Self-Regulation Prompts Promote the Achievement of Learning Goals – But Only Briefly: Uncovering Hidden Dynamics in the Effects of a Psychological Intervention

Jasmin Breitwieser^a, Andreas B. Neubauer^a, Florian Schmiedek^{a, b}, and Garvin Brod^{a, b}

^aDIPF | Leibniz Institute for Research and Information in Education, Frankfurt am Main, Germany; ^bGoethe University Frankfurt, Frankfurt am Main, Germany

This document is a pre-publication version of the following manuscript:

Breitwieser, J., Neubauer, A. B., Schmiedek, F., & Brod, G. (2021). Self-regulation prompts promote the achievement of learning goals – But only briefly: Uncovering hidden dynamics in the effects of a psychological intervention. *Learning and Instruction*. <https://doi.org/10.1016/j.learninstruc.2021.101560>

This paper is not the copy of record and may not exactly replicate the final, authoritative version of the article published in *Learning and Instruction*.

The final authenticated version is available online at the journal's website:

<https://www.sciencedirect.com/science/article/abs/pii/S0959475221001195>

Abstract

Most psychological interventions have to be administered repeatedly to be effective, but what is the optimal frequency? The answer will depend on how quickly the effects build up and wear off between intervention prompts. We investigated these temporal dynamics in a popular self-regulation intervention: implementation intentions. We combined a novel intervention design with objective high-resolution data of students' learning success during 40 days of preparation for an exam. Students ($n = 223$) received intervention prompts on half of the days, alternating between 2-3 consecutive days of prompting and no-prompting. These students outperformed a no-prompt control group ($n = 116$) in the final exam ($d = .21$). However, the beneficial effect of prompting on learning success increased over consecutive days of prompting and decreased when prompting was discontinued. These results suggest that the beneficial effects of self-regulation prompts on learning success are highly volatile and might benefit from regular repetitions.

Keywords: implementation intentions, ambulatory assessment, intra-individual dynamics, self-regulation prompts, educational interventions

Self-Regulation Prompts Promote the Achievement of Learning Goals – but Only Briefly: Uncovering Hidden Dynamics in the Effects of a Psychological Intervention

1 Introduction

Most psychological interventions are no one-off remedies: They need to be administered repeatedly to produce desired effects. Educational interventions are no exception, on the contrary: Because studying usually takes place over a longer period of time, the processes involved must be repeatedly promoted. Prime examples include journal writing to stimulate reflections on class lessons or repeated motivational prompts to boost students' interest in a science course. While intervention effects are routinely tested for their long-term stability, more dynamic short-term fluctuations are rarely investigated.

Pharmacology, to draw on an example from a neighboring discipline, investigates dose-response relations (Aronson, 2007) with intensive longitudinal data to uncover the time course of drug concentration in the blood between injections (e.g., Karsdal et al., 2010). Although metabolic and psychological processes are of course quite different, we argue that similar research is needed for psychological interventions if we want to know how quickly their effects build up and wear off. As in pharmacology, practical decisions of “dosage” should be based on a theoretical understanding of the temporal dynamics of an intervention. However, in educational psychology, the temporal variability of intervention effects has mostly been studied in terms of the fadeout of effects that takes place after the treatment program has been completed (see Bailey et al., 2020). In contrast, research on how the effects of an *ongoing* intervention program unfold within individuals over time has been largely neglected. The current study demonstrates how

examining short-term fluctuations in intervention effects can give new insights into the mechanisms of an intervention and provide the foundation for practical recommendations on its optimal use.

We targeted a prominent type of psychological intervention that is aimed at improving self-regulation and has been applied to foster learning: implementation intentions. Its effectiveness has been established, yet questions of its temporal variability are largely untested. We set out to address this gap by using an intervention design that altered the sequencing of intervention prompts, thus allowing us to test the emerging dynamics. The study was conducted in an educational setting to help medical students self-regulate their learning for a high-stakes exam.

1.1 The Importance of Prompting Self-Regulated Learning

Self-regulated learning (SRL) can be conceptualized as a self-directed process during which learners set and pursue learning goals whilst monitoring and regulating their cognition, motivation, and behavior in accordance with their study goals (Pintrich, 2000; Zimmerman, 2000). Research on SRL and how to support it is highly relevant because SRL skills are a strong predictor of academic achievement (Kitsantas et al., 2008; Richardson et al., 2012; Sitzmann & Ely, 2011). However, many students struggle with self-regulatory demands, resulting in common self-regulation failures such as procrastination (Balkis & Duru, 2009; Steel & Ferrari, 2013), off-task thinking (Hollis & Was, 2016), or spending less time on studying than initially intended (Oreopoulos & Petronijevic, 2019). Thus, a plethora of educational interventions are aimed at improving students' use of SRL strategies to combat these difficulties.

The present study focuses on instructional support techniques such as prompts or guides that aid the production of SRL skills (Bannert & Reimann, 2012; Zheng, 2016). Unlike training programs that teach SRL skills (Dignath & Büttner, 2008; Theobald, 2021), indirect instructional support via prompts is preferable for students who already possess knowledge of SRL but struggle to apply their skills during studying (Bannert & Reimann, 2012). Although SRL trainings are beneficial even for university students (Jansen et al., 2019; Theobald, 2021), a recent survey revealed that university students already possess advanced knowledge of SRL strategies but struggle to put this knowledge into action (Foerst et al., 2017).

Furthermore, recent ambulatory assessment studies that measured components of SRL repeatedly over relatively short periods of time have revealed that SRL fluctuates substantially within students. These studies are based on process models that conceptualize SRL as a sequence of learning states that are interrelated by feedback loops (Schmitz & Wiese, 2006; Zimmerman, 2000). For instance, several studies find that motivation and the use of strategies to regulate motivation do not only differ between students on a trait level, but also fluctuate within students week by week, day by day, or even within the same learning session (Bäulke et al., 2021; Bellhäuser et al., 2019; Bernacki et al., 2015; Dietrich et al., 2019; Ketonen et al., 2018; Murayama et al., 2017; Vandekerckhove et al., 2019). A recent study, for instance, found that SRL components such as procrastination (i.e., failure to self-regulate) affected study motivation on the next day via study satisfaction (Bellhäuser et al., 2019). These findings highlight the fact that students are not able to apply their study skills equally well across all situations and that

these fluctuations have effects on future studying. Consequently, prompts could be used repeatedly across situations to stimulate SRL.

There are many SRL interventions designed to encourage students to use SRL strategies repeatedly. Examples include prompts that encourage metacognitive control (e.g., Menekse et al., 2020; Nückles et al., 2010; Sitzmann et al., 2009), learning diaries that encourage students to self-monitor their learning (e.g., Dörrenbächer & Perels, 2016; Fabriz et al., 2014; Schmitz & Perels, 2011), and text messages that remind students of their goals or provide coaching throughout a semester (Oreopoulos & Petronijevic, 2019). However, if SRL processes are as volatile and situation-specific as suggested by process models and previous findings, the question arises as to how volatile the effects of interventions targeting these processes are. To address this question, the present study used a prominent strategy that can easily be used as a repeated prompt to promote self-regulation during studying.

1.2 Implementation Intentions as an Effective Self-Regulation Strategy

The present study focused on a specific type of self-regulation intervention, namely implementation intentions (Gollwitzer, 1999). Implementation intentions are simple plans on when, where, and how to enact a goal-directed action. Due to their format, they are also called ‘if-then plans’: The if-part of the plan specifies either a critical situation to act on the goal or an obstacle that needs to be overcome, while the then-part specifies a goal-promoting thought, feeling, or action (Bieleke et al., 2021). For instance, a student struggling with test anxiety during studying (obstacle) could plan to meditate whenever they start to worry about the exam: “If I worry about the exam, then I meditate for ten minutes.”

