Editorial

Inside Self-Regulated Learning

Measuring and Predicting Intraindividual and Interindividual Variation in Self-Regulated Learning Over Time

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When should I start preparing for an exam? How much time should I invest to achieve my learning goal? How can I enhance my motivation to go to the lecture today? All of these questions refer to the process of self-regulated learning (SRL). Good SRL strategies are important for academic success and study satisfaction – especially for university students (see, e.g., Liborius et al., 2019; Park et al., 2012; Schneider & Preckel, 2017). University students are frequently required to self-organize their studying. For instance, SRL strategies are needed to accomplish tasks without strict external guidance – for example, preparing for an exam or writing a term paper during non-lecture times. To master those tasks, students have to plan when, how, and for how long they want to study. Students further require strategies to increase or maintain their motivation during studying. After studying, students need adaptive strategies to deal with potential goal failure and to modify their learning strategies accordingly. In sum, successful SRL requires continual monitoring and adaptive regulation of a multitude of strategies (Schmitz & Wiese, 2006; Zimmerman, 2002). This dynamic conceptualization of SRL highlights the fact that SRL constitutes a process that can vary from one study session to the next – that is, a student will likely answer the abovementioned questions differently depending on a given situation. Hence, an intraindividual view on SRL processes is crucial.

This special issue is, thus, dedicated to (1) describing interindividual and intraindividual differences in SRL processes and (2) identifying predictors of successful daily SRL. The articles in this special issue contribute to the question of how to describe and predict SRL, in several ways. The studies tested various aspects of SRL (e.g., goal setting, planning, time investment, volitional control, and motivation regulation strategies) and investigated how they predict a multitude of outcome variables (e.g., daily goal achievement, procrastination, motivation, and affect). A unique common feature of all studies is that they assessed students' SRL using learning diaries. Doing so, the studies offer novel insights into the development and dynamics of SRL processes.

The present introductory article is organized as follows: First, we describe strategies and assessment methods to set a common research framework. Second, we summarize the design and key findings of the studies in this special issue. Third, we discuss implications for SRL assessment, SRL models, and SRL interventions that open up avenues for further research.

Self-Regulated Learning Strategies and Models

SRL is described as a process whereby learners monitor and regulate their cognition, motivation, and behavior to achieve self-set goals (Zimmerman, 2002). Figure 1 shows an adapted process model of SRL (based on SRL models by Schmitz & Wiese, 2006, and Zimmerman, 2002) that focuses on the variables that were assessed in the studies in this special issue.

According to the model provided in Figure 1, each study session can be divided into three phases: a forethought phase, a performance phase, and a self-reflection phase. In the forethought phase, learners set goals and make plans – for example, how much time they want to study. Further, self-motivation beliefs, such as self-efficacy beliefs and intrinsic or extrinsic motivation, affect how students approach the task.

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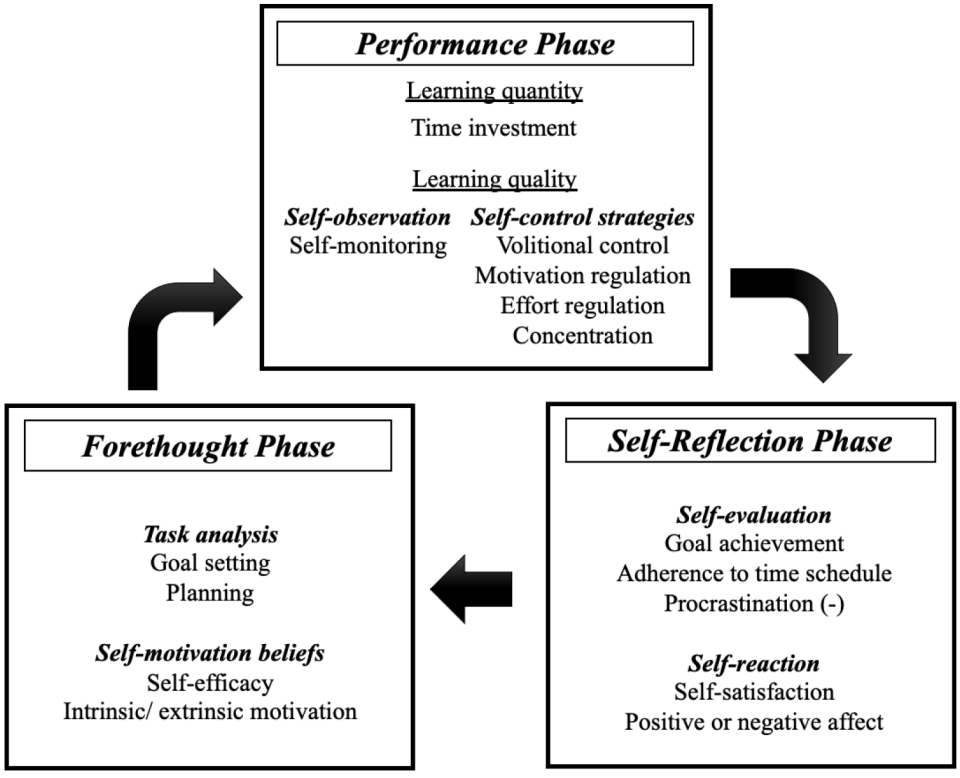

