b>1.32</b>            | .027 | <b>0.06</b>        | .032 | <b>1.53</b>      | .002  |
| Reflection × Previous Score          | -0.06            | .683 | 0.32         | .16  | <b>0.49</b>  | .024 | -0.06       | .56   | 0.33                   | .15  | 0.02               | .15  | <b>0.45</b>      | .043  |
| Reflection × Prompt × NFC            | -0.09            | .691 | 0.23         | .691 | -0.27        | .691 | -0.05       | .797  | -0.45                  | .24  | -0.03              | .24  | 0.18             | .797  |
| Reflection × Prompt × Previous Score | -0.32            | .15  | <b>-0.69</b> | .039 | <b>-0.68</b> | .039 | -0.21       | .237  | <b>-1.22</b>           | .001 | <b>-0.06</b>       | .001 | -0.44            | .237  |

*Note.* All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Interaction effects are denoted with a cross (×). The Previous Score was given by the score the participant obtained in the previous trial.

TABLE 20: Regression results on whether and how much the effects of reflection on the change in the participant’s performance and amount of planning are moderated by the adaptiveness of the strategy used in the previous trial.

| Fixed Effect                               | Outcome Variable |      |              |       |              |       |              |       |                        |       |                    |       |                  |      |
|--|------------------|------|--------------|-------|--------------|-------|--------------|-------|------------------------|-------|--------------------|-------|------------------|------|
|  | Change of        |      |              |       |              |       |              |       | Magnitude of change of |       |                    |       |                  |      |
|  | Strategy         |      | Type         |       | Adaptiveness |       | Clicks       |       | Expected score         |       | Adaptiveness Level |       | Number of clicks |      |
|  | $\beta$          | $p$  | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$                | $p$   | $\beta$            | $p$   | $\beta$          | $p$  |
| Reflection                                 | 0.24             | .659 | -0.1         | .807  | 0.48         | .48   | -0.37        | .227  | 0.93                   | .155  | 0.04               | .155  | -0.48            | .227 |
| Prompt                                     | 0.26             | .795 | 0.26         | .795  | 0.09         | .81   | -0.25        | .576  | 0.29                   | .998  | 0                  | .998  | 0.24             | .63  |
| NFC  | -0.04            | .792 | -0.06        | .792  | -0.07        | .792  | 0.17         | .506  | 0.1                    | .948  | 0                  | .948  | 0.04             | .783 |
| Previous Adaptive                          | <b>-0.58</b>     | .046 | <b>-2.48</b> | <.001 | <b>-1.63</b> | <.001 | 0.33         | .468  | <b>-1.87</b>           | <.001 | <b>-0.19</b>       | <.001 | -0.22            | .546 |
| Previous Maladaptive                       | <b>-0.81</b>     | .03  | 0.02         | .952  | -0.44        | .332  | <b>-3.07</b> | <.001 | <b>3.27</b>            | <.001 | <b>0.07</b>        | .007  | -0.11            | .772 |
| Prompt × NFC                               | 0.07             | .666 | -0.39        | .361  | 0.13         | .666  | -0.1         | .907  | 0.33                   | .18   | 0.02               | .089  | 0                | .987 |
| Prompt × Previous Adaptive                 | -0.1             | .994 | 0.11         | .994  | 0            | .994  | <b>0.77</b>  | .042  | -0.3                   | .967  | 0                  | .967  | 0.09             | .891 |
| Prompt × Previous Maladaptive              | -0.62            | .28  | -0.8         | .28   | -0.25        | .645  | 0.39         | .423  | -0.48                  | .86   | -0.01              | .86   | 0.18             | .777 |
| Reflection × NCS                           | 0.15             | .47  | 0.42         | .308  | 0.19         | .47   | 0.18         | .669  | 0.21                   | .61   | 0.01               | .61   | -0.08            | .669 |
| Reflection × Prompt                        | -0.07            | .922 | 0.05         | .922  | -0.1         | .922  | 0.55         | .084  | -0.86                  | .467  | -0.02              | .568  | 1.35             | .084 |
| Reflection × Previous Adaptive             | -0.26            | .484 | 0.55         | .484  | -0.55        | .484  | 0.26         | .794  | <b>-1.56</b>           | .042  | <b>-0.07</b>       | .042  | 0.13             | .794 |
| Reflection × Previous Maladaptive          | 0.97             | .059 | 1            | .068  | 0.6          | .195  | <b>1.87</b>  | <.001 | <b>2.52</b>            | .001  | <b>0.12</b>        | .001  | 0.53             | .308 |
| Reflection × Prompt × NFC                  | -0.09            | .698 | 0.29         | .576  | -0.25        | .576  | -0.03        | .854  | -0.41                  | .252  | -0.02              | .252  | 0.17             | .854 |
| Reflection × Prompt × Previous Adaptive    | 0.62             | .356 | 0.95         | .376  | 1.16         | .356  | -0.57        | .415  | 0.22                   | .812  | -0.03              | .812  | -0.65            | .448 |
| Reflection × Prompt × Previous Maladaptive | 0.99             | .238 | 1.03         | .238  | 0.64         | .342  | 0.18         | .885  | 2.05                   | .062  | 0.06               | .215  | -0.13            | .885 |