Implementation intentions have many qualities that make them a good prompting technique for the purposes of this study. First, they can be used as a flexible metacognitive strategy (Duckworth et al., 2013) to implement any other type of SRL strategy. For this reason, implementation intentions have been proposed as a tool to aid the self-guided use of trained SRL strategies (McDaniel & Einstein, 2020). In the current study, we use an implementation intention to promote the use of a simple strategy to regulate motivation during learning, namely talking oneself out of quitting before achieving one's goal. Prompting students to regulate their motivation is an effective strategy to foster learning (Daumiller & Dresel, 2019). The format of the implementation intention – ignoring or countering a detrimental thought – was based on previous studies that successfully used similar plans to promote goal achievement (Achtziger et al., 2008; Palayiwia et al., 2010; Parks-Stamm et al., 2010; Webb et al., 2012).

Second, implementation intentions are quick to implement, which makes them easy to use as a repeatable prompting technique. Yet, most implementation intention protocols ask participants to internalize their plan only once at the start of a goal-directed endeavor, even if it takes repeated efforts to achieve the goal. In a recent study, for instance, university students were asked to set study time goals and formulate two implementation intentions to overcome obstacles that could stand in the way of achieving these goals (Clark et al., 2020). Participants were then left to their own devices to repeat and implement their plans during the following four weeks, after which goal achievement was assessed. It is, thus, unclear if/how often participants repeated their plans and, consequently, how their effects varied as a function of these repetitions.

Third, the effectiveness of implementation intentions is well documented and supported by meta-analyses (Adriaanse et al., 2011; Bélanger-Gravel et al., 2013; Gollwitzer & Sheeran, 2006). This effect is assumed to be based on the cue specified in the if-part becoming readily accessible and the action specified in the then-part being automatically triggered (e.g., Achtziger et al., 2012; Brandstätter et al., 2001; Gollwitzer & Brandstätter, 1997; Wieber & Sassenberg, 2006). However, recent failures to find a positive effect of implementation intentions in academic settings indicate that their effects might be less strong in university students (Hoch et al., 2020a, 2020b; Janson & Dickhäuser, 2019; van der Beek et al., 2020;). Students could possibly benefit from repeated reminders, especially if goal-striving (i.e., studying) takes place over longer periods of time (Janson & Dickhäuser, 2019). It thus appears worthwhile to test whether repeated prompts could boost the effectiveness of implementation intentions in academic contexts.

1.3 Temporal Dynamics in Intervention Effects

The invigorated interest in within-person processes in psychological research (e.g., Hamaker, 2012; Molenaar, 2004) has led to an increased use of intensive longitudinal data and accompanying analysis methods to investigate them (Anonymous, 2016; Bolger & Laurenceau, 2013; Hamaker & Wichers, 2017). Researchers have recently begun to discuss the role of time in the understanding of psychological mechanisms (Berli et al., 2020; Driver & Voelkle, 2018; Voelkle et al., 2018). However, the use of intensive longitudinal designs to investigate the intraindividual dynamics in intervention effects has yet to gain momentum.

As outlined by Könen and Karbach (2015), an intra-individual approach to intervention effects has several advantages. First, it allows to study intraindividual effect trajectories and identify participants whose performance increases versus those whose performance stagnates or even decreases over the course of the intervention. Second, intraindividual performance fluctuations between treatment occasions can be assessed and, third, analyzed for their couplings with other varying factors. Furthermore, there might be inter-individual differences in the strength of the causal effect and in its couplings with other factors (Bolger et al., 2019).

An important question that has not yet received much attention concerns the temporal dynamics of intervention effects. What is meant here are performance fluctuations as a function of the timing of intervention prompts. Researchers frequently assess the long-term stability of intervention effects (e.g., Ball et al., 2002; Muennig et al., 2009; Stadler et al., 2010; Venema et al., 2018). However, when intervention prompts are delivered repeatedly, it would not only be important to know what the long-term effects of the intervention as a whole are but also how quickly the effect of each prompt fades until the next prompt is delivered. Conversely, the effects might build up when prompts are delivered in quick succession, similar to a drug that increases concentration levels in the blood after each intake up until saturation.

For instance, one study tested the within-person change in the effects of SRL prompts on test scores across multiple training modules (Sitzmann et al., 2009).

Performance of participants who received repeated SRL prompts gradually increased over time, whereas performance of participants without prompts decreased over time. Eventually, the prompting effect leveled off. This pattern suggests that, at least in the

beginning of an intervention program, participants benefit from repeated external reminders of SRL strategies. This study, thus, highlights how a within-person analysis of changes in intervention effects can inform decisions on how to optimally schedule an intervention. However, the study did not investigate if a discontinuation of prompting would lead to a rapid decline in the intervention effect or whether it would just halt the continued increase in performance. Therefore, the present study aimed to investigate both effects (i.e., potential increases with repeated prompts and potential decreases with interrupted prompts) within the same study.

So far, tests of the effectiveness of repeated implementation intentions prompts have produced mixed results. While some studies found beneficial effects of repeated prompts on goal achievement (e.g., Chapman & Armitage, 2010; Conner & Higgins, 2010; Luers et al., 2019), others found no such effect (e.g., Kramer et al., 2020; Scholz et al., 2013; Schwerdtfeger et al., 2012). Furthermore, the effects of repeated implementation intentions have been almost exclusively studied for health-related goals. To the best of our knowledge, no study has investigated the effectiveness of repeated implementation prompts in an educational setting. Repeated prompts might be particularly helpful in educational settings, though, because preparing for a big exam entails studying over weeks to months, thus requiring repeated self-regulatory efforts.

1.4 The Current Study

Implementation intentions are a popular self-regulation intervention often used in educational settings, and their effectiveness has been demonstrated repeatedly. Yet, its temporal dynamics are largely unknown due to the lack of intensive longitudinal data that can capture the waxing and waning of effects due to the repeated delivery of intervention

prompts. The current study, therefore, explored if repeated prompts to internalize an implementation intention boost its effectiveness and at what rate the effects diminish in the absence of prompts.

The study was conducted in a large sample of medical students who prepared for a high-stakes exam. We tested the learning success of students who received intervention prompts against a no-intervention control group. During four weeks of studying for the exam, students in the intervention group received an implementation intention prompt on 2–3 consecutive days, which alternated with 2–3 consecutive days of receiving no prompt. The implementation intention was aimed at overcoming a detrimental inner state that, if not counteracted, would prevent students from achieving their goals. Inner states such as thoughts or feelings have been recommended over external cues if there are many events that could hinder goal striving, but that would all cause the same detrimental inner state (Achtziger et al., 2008). Daily learning success was assessed objectively via log-files of students' learning activities on a digital learning platform. This objective high-resolution data allowed us to explore the temporal dynamics of students' learning behavior as a function of the sequencing of intervention prompts. In addition to these exploratory analyses, we expected a positive main effect of implementation intentions on exam performance and daily goal achievement (between and within persons).

2 Method

2.1 Participants

In July 2018, we recruited medical students across Germany who intended to take the second medical state exam in October 2018 and used a digital learning platform (www.amboss.com) as their main source for preparation. Choosing this population

provided us with the unique opportunity to obtain extensive information on students' natural learning behavior via log-file data. We, thus, did not set a sample size *a priori* but invited all students preparing for the exam in the learning platform's database to participate in the study. 365 students participated in the pretest survey, 359 of whom also participated in the ambulatory assessment (i.e., daily questionnaires before and after learning). The final sample for the analyses presented here consisted of 339 students. They were randomly assigned (with a 2:1 ratio) to the intervention and the control group while keeping sample characteristics comparable between groups (see Table 1). The 20 excluded students either did not use the learning platform for their studies, set unrealistically high learning goals (> 3 SD above the sample mean), or – in the intervention group only – received each within-person condition less than twice (i.e., participated for less than 4 days). Control group participants were not excluded based on the number of days participated because they were treated identically across all days (i.e., no intra-individual manipulation).

All participants gave written informed consent prior to testing. Participants received 1 Euro for each day of the ambulatory assessment period with complete data and a bonus of 10 Euro if they provided complete data for at least 30 days. Ethics approval was obtained from the ethics committee of **[blinded]**.

Table 1

Characteristics of the Final Sample by Group

Intervention Group	Control Group
(n = 223)	(n = 116)

<i>Age</i>	25.87 (3.34; 22-41)	26.22 (4.02; 22-53)
<i>%female</i>	69.51%	73.28%
<i>Number of days participated</i>	30.03 (5.93; 5-40)	29.83 (7.37; 1-40)
<i>Grade of intermediate medical exam in %</i>	Data from 175 students 78.46% (9.02%; 50%-96%)	Data from 97 students 78.62% (7.65%; 64%-93%)

Note. SD and range in parentheses.

2.2 Design

The study used a combination of a between-subjects design (intervention group vs. control group) and a within-subjects experimental manipulation (consecutive days of implementation intention prompts vs. no prompts). Two-thirds of participants were assigned to the intervention group and one-third was assigned to the no-intervention control group. This unequal assignment was intended by design and resulted from our focus on the intra-individual analyses in the intervention group. Participants in the intervention group received implementation intention prompts on half of the days, with two-to-three days of consecutive prompts alternating with two-to-three days without prompts (see Figure 1a). This randomization scheme was chosen to enable the analysis of causal relations between time from last implementation intention and repeated planning on goal achievement. We alternated between two and three days so that it was harder for students to anticipate if they would receive a plan prompt or not. The choice for up to three days was further based on practical considerations because even with this short interval, each of the six day types (i.e., the first day with prompt, the second day with prompt, ..., the third day without prompt) occurred only a few times. There were only

three to four events of day type 3 and 6 (i.e., the third day with prompt/the third day without prompt) within the 30–40 day study period. Longer sequences (e.g., 4 or 5 days of prompting and no prompting in a row) would have resulted in even fewer events per day type.

Figure 1
Overview of the Intra-individual Experimental Manipulation That Was Embedded in a Between-subjects Design

Note. Panel a: Schematic overview of the study design and the randomization order (excerpt of days 11-20). Panel b: Flowchart of the daily experimental procedure. Panel c: Means and standard errors of goal achievement across participants for each type of day (data were trimmed by 10% on each side for visualization purposes only), overlaid with a linear trend.

We employed two complementary sequences of prompt and no-prompt days (i.e., an intervention day in randomization order 1 corresponded to a non-intervention day in order 2) that were counterbalanced across participants. Thus, half of the participants in the intervention group started the study with two consecutive days with prompt, followed by two days without prompt; the order was reversed for the other half (see Figure S2). The group that started with two consecutive days of prompting achieved their goals on less days ($M = 0.63$, $SD = 0.24$) than the group starting with two days of no-prompting ($M = 0.70$, $SD = 0.25$) ($b = 0.41$, 95% CI [0.04, 0.78]). However, this difference was likely not based on the different prompt/no-prompt sequences, because, descriptively, the effect of prompting was even slightly stronger in the group starting with two days of prompting (3.7% vs. 2.9% difference in goal achievement between days with and without prompt). Furthermore, comparing only the intervention group with the higher baseline performance to the control group did not alter the results. Therefore, we decided to analyze both intervention groups together as intended.

The dependent variables were exam performance (which varied between participants only) and daily goal achievement (which varied both between and within participants).

2.3 General Procedure

This study was part of a larger project that assessed different components of students' daily self-regulation. The 40-day ambulatory assessment period started 64 days before the exam. Participants filled out two questionnaires daily, which were sent to them via e-mail and took two to five minutes each to complete. We instructed participants that they should fill in the first questionnaire (pre-learning questionnaire) just before they

started learning on the digital learning platform and the second questionnaire directly after finishing learning (post-learning questionnaire). After the pre-learning questionnaire, participants were forwarded to a working memory task (data not reported here). The present analyses only included measures from the pre-learning questionnaire, which included the experimental manipulation. Participants were instructed to not fill in any questionnaire if they did not intend to learn that day. If participants missed a day because they did not learn that day or forgot to fill in the questionnaire, the randomization order was maintained (i.e., the student either received or did not receive a plan prompt with the next questionnaire that they filled in). Due to the different inclusion criteria for the two groups (see above), the number of participated days ranged from 5 to 40 in the intervention group and 1 to 40 in the control group.

2.4 Implementation Intention Procedure

In the pre-learning questionnaire, all participants were asked to set a goal for how much they wanted to learn on the digital learning platform that day (cf. Figure 1b). Learning on the online platform involved two learning activities: Reading learning cards and answering old exam questions (multiple choice format). The learning platform provided a non-binding study plan that spread the exam-relevant topics (e.g., internal medicine, dermatology) across 100 days. On the platform, students could select a topic from the study plan and were presented corresponding exam questions (mean = 76, range = 20-112). Most students followed this plan, even though they were free not to do so (i.e., it was possible to complete less or more than one study day on the same calendar day). Thus, in the pre-learning questionnaire, students first chose up to three topics from the learning plan that they intended to study that day. They were then shown how many

questions and how many learning cards their choices included according to the learning platform, but they were asked to report their personal goals, which could differ from this preset learning plan. On non-intervention days, participants answered the pre-learning questionnaire and were then forwarded to the working memory task, at the end of which they were asked to start learning. The procedure was identical for the control group (on all days) and for the non-intervention days of the intervention group.

On intervention days, participants in the intervention group were prompted to internalize an implementation intention after they had set their goals. They saw a short paragraph, which motivated the use of planning to use self-talk whenever learning motivation dropped (see supplements). Self-talk is an effective strategy for the regulation of motivation (Wolters, 1999, 2003) and easy to use in all kinds of situations. On the same page, students were prompted to implement the plan *“If I am thinking about stopping to answer questions for today, then I will tell myself that I will continue answering questions until I have reached my intended workload!”* (*“Wenn mir der Gedanke kommt, für heute mit dem Kreuzen aufzuhören, dann sage ich mir, dass ich heute so lange kreuzen werde, bis ich mein Tagespensum erreicht habe!”*). The plan was aimed at shielding the learning goal from a detrimental thought (Achtziger et al., 2008) that is common among students and likely to occur on a daily basis. Following the plan, participants were reminded of the goal they had set. To continue the questionnaire, participants had to confirm that they had re-read the plan three times and internalized it. After filling out the pre-learning questionnaire, we checked memory for the implementation intention by showing the first half of the plan (*“If I am thinking about stopping to answer questions for today, then I will tell myself...”*) and participants had to

type the other half of the plan into a text box. On the next page, participants saw the correct plan as well as their goal again and were asked to re-read it one more time.

2.5 Measurements

2.5.1 Daily Goal

Participants reported their goal for the day with one item in the pre-learning questionnaire. Participants were asked how many questions they wanted to answer on the digital learning platform today and to type in the number into a text field.

2.5.2 Number of Questions Answered

The number of questions a participants had answered on any given day was determined via log-files, which we received from the digital learning platform. Log-files contained a timestamp for each question that was answered.

2.5.3 Exam Results

We asked participants to report the results of their written exam (% of questions correctly answered) four weeks after the exam had taken place. 215 students in the intervention group and 113 students in the control group provided information on the results of their written exam.

2.6 Data Analysis

We first evaluated the effectiveness of planning with implementation intentions by comparing goal achievement between the intervention group and the control group. Goal achievement was operationalized on two levels: a) the superordinate goal of performing well in the exam (i.e., exam performance), b) the proximal goal of achieving the daily learning goal that was targeted by the implementation intention. We expected both exam performance and average goal achievement to be improved in the intervention

group compared to the control group. All inter-individual comparisons were computed as linear regressions with group (intervention vs. control) as the predictor.