Note. All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Interaction effects are denoted with a cross (×).

TABLE 21: Moderation of the effect of reflection and trial number on whether and how much the participant’s performance and amount of planning change by the type of the strategy used in the previous trial.

| Fixed Effect                                | Outcome Variable |      |             |       |              |       |              |       |                        |       |                    |       |                  |      |
|---|------------------|------|-------------|-------|--------------|-------|--------------|-------|------------------------|-------|--------------------|-------|------------------|------|
|   | Change of        |      |             |       |              |       |              |       | Magnitude of change of |       |                    |       |                  |      |
|   | Strategy         |      | Type        |       | Adaptiveness |       | Clicks       |       | Expected score         |       | Adaptiveness Level |       | Number of clicks |      |
|   | $\beta$          | $p$  | $\beta$     | $p$   | $\beta$      | $p$   | $\beta$      | $p$   | $\beta$                | $p$   | $\beta$            | $p$   | $\beta$          | $p$  |
| Reflection                                  | 0.16             | .743 | -0.06       | .894  | 0.47         | .335  | -0.08        | .754  | 0.17                   | .551  | 0.01               | .551  | -0.29            | .48  |
| Prompt                                      | 0.19             | .547 | 0.29        | .548  | 0.35         | .547  | 0.26         | .257  | 0.12                   | .763  | 0.01               | .763  | 0.36             | .257 |
| NFC   | -0.04            | .857 | -0.03       | .857  | -0.06        | .857  | 0.12         | .763  | -0.05                  | .763  | -0.01              | .763  | 0.04             | .763 |
| Previous Other                              | <b>0.98</b>      | .012 | <b>2.91</b> | <.001 | <b>1.84</b>  | <.001 | 0.68         | .193  | 0.59                   | .382  | <b>0.09</b>        | .008  | -0.24            | .687 |
| Previous Near-Sighted                       | -0.35            | .203 | <b>1.6</b>  | <.001 | 0.54         | .169  | <b>-3.22</b> | <.001 | <b>1.3</b>             | <.001 | <b>0.06</b>        | <.001 | 0.06             | .834 |
| Prompt × NFC                                | 0.05             | .774 | -0.48       | .184  | 0.13         | .774  | -0.1         | .843  | 0.36                   | .167  | 0.03               | .076  | -0.01            | .953 |
| Prompt × Previous Other                     | 0.12             | .941 | -0.06       | .941  | -1.08        | .495  | -1           | .097  | -0.07                  | .954  | -0.03              | .954  | 0.23             | .825 |
| Prompt × Previous Near-Sighted              | -0.56            | .291 | -0.8        | .291  | -0.49        | .338  | -0.13        | .883  | -0.12                  | .968  | 0                  | .968  | -0.07            | .883 |
| Reflection × NCS                            | 0.14             | .481 | 0.39        | .359  | 0.16         | .481  | 0.22         | .594  | 0.17                   | .432  | 0.01               | .432  | -0.09            | .644 |
| Reflection × Prompt                         | 0.31             | .439 | 0.67        | .439  | 0.05         | .898  | 0.09         | .71   | -0.66                  | .188  | -0.04              | .187  | 0.81             | .134 |
| Reflection × Previous Other                 | -0.11            | .95  | -0.04       | .95   | -0.59        | .83   | -0.74        | .25   | 0.69                   | .801  | 0                  | .923  | -0.55            | .447 |
| Reflection × Previous Near-Sighted          | 0.77             | .122 | 0.81        | .221  | 0.35         | .431  | <b>1.36</b>  | <.001 | 0.94                   | .066  | 0.04               | .066  | 0.46             | .3   |
| Reflection × Prompt × NFC                   | -0.05            | .829 | 0.4         | .623  | -0.24        | .623  | -0.01        | .963  | -0.4                   | .299  | -0.02              | .299  | 0.17             | .963 |
| Reflection × Prompt × Previous Other        | -0.24            | .727 | -0.52       | .727  | 1.07         | .706  | 1.19         | .113  | 0.73                   | .612  | 0.08               | .498  | 0.88             | .489 |
| Reflection × Prompt × Previous Near-Sighted | 0.75             | .49  | 0.51        | .518  | 0.57         | .518  | 0.83         | .065  | <b>2.25</b>            | .016  | <b>0.1</b>         | .017  | 0.28             | .707 |