Next, we evaluated the effectiveness of the within-subjects experimental manipulation by comparing the likelihood of achieving the daily goal between days with intervention prompt and days without intervention prompt. We hypothesized that daily goal achievement would be more likely on days with intervention prompt than on days without intervention prompt. Lastly, we explored whether plan effectiveness changed as a function of the experimentally manipulated sequencing of intervention prompts. The intra-individual data were analyzed as multilevel regression models with the full random effects structure.

We analyzed data within a Bayesian framework, using the R package “brms”, version 2.12.0 (Bürkner, 2017) with default uninformative priors (but see exception below). Regression models were computed with 6,000 iterations, 2,000 warmup samples, and 4 chains; for multilevel regression models, 12,000 iterations were used to ensure convergence of the sampling for the random effects estimates. Model diagnostics indicated good model convergence for all analyses (see supplements).

In addition to point estimates, we report credible intervals (CI) that mark the interval that a parameter θ falls in with a certain probability (90% for one-tailed hypotheses and 95% for two-tailed hypotheses). We further computed the Bayes Factor (BF) for hypothesis testing; BFs indicate the amount of evidence of one hypothesis over another (e.g., $\theta > 0$ against $\theta \leq 0$). As the BF for a point-null hypothesis cannot be calculated from flat priors, we chose plausible weakly informative priors when testing the null hypotheses on goalsetting behavior between and within groups (i.e., a Student’s t

distribution with 3 degrees of freedom, mean 0, and standard deviation 100). Cohen's d was calculated as a more commonly known measure of effect size. To compare the predictive performance of different models, we computed the difference in expected log predictive density (ELPD), using the “loo” package, version 2.2.0 (Vehtari et al., 2019). Similar to other information criteria such as the Akaike Information Criterion, smaller ELPD values indicate better model fit.

3 Results

3.1 Descriptive Statistics

Descriptive results are presented in Table 2. As hypothesized, the intervention group performed, on average, better in the exam and achieved their learning goals on more days than the control group. Within the intervention group, students had a higher chance to reach their goals on days with prompt than on days without prompt.

Table 2

Descriptive Statistics

	Intervention Group <i>M (SD)</i>		Control Group <i>M (SD)</i>
	Days with prompt	Days without prompt	
Exam performance	81.03% (6.00%)		79.77% (6.42%)
Goal Setting (number of questions)	90.90 (22.80)		90.78 (21.98)
	90.63 (24.27)	91.22 (23.54)	
	88.11 (33.37)		85.44 (26.34)

Number of questions answered	88.96 (36.03)	87.63 (33.76)	
Daily Goal Achievement	66.29% (24.54%)		64.72% (28.01%)
	68.04% (25.43%)	64.69% (26.44%)	

There was strong evidence ($BF_{r>0} = 247.32$) for a positive correlation between the proximal outcome (i.e., daily goal achievement) and the distal outcome (i.e., exam performance) (see Table 3). There was, however, no evidence ($BF_{r>0} = 0.39$) for a positive correlation between the average number of questions students had answered and exam performance. These results suggest that the achievement of personal learning goals, rather than the sheer quantity of material learned, was critical to performance on the exam.

Table 3

Correlation Matrix

Variable	1	2	3
Exam Performance			
Goal Setting	-.03 [-.13, .08]		
Number of questions answered	.06 [-.04, .18]	.49 [.40, .56] *	
Daily Goal Achievement	.20 [.10, .30] *	-.30 [-.40, -.20] *	.39 [.30, .48] *

Note. 95% CI in brackets. The mean scores of each variable were aggregated per participant before calculating the bivariate correlations. The coefficients thus reflect the associations at the between-person level.

* $BF_{r \neq 0} > 3$

We checked whether the two intervention groups with complimentary prompt/no-prompt sequences and the control group were equivalent on important baseline measures. We compared these groups regarding their performance in the intermediate medical exam and regarding their scores on two self-regulation questionnaires that students answered before the daily assessment period, namely the Brief Self-Control Scale (BSCS; Tangney et al., 2004) and a self-constructed 18-item questionnaire measuring different aspects of SRL. We computed Bayesian one-way ANOVAs with the three-level factor group (intervention group 1, intervention group 2, control group) and compared them to an intercept only model. Evidence in favor of the intercept only model speaks for equivalence between the groups. There was substantial evidence for equivalence on all baseline measures (intermediate exam: $BF = 6.16$; BSCS: $BF = 7.04$; SRL questionnaire: $BF = 22.59$).

3.2 Inter-individual Comparisons

3.2.1 Exam Performance

We first tested whether the implementation intention helped students in the intervention group to perform better in the exam than students in the control group (see Figure 2). The estimated difference was 1.26% (90% CI [0.05%, 2.45%]), which corresponded to a small effect ($d = .21$, 90% CI [.01, .40]). The evidence strongly favored

the hypothesis that the intervention group performed better than the control group ($BF_{b>0} = 22.09$).

Figure 2

Estimated Effect of the Intervention on Exam Performance

Note. Point estimate with 90% CI in brackets, underlaid by density plots of the raw data.

3.2.2 Achievement of Daily Learning Goals

We first tested the hypothesis that there was no difference between groups in their average goal setting. The evidence was clearly in favor of this hypothesis ($b = 0.11$, 95% CI $[-4.99, 5.09]$, $BF_{b=0} = 42.19$).

Next, we modeled daily goal achievement as a dichotomous outcome variable (i.e., goal achieved vs. missed). That is, on the inter-individual level, the dependent variable was the percentage of days on which the students achieved their daily goals.¹ The hypothesis that students in the intervention group ($66.29\% \pm 24.54\%$) achieved their learning goals on more days than students in the control group ($64.72\% \pm 28.00\%$) was not supported by the data ($b = 1.57$, 90% CI $[-3.53, 6.67]$, $\text{BF}_{b>0} = 2.26$, $d = .06$, 90% CI $[-.14, .26]$).

3.3 Intra-individual Comparisons

3.3.1 Achievement of Daily Learning Goals

Again, we first checked whether participants set equally ambitious goals on days with prompts compared to days without prompts by computing a linear mixed-effects model. We again did not find a meaningful difference in goal setting ($b = -0.64$, 95% CI $[-2.49, 1.22]$, $\text{BF}_{b=0} = 91.41$, $d = -.01$ $[-.06, .03]$).

In contrast to the results of the inter-individual comparison between groups, however, the intra-individual data supported the hypothesis that the likelihood of goal achievement was higher on days with prompt than on days without prompt (see Table 4, Model 1). The estimated slope variability was rather small ($SD = 0.25$), indicating that the effect of implementation intention prompts on goal achievement was similarly strong

¹ Using the continuous outcome measure (i.e., the average difference between the number of questions completed and the number of question planned) yielded the same interpretation of results (see supplements).

across participants. Indeed, there was no meaningful difference between a random slope model and a random intercept model ($ELPD_{Diff} = -0.1$, $SE_{Diff} = 1.5$).

The results suggest that the beneficial effect of planning might not have been fully sustained on days on which the plan was not explicitly repeated but that participants experienced a boost whenever they internalized their plan again. We more closely explored this hypothesis by investigating the temporal dynamics in intervention effectiveness.

Table 4

Results of the Intra-individual Comparisons: Multilevel Logistic Regressions on Daily Goal Achievement

	Model 1	Model 2
	Slope: Effect of Intervention	Slope: Linear Trend of Day
	Prompts (prompting vs. no prompting)	Type (NP1-P3)
<i>Population-level</i>		
Intercept	0.81 [0.64, 0.98]	0.95 [0.79, 1.12]
Slope	0.18 [0.07, 0.28]	0.08 [0.03, 0.13]
$BF_{Slope > 0}$	237.10	505.33
<i>Group-level</i>		
SD(Intercept)	1.37 [1.23, 1.53]	1.33 [1.19, 1.48]

SD(Slope)	0.25 [0.03, 0.48]	0.11 [0.01, 0.20]
Cor(Intercept, Slope)	-0.19 [-0.77, 0.53]	-0.18 [-0.81, 0.44]
<i>Model fit</i>		
ELPD (SE)	-3531.74 (40.21)	-2849.87 (35.85)

Note. 90% CI in brackets; ELPD = expected log predictive density.

3.3.2 Temporal Dynamics

The randomization scheme alternated between two-to-three consecutive days of planning prompts (P1-P3) and two-to-three days without planning prompts (NP1-NP3), which allowed us to explore the temporal trajectory of the effectiveness of plan prompting. We discarded days P2 and P3 if more than 24 and 48 hours lay between that day's prompt and the last P1 prompt, respectively, as this meant that the participants had skipped a day of planning, thus interrupting the consecutive order of planning. Doing so led to the exclusion of 19.93% of daily observations. Keeping these observations in the analyses would have changed parameter values only slightly.

As can be seen from Figure 1c, plan effectiveness depended on the sequencing of intervention prompts. That is, the likelihood of goal achievement gradually wore off with time since last prompt and built up over consecutive days of prompting. A linear model of this trend revealed that the likelihood of goal achievement changed by 1.58% per day of prompting or no-prompting (see Table 4, Model 2).

We further explored whether the prompting effect increased or decreased over the study period. A conditional growth model within the intervention group revealed that the difference in goal achievement between days with prompt vs. days without prompt did not change over time ($b_{\text{growth} \times \text{prompting}} = 0.00$, 95% CI [-0.01, 0.02]). Similarly, the likelihood of goal achievement neither increased nor decreased more strongly in the intervention group than in the control group ($b_{\text{growth} \times \text{prompting}} = 0.00$, 95% CI [-0.01, 0.02]; see Figure S12). In fact, there was no change in goal achievement in either of the groups ($b_{\text{growth}} = 0.00$, 95% CI [-0.01, 0.01]). Thus, we found no indication that the prompting effect changed over the study period.

4 Discussion

In addition to a common between-group comparison, the present study used an intra-individual intervention design and combined it with objective data on learning outcomes to investigate the temporal dynamics of a self-regulation intervention. This novel approach revealed that the beneficial effects of implementation intention prompts on learning goal achievement built up over consecutive days of prompting and wore off when prompting was discontinued. This finding has important theoretical and practical implications.

Our study suggests that between-subject data, which are the predominant data in research on SRL, should be complemented by within-subject process data to fully capture the effects of an intervention. Our study demonstrates that adding within-subject process data can even change the conclusions of a study. On a between-subject level, our intervention benefitted the superordinate goal of exam performance but not the proximal goal of daily achievement of learning goals. This finding was surprising, as the

intervention would be expected to benefit long-term academic outcomes (i.e., exam performance) through its effect on immediate learning outcomes (i.e., daily goal achievement) (Oreopoulos & Petronijevic, 2019). Adding the within-subject data revealed that the intervention did indeed have an effect on the likelihood of daily goal achievement, but that this beneficial effect wore off rapidly (i.e., by 1.58% per day) when prompting was discontinued. Intra-individual process data are needed to capture such short-term dynamics induced by psychological interventions.

The intra-individual perspective also offers new insights for existing theories on the mechanisms underlying implementation intention effects. Implementation intention effects are commonly ascribed to the associative link between the cue specified in the if-part and the action specified in the then-part of the plan (Gollwitzer, 2014; Gollwitzer & Sheeran, 2006). The cue-behavior link is hypothesized to increase accessibility of the cue (e.g., Achtziger et al., 2012; Wieber & Sassenberg, 2006) and to automatize the action (e.g., Brandstätter et al., 2001; Gollwitzer & Brandstätter, 1997). Implementation intentions are, thus, similar to habits which are also automatically triggered by context cues (Wood & Rünger, 2016). However, habit formation requires several repetitions before the behavioral pattern is automatized (Lally et al., 2010). The temporal dynamics found in our data suggest that the automatization of implementation intentions goes through a similar acquisition phase to strengthen the initially highly volatile cue-behavior association. Our intra-individual results, thus, go beyond previous findings that implementation intention effects are not fully sustained on unprompted days (Luers et al., 2019), by showing that the formation of the cue-behavior link is a process similar to other learning processes.

If the automatization of implementation intentions takes time, it could be assumed that the prompting effect should decrease over the study period. That is, as the implementation intention becomes more automatized, students should execute their plan whether or not they are externally prompted. For the same reason, students in the intervention group should become increasingly better at achieving their goals over time. However, we did not find any evidence for such effects in our data. Are we therefore wrong in concluding that repeated prompts promote the automatization of implementation intentions? Not necessarily. One explanation could be that the discontinuation of prompting for 2-3 days had a disruptive effect that prevented the automatization of the implementation intention. In addition, students' motivation to adhere to the intervention prompt might have decreased over time as its novelty wore off. Together, the effects of increasing automatization and decreasing motivation might have cancelled each other out. These predictions need to be tested in future studies.

There further remains an open question of why we observed an effect on exam performance but not on the achievement of learning goals when comparing the intervention group to the control group. Notably, a recent study found a similar pattern of results: Students prompted to form an implementation intention outperformed students in the control group on final exam performance but did not show different learning behaviors in an online learning environment (Janson & Dickhäuser, 2019). In their discussion of the findings, the authors suggest that the effect of implementation intentions might have generalized to other, unmeasured learning behaviors, which caused the effect on exam performance. A similar explanation could apply in the current context, because the behavior specified by the plan (i.e., talking oneself out of quitting studying) could

easily be transferred to other learning activities such as reading textbooks or memorizing medical facts. Furthermore, the implementation intention could have had an effect on secondary outcome variables such as motivation or self-efficacy beliefs (Gentner & Seufert, 2020) that had a long-lasting effect on studying and thus on exam performance. Our recommendation for future studies is, thus, to ask students during which activities they applied their plan and to consider additional outcome variables such as motivation.

Some limitations of the present study should be addressed in future research. One important limitation is the highly selective sample: high-achieving final-year medical students with likely above-average self-regulation skills. The learning platform further provided additional structure that reduced self-regulatory demands. This means that our study potentially underestimated the average effect of the self-regulation intervention. There is a clear need to see whether our findings generalize to different populations, learning settings, and types of implementation intentions.

The generalizability of our findings is further limited because we could only test a rather short sequence of prompts (i.e., 2-3 consecutive days of prompting/no prompting) over a short time span of 30-40 days. Future studies should run longer sequences for longer periods of time to determine a) at which point the intervention effect fades out completely when promoting is discontinued, and b) at which point the intervention becomes fully automatized and, thus, potentially independent of external reminders. External reminders might even become detrimental when students have mastered the use of the self-regulation strategy (Nückles et al., 2010). It could further be informative to test different prompting patterns, such as quicker alternations between prompting and no-prompting, to see what effect this has on the effectiveness of the intervention.

Another limitation of our study, which might have weakened the intervention effect, is the lack of evidence on adherence to the experimental manipulation. That is, we do not actually know if students internalized and implemented the plan when asked to, and abstained from active planning when not prompted. A possible remedy for future studies could be to measure adherence to the implementation intention while treating the random delivery of prompts as an instrumental variable, which would allow an estimation of the actual treatment effect in so-called within-person encouragement designs (Anonymous, 2020). For similar reasons, we cannot make inferences about the causal mechanism by which the intervention affected goal achievement. We do not know whether students a) internalized the implementation intention when prompted to, b) applied the behavior specified by the implementation intention during studying, and c) whether applying the plan during studying caused the increase in goal achievement.

Despite these limitations, our findings have important implications for the practical use of implementation intentions in real-world contexts. The typical instruction used for implementation intentions asks participants to internalize their plan only once (e.g., Duckworth et al., 2011; Gollwitzer & Brandstätter, 1997). However, our findings suggest that the effects of individual implementation intention prompts decrease rather quickly. In the current study, daily prompts appeared to be ideal – not only to counteract the fading of the effect but also to build up the full effectiveness of the intervention. An indirect conclusion from these results is that repeatedly prompting learners to internalize the same plan is likely more effective than a one-off intervention in the beginning or repeated prompting of different plans. Thus, previous failures to demonstrate the

effectiveness of implementation intentions in educational settings might be due to a suboptimal delivery of this intervention.