Note. All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Interaction effects are denoted with a cross (×).

TABLE 22: Regression results on whether and how much the participant’s performance and amount of planning changed in transitions with reflection prompts and whether these effects were moderated by Engagement.

| Fixed Effect                           | Outcome Variable |      |              |       |              |      |             |       |                        |       |                    |       |                  |      |
|--|------------------|------|--------------|-------|--------------|------|-------------|-------|------------------------|-------|--------------------|-------|------------------|------|
|  | Change of        |      |              |       |              |      |             |       | Magnitude of change of |       |                    |       |                  |      |
|  | Strategy         |      | Type         |       | Adaptiveness |      | Clicks      |       | Expected score         |       | Adaptiveness Level |       | Number of clicks |      |
|  | $\beta$          | $p$  | $\beta$      | $p$   | $\beta$      | $p$  | $\beta$     | $p$   | $\beta$                | $p$   | $\beta$            | $p$   | $\beta$          | $p$  |
| Previous Value                         | -0.23            | .117 | <b>-0.74</b> | <.001 | -0.35        | .117 | <b>0.86</b> | <.001 | <b>-2.29</b>           | <.001 | <b>-0.11</b>       | <.001 | -0.51            | .073 |
| NFC                                    | 0.09             | .828 | 0.32         | .317  | -0.03        | .845 | 0.34        | .066  | 0.33                   | .428  | 0.02               | .428  | 0.22             | .388 |
| High Engagement                        | 0.18             | .551 | 0.21         | .551  | 0.29         | .551 | 0.2         | .449  | 0.84                   | .198  | 0.1                | .114  | 0.58             | .449 |
| Previous Value ×NFC                    | 0                | .99  | 0.18         | .89   | 0.04         | .99  | 0.32        | .055  | <b>0.82</b>            | .046  | 0                  | .955  | 0.5              | .074 |
| Previous Value ×High engagement        | 0.04             | .917 | 0.03         | .917  | -0.23        | .917 | -0.28       | .523  | <b>-1.52</b>           | .043  | -0.06              | .101  | -0.22            | .67  |
| Previous Value × High engagement × NFC | -0.38            | .221 | -0.42        | .221  | -0.36        | .232 | -0.29       | .19   | <b>-2.75</b>           | <.001 | -0.02              | .347  | -0.85            | .149 |

Note. All p-values were corrected for multiple comparisons. Significant predictors are marked in bold. Interaction effects are denoted with a cross (×).