The effects of other types of SRL interventions could also be enhanced by repeated reminders. Similar to the implementation intention used in the current study, cognitive and metacognitive prompts aim to stimulate students' use of SRL strategies during studying (Bannert & Reimann, 2012). However, previous tests of their temporal stability show that the effects of metacognitive prompts are not always transferred to unprompted study sessions (Bannert et al., 2015; Engelmann et al., 2021). These results suggest that the effects of metacognitive prompts decline rather quickly. Our novel intra-individual intervention design could serve as a template for future studies to obtain a better understanding of how rapid this decline is and how effectively it can be counteracted by repeated reminders.

To conclude, the present research suggests that the effects of psychological interventions such as self-regulation interventions to boost learning might wax and wane more quickly than previously believed. Interventions like implementation intentions are often treated as one-off remedies that students ought to internalize only once to produce large changes in their learning behavior. The results of our study suggest that they actually undergo an acquisition phase that can be accelerated by repeated intervention prompts. Studying the short-term temporal dynamics of intervention effects should, thus, be considered an integral part of intervention research, in education and beyond.

References

- Achtziger, A., Bayer, U. C., & Gollwitzer, P. M. (2012). Committing to implementation intentions: Attention and memory effects for selected situational cues. *Motivation and Emotion*, 36(3), 287–300. <https://doi.org/10.1007/s11031-011-9261-6>
- Achtziger, A., Gollwitzer, P. M., & Sheeran, P. (2008). Implementation intentions and shielding goal striving from unwanted thoughts and feelings. *Personality and Social Psychology Bulletin*, 34(3), 381–393. <https://doi.org/10.1177/0146167207311201>
- Adriaanse, M. A., Vinkers, C. D. W., De Ridder, D. T. D., Hox, J. J., & De Wit, J. B. F. (2011). Do implementation intentions help to eat a healthy diet? A systematic review and meta-analysis of the empirical evidence. *Appetite*, 56(1), 183–193. <https://doi.org/10.1016/J.APPET.2010.10.012>
- [Anonymous 2016] Details omitted for double-blind reviewing.
- [Anonymous 2020] Details omitted for double-blind reviewing.
- Aronson, J. K. (2007). Concentration-effect and dose-response relations in clinical pharmacology. *British Journal of Clinical Pharmacology*, 63(3), 255–257. <https://doi.org/10.1111/j.1365-2125.2007.02871.x>
- Bailey, D. H., Duncan, G. J., Cunha, F., Foorman, B. R., & Yeager, D. S. (2020). Persistence and fadeout of educational intervention effects: Mechanisms and potential solutions. *Psychological Science in the Public Interest*, 21(2), 55-97. <https://doi.org/10.1177/1529100620915848>
- Balkis, M., & Duru, E. (2009). Prevalence of academic procrastination behavior among pre-service teachers and its relationships with demographics and individual preferences. *Journal of Theory and Practice in Education*, 5(1), 18–32.

- Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., Morris, J. N., Rebok, G. W., Smith, D. M., Tennstedt, S. L., Unverzagt, F. W., Willis, S. L., & for the ACTIVE Study Group. (2002). Effects of cognitive training interventions with older adults: A randomized controlled trial. *JAMA*, 288(18), 2271.
<https://doi.org/10.1001/jama.288.18.2271>
- Bannert, M., & Reimann, P. (2012). Supporting self-regulated hypermedia learning through prompts. *Instructional Science*, 40(1), 193–211.
<https://doi.org/10.1007/s11251-011-9167-4>
- Bannert, M., Sonnenberg, C., Mengelkamp, C., & Pieger, E. (2015). Short- and long-term effects of students' self-directed metacognitive prompts on navigation behavior and learning performance. *Computers in Human Behavior*, 52, 293–306.
<https://doi.org/10.1016/j.chb.2015.05.038>
- Bäulke, L., Daumiller, M., & Dresel, M. (2021). The role of state and trait motivational regulation for procrastinatory behavior in academic contexts: Insights from two diary studies. *Contemporary Educational Psychology*, 65, 101951.
<https://doi.org/10.1016/j.cedpsych.2021.101951>
- Bélanger-Gravel, A., Godin, G., & Amireault, S. (2013). A meta-analytic review of the effect of implementation intentions on physical activity. *Health Psychology Review*, 7(1), 23–54. <https://doi.org/10.1080/17437199.2011.560095>
- Bellhäuser, H., Mattes, B., & Liborius, P. (2019). Daily fluctuations in motivation: A longitudinal diary study over an entire semester at university. *German Journal of Developmental and Educational Psychology*, 51(4), 228–242.
- Berli, C., Inauen, J., Stadler, G., Scholz, U., & Shrout, P. E. (2020). Understanding

between-person interventions with time-intensive longitudinal outcome data:

Longitudinal mediation analyses. *Annals of Behavioral Medicine*, 55(5), 476-488.

<https://doi.org/10.1093/abm/kaaa066>

Bernacki, M. L., Nokes-Malach, T. J., & Aleven, V. (2015). Examining self-efficacy during learning: variability and relations to behavior, performance, and learning.

Metacognition and Learning, 10(1), 99–117. <https://doi.org/10.1007/s11409-014-9127-x>

Bieleke, M., Keller, L., & Gollwitzer, P. M. (2021). If-then planning. *European Review of Social Psychology*, 32(1), 88–122.

<https://doi.org/10.1080/10463283.2020.1808936>

Bolger, N., & Laurenceau, J.-P. (2013). *Intensive longitudinal methods: An introduction to diary and experience sampling research*. The Guilford Press.

Bolger, N., Zee, K. S., Rossignac-Milon, M., & Hassin, R. R. (2019). Causal processes in psychology are heterogeneous. *Journal of Experimental Psychology: General*,

148(4), 601–618. <https://doi.org/10.1037/xge0000558>

Brandstätter, V., Lengfelder, A., & Gollwitzer, P. M. (2001). Implementation intentions and efficient action initiation. *Journal of Personality and Social Psychology*, 81(5),

946–960. <https://doi.org/10.1037/0022-3514.81.5.946>

Bürkner, P. C. (2017). brms: An R package for Bayesian multilevel models using Stan.

Journal of Statistical Software, 80(1). <https://doi.org/10.18637/jss.v080.i01>

Chapman, J., & Armitage, C. J. (2010). Evidence that boosters augment the long-term

impact of implementation intentions on fruit and vegetable intake. *Psychology and Health*, 25(3), 365–381. <https://doi.org/10.1080/08870440802642148>

- Clark, M., Miller, A., Berry, J., & Cheng, K. (2020). Mental contrasting with implementation intentions increases study time for university students. *British Journal of Educational Psychology*, 1–15. <https://doi.org/10.1111/bjep.12396>
- Conner, M., & Higgins, A. R. (2010). Long-term effects of implementation intentions on prevention of smoking uptake among adolescents: A cluster randomized controlled trial. *Health Psychology*, 29(5), 529–538. <https://doi.org/10.1037/a0020317>
- Daumiller, M., & Dresel, M. (2019). Supporting self-regulated learning with digital media using motivational regulation and metacognitive prompts. *The Journal of Experimental Education*, 87(1), 161–176. <https://doi.org/10.1080/00220973.2018.1448744>
- Dietrich, J., Moeller, J., Guo, J., Viljaranta, J., & Kracke, B. (2019). In-the-moment profiles of expectancies, task values, and costs. *Frontiers in Psychology*, 10:1662. <https://doi.org/10.3389/fpsyg.2019.01662>
- Dignath, C., & Büttner, G. (2008). Components of fostering self-regulated learning among students. A meta-analysis on intervention studies at primary and secondary school level. *Metacognition and Learning*, 3(3), 231–264. <https://doi.org/10.1007/s11409-008-9029-x>
- Dörrenbächer, L., & Perels, F. (2016). More is more? Evaluation of interventions to foster self-regulated learning in college. *International Journal of Educational Research*, 78, 50–65. <https://doi.org/10.1016/j.ijer.2016.05.010>
- Driver C.C., Voelkle M.C. (2018) Understanding the time course of interventions with continuous time dynamic models. In K. van Montfort, J. H. L. Oud, M. C. Voelkle (Eds.), *Continuous time modeling in the behavioral and related sciences* (pp. 79-

109). Springer, Cham. https://doi.org/10.1007/978-3-319-77219-6_4

Duckworth, A. L., Grant, H., Loew, B., Oettingen, G., & Gollwitzer, P. M. (2011). Self-regulation strategies improve self-discipline in adolescents: Benefits of mental contrasting and implementation intentions. *Educational Psychology, 31*(1), 17–26. <https://doi.org/10.1080/01443410.2010.506003>

Duckworth, A. L., Kirby, T. A., Gollwitzer, A., & Oettingen, G. (2013). From fantasy to action: Mental Contrasting with Implementation Intentions (MCII) improves academic performance in children. *Social Psychological and Personality Science, 4*(6), 745–753. <https://doi.org/10.1177/1948550613476307>

Engelmann, K., Bannert, M., & Melzner, N. (2021). Do self-created metacognitive prompts promote short- and long-term effects in computer-based learning environments? *Research and Practice in Technology Enhanced Learning, 16*:3. <https://doi.org/10.1186/s41039-021-00148-w>

Fabriz, S., Dignath-van Ewijk, C., Poarch, G., & Büttner, G. (2014). Fostering self-monitoring of university students by means of a standardized learning journal - A longitudinal study with process analyses. *European Journal of Psychology of Education, 29*(2), 239–255. <https://doi.org/10.1007/s10212-013-0196-z>

Foerst, N. M., Klug, J., Jöstl, G., Spiel, C., & Schober, B. (2017). Knowledge vs. action: Discrepancies in university students' knowledge about and self-reported use of self-regulated learning strategies. *Frontiers in Psychology, 8*:1288. <https://doi.org/10.3389/fpsyg.2017.01288>

Gentner, N., & Seufert, T. (2020). The double-edged interactions of prompts and self-efficacy. *Metacognition and Learning, 15*(2), 261–289.

<https://doi.org/10.1007/s11409-020-09227-7>

Gollwitzer, P. M. (1999). Implementation intentions: Strong effects of simple plans.

American Psychologist, 54(7), 493–503. <https://doi.org/10.1177/0146167207311201>

Gollwitzer, P. M. (2014). Weakness of the will: Is a quick fix possible? *Motivation and*

Emotion, 38(3), 305–322. <https://doi.org/10.1007/s11031-014-9416-3>

Gollwitzer, P. M., & Brandstätter, V. (1997). Implementation intentions and effective goal pursuit. *Journal of Personality and Social Psychology*, 73(1), 186–199.

<https://doi.org/10.1037/0022-3514.73.1.186>

Gollwitzer, P. M., & Sheeran, P. (2006). Implementation intentions and goal

achievement: A meta-analysis of effects and processes. *Advances in Experimental*

Social Psychology, 38(6), 69–119. [https://doi.org/10.1016/S0065-2601\(06\)38002-1](https://doi.org/10.1016/S0065-2601(06)38002-1)

Hamaker, E. L. (2012). Why researchers should think “within-person”: A paradigmatic

rationale. In M. R. Mehl & T. S. Conner (Eds.), *Handbook of research methods for studying daily life* (pp. 43–61). Guilford Publications.

Hamaker, E. L., & Wichers, M. (2017). No time like the present: Discovering the hidden

dynamics in intensive longitudinal data. *Current Directions in Psychological*

Science, 26(1), 10–15. <https://doi.org/10.1177/0963721416666518>

Hoch, E., Scheiter, K., & Schüler, A. (2020a). Implementation intentions for improving

self-regulation in multimedia learning: Why don’t they work? *Journal of*

Experimental Education, 88(4), 536–558.

<https://doi.org/10.1080/00220973.2019.1628693>

Hoch, E., Scheiter, K., & Schüler, A. (2020b). Implementation intentions related to self-

regulatory processes do not enhance learning in a multimedia environment.

Frontiers in Psychology, 11, 1-11. <https://doi.org/10.3389/fpsyg.2020.00046>

Hollis, R. B., & Was, C. A. (2016). Mind wandering, control failures, and social media distractions in online learning. *Learning and Instruction*, 42, 104–112.

<https://doi.org/10.1016/j.learninstruc.2016.01.007>

Jansen, R. S., van Leeuwen, A., Janssen, J., Jak, S., & Kester, L. (2019). Self-regulated learning partially mediates the effect of self-regulated learning interventions on achievement in higher education: A meta-analysis. *Educational Research Review*, 28, 100292. <https://doi.org/10.1016/j.edurev.2019.100292>

Janson, M. P., & Dickhäuser, O. (2019). Prüfungsvorbereitung an der Hochschule mittels Lernsoftware: Die Effekte von Wenn-Dann-Plänen [Preparing for college exams using educational software: The effects of if-then plans]. *Unterrichtswissenschaft – Zeitschrift für Lernforschung*, 47(3), 295–312. <https://doi.org/10.1007/s42010-018-0018-8>

Karsdal, M. A., Byrjalsen, I., Henriksen, K., Riis, B. J., & Christiansen, C. (2010). Investigations of inter- and intraindividual relationships between exposure to oral salmon calcitonin and a surrogate marker of pharmacodynamic efficacy. *European Journal of Clinical Pharmacology*, 66(1), 29–37. <https://doi.org/10.1007/s00228-009-0735-3>

Ketonen, E. E., Dietrich, J., Moeller, J., Salmela-Aro, K., & Lonka, K. (2018). The role of daily autonomous and controlled educational goals in students' academic emotion states: An experience sampling method approach. *Learning and Instruction*, 53.

<https://doi.org/10.1016/j.learninstruc.2017.07.003>

Kitsantas, A., Winsler, A., & Huie, F. (2008). Self-regulation and ability predictors of

- academic success during college: A predictive validity study. *Journal of Advanced Academics*, 20(1), 42–68. <https://doi.org/10.4219/jaa-2008-867>
- Könen, T., & Karbach, J. (2015). The benefits of looking at intraindividual dynamics in cognitive training data. *Frontiers in Psychology*, 6, 615. <https://doi.org/10.3389/fpsyg.2015.00615>
- Kramer, J.-N., Künzler, F., Mishra, V., Smith, S. N., Kotz, D., Scholz, U., Fleisch, E., & Kowatsch, T. (2020). Which components of a smartphone walking app help users to reach personalized step goals? Results from an optimization trial. *Annals of Behavioral Medicine*, 54(7), 518–528. <https://doi.org/10.1093/abm/kaaa002>
- Lally, P., Van Jaarsveld, C. H. M., Potts, H. W. W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology*, 40, 998–1009. <https://doi.org/10.1002/ejsp.674>
- Luers, B., Klasnja, P., & Murphy, S. (2019). Standardized effect sizes for preventive mobile health interventions in micro-randomized trials. *Prevention Science*, 20(1), 100–109. <https://doi.org/10.1007/s11121-017-0862-5>
- McDaniel, M. A., & Einstein, G. O. (2020). Training learning strategies to promote self-regulation and transfer: The knowledge, belief, commitment, and planning framework. *Perspectives on Psychological Science*, 15(6), 1363–1381. <https://doi.org/10.1177/1745691620920723>
- Menekse, M., Anwar, S., & Akdemir, Z. G. (2020). How do different reflection prompts affect engineering students' academic performance and engagement? *Journal of Experimental Education*. <https://doi.org/10.1080/00220973.2020.1786346>
- Molenaar, P. C. M. (2004). A manifesto on psychology as idiographic science: Bringing

the person back into scientific psychology, this time forever. *Measurement: Interdisciplinary Research & Perspective*, 2(4), 201–218.

https://doi.org/10.1207/s15366359mea0204_1

Muennig, P., Schweinhart, L., Montie, J., & Neidell, M. (2009). Effects of a prekindergarten educational intervention on adult health: 37-Year follow-up results of a randomized controlled trial. *American Journal of Public Health*, 99(8), 1431–1437. <https://doi.org/10.2105/AJPH.2008.148353>

Murayama, K., Goetz, T., Malmberg, L.-E., Pekrun, R., Tanaka, A., & Martin, A. J. (2017). Within-person analysis in educational psychology: Importance and illustrations. In D. W. Putwain & K. Smart (Eds.), *British Journal of Educational Psychology Monograph Series II: Psychological Aspects of Education --- Current Trends: The role of competence beliefs in teaching and learning* (pp. 71–87). Wiley.

Nückles, M., Hübner, S., Dümer, S., & Renkl, A. (2010). Expertise reversal effects in writing-to-learn. *Instructional Science*, 38(3), 237–258.

<https://doi.org/10.1007/s11251-009-9106-9>

Oreopoulos, P., & Petronijevic, U. (2019). *The remarkable unresponsiveness of college students to nudging and what we can learn from it*. National Bureau of Economic Research.

Palayiwa, A., Sheeran, P., & Thompson, A. (2010). “Words will never hurt me!”: Implementation intentions regulate attention to stigmatizing comments about appearance. *Journal of Social and Clinical Psychology*, 29(5), 575–598.

<https://doi.org/10.1521/jscp.2010.29.5.575>

Parks-Stamm, E. J., Gollwitzer, P. M., & Oettingen, G. (2010). Implementation intentions

- and test anxiety: Shielding academic performance from distraction. *Learning and Individual Differences*, 20(1), 30–33. <https://doi.org/10.1016/j.lindif.2009.09.001>
- Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of Self-Regulation* (pp. 451–502). Academic Press. <https://doi.org/10.1016/b978-012109890-2/50043-3>
- Richardson, M., Abraham, C., & Bond, R. (2012). Psychological correlates of university students' academic performance: A systematic review and meta-analysis. *Psychological Bulletin*, 138(2), 353–387. <https://doi.org/10.1037/a0026838>
- Schmitz, B., & Perels, F. (2011). Self-monitoring of self-regulation during math homework behaviour using standardized diaries. *Metacognition and Learning*, 6(3), 255–273. <https://doi.org/10.1007/s11409-011-9076-6>
- Schmitz, B., & Wiese, B. S. (2006). New perspectives for the evaluation of training sessions in self-regulated learning: Time-series analyses of diary data. *Contemporary Educational Psychology*, 31(1), 64–96. <https://doi.org/10.1016/j.cedpsych.2005.02.002>
- Scholz, U., Ochsner, S., & Luszczynska, A. (2013). Comparing different boosters of planning interventions on changes in fat consumption in overweight and obese individuals: A randomized controlled trial. *International Journal of Psychology*, 48(4), 604–615. <https://doi.org/10.1080/00207594.2012.661061>
- Schwerdtfeger, A. R., Schmitz, C., & Warken, M. (2012). Using text messages to bridge the intention-behavior gap? A pilot study on the use of text message reminders to increase objectively assessed physical activity in daily life. *Frontiers in Psychology*, 3, 270. <https://doi.org/10.3389/fpsyg.2012.00270>

- Sitzmann, T., Bell, B. S., Kraiger, K., & Kanar, A. M. (2009). A multilevel analysis of the effect of prompting self-regulation in technology-delivered instruction. *Personnel Psychology*, 62(4), 697–734. <https://doi.org/10.1111/j.1744-6570.2009.01155.x>
- Sitzmann, T., & Ely, K. (2011). A meta-analysis of self-regulated learning in work-related training and educational attainment: What we know and where we need to go. *Psychological Bulletin*, 137(3), 421–442. <https://doi.org/10.1037/a0022777>
- Stadler, G., Oettingen, G., & Gollwitzer, P. M. (2010). Intervention effects of information and self-regulation on eating fruits and vegetables over two years. *Health Psychology*, 29(3), 274–283. <https://doi.org/10.1037/a0018644>
- Steel, P., & Ferrari, J. (2013). Sex, education and procrastination: An epidemiological study of procrastinators' characteristics from a global sample. *European Journal of Personality*, 27(1), 51–58. <https://doi.org/10.1002/per.1851>
- Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality*, 72(2), 271–324. <https://doi.org/10.1111/j.0022-3506.2004.00263.x>
- Theobald, M. (2021). Self-regulated learning training programs enhance university students' academic performance, self-regulated learning strategies, and motivation: A meta-analysis. *Contemporary Educational Psychology*, 66(3), 101976. <https://doi.org/10.1016/j.cedpsych.2021.101976>
- van der Beek, S., Bellhäuser, H., & Hertel, S. (2020). Do minimal interventions increase participation rates in voluntary online training at high school? *Psychology Learning & Teaching*. <https://doi.org/10.1177/1475725720965002>

- Vandekerckhove, B., Soenens, B., Van der Kaap-Deeder, J., Brenning, K., Luyten, P., & Vansteenkiste, M. (2019). The role of weekly need-based experiences and self-criticism in predicting weekly academic (mal)adjustment. *Learning and Individual Differences, 69*, 69–83. <https://doi.org/10.1016/j.lindif.2018.11.009>
- Vehtari, A., Gabry, J., Magnusson, M., Yao, Y., & Gelman, A. (2019). *loo: Efficient leave-one-out cross-validation and WAIC for Bayesian models. R package version 2.2.0* (R package version 2.2.0). <https://mc-stan.org/loo>
- Venema, T. A. G., Kroese, F. M., & De Ridder, D. T. D. (2018). I'm still standing: A longitudinal study on the effect of a default nudge. *Psychology & Health, 33*(5), 669–681. <https://doi.org/10.1080/08870446.2017.1385786>
- Voelkle, M. C., Gische, C., Driver, C. C., & Lindenberger, U. (2018). The role of time in the quest for understanding psychological mechanisms. *Multivariate Behavioral Research, 53*(6), 782–805. <https://doi.org/10.1080/00273171.2018.1496813>
- Webb, T. L., Sheeran, P., Totterdell, P., Miles, E., Mansell, W., & Baker, S. (2012). Using implementation intentions to overcome the effect of mood on risky behaviour. *British Journal of Social Psychology, 51*(2), 330–345. <https://doi.org/10.1348/014466610X533623>
- Wieber, F., & Sassenberg, K. (2006). I can't take my eyes off of it – Attention attraction effects of implementation intentions. *Social Cognition, 24*(6), 723–752. <https://doi.org/10.1521/soco.2006.24.6.723>
- Wolters, C. A. (1999). The relation between high school students' motivational regulation and their use of learning strategies, effort, and classroom performance. *Learning and Individual Differences, 11*(3), 281–299.

[https://doi.org/10.1016/S1041-6080\(99\)80004-1](https://doi.org/10.1016/S1041-6080(99)80004-1)

Wolters, C. A. (2003). Regulation of motivation: Evaluating an underemphasized aspect of self-regulated learning. *Educational Psychologist*, 38(4), 189–205.

https://doi.org/10.1207/S15326985EP3804_1

Wood, W., & Rünger, D. (2016). Psychology of habit. *Annual Review of Psychology*, 67(1), 289–314. <https://doi.org/10.1146/annurev-psych-122414-033417>

Zheng, L. (2016). The effectiveness of self-regulated learning scaffolds on academic performance in computer-based learning environments: a meta-analysis. *Asia Pacific Education Review*, 17(2), 187–202. <https://doi.org/10.1007/s12564-016-9426-9>

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of Self-Regulation* (pp. 13–39). Elsevier. <https://doi.org/10.1016/B978-012109890-2/50031-7>