Figure 1. A process model of self-regulated learning (SRL; adapted from Schmitz & Wiese 2006; Zimmerman, 2002). The model focuses on SRL strategies and outcomes that were assessed in the studies in this special issue.

During the performance phase, learners invest time in putting their goals and plans into practice. Thereby, learners apply several strategies to monitor (self-observation) and to regulate (self-control strategies) their studying. For instance, learners monitor their current level of motivation and apply motivation regulation strategies to maintain or enhance their motivation. In the self-reflection phase, learners compare their intended goals and plans with their actual learning outcomes. For instance, learners evaluate whether they have achieved their goals or whether they have met their time schedule. Poor planning strategies in the forethought phase or a lack of self-control strategies in the performance phase can, thereby, increase the likelihood of goal failure or procrastination, which is defined as a postponement of intended study tasks (Steel, 2007). The self-evaluation of learning outcomes further stimulates affective self-reactions, such as self-satisfaction in case of goal success, or negative affect in case of goal failure. Ideally, learners use this internal self-evaluation feedback to adapt their strategies for the next study session. Taken together, SRL subsumes various strategies and subprocesses that are interrelated via an internal feedback loop.

Assessing Self-Regulated Learning as a Process

The process model emphasizes that SRL is a dynamic, adaptive process, which raises the question of how these dynamics can be assessed most adequately. For this special issue, we focus on and differentiate between retrospective self-report questionnaires and daily self-report measures. Retrospective questionnaires typically require students to report their general use of SRL strategies (Veenman, 2011) – that is, students have to average their perceptions of their use of SRL strategies over several learning situations. This aggregation, inevitably, leads to a loss of information and can increase the risk of memory biases (see Klug et al., 2011; Panadero et al., 2016, for an overview). Further, retrospective self-report questionnaires cannot account for intraindividual differences in SRL over time. Daily self-report measures, in contrast, have several advantages compared with retrospective questionnaires. First, the daily assessment is more closely linked to a specific learning situation, which reduces the risk of memory biases (Veenman, 2011). Second, a repeated assessment enables the investigation of the development of SRL over time, and the differentiation between interindi-

vidual and intraindividual differences in SRL (Schmitz, 2006). Hence, daily self-report measures are more suitable to capture daily, dynamic adaptations in SRL.

Summary of the Studies in This Special Issue

Description of Common Methodology: Diary Methods and Analysis Strategy

All studies in this special issue used learning diaries to assess SRL. Bäulke et al. (2021) tested 128 economic science and mathematics students over the course of 28 days during exam preparation. The authors used end-of-day diaries and obtained 3,121 measurement occasions in total. Bellhäuser et al. (2021) tested 105 students from a technical university, mainly engineer students, over the course of a whole semester (154 days: 12 weeks of lecture period and 10 weeks of non-lecture period). The authors used daily morning and evening diaries and obtained a total of 9,402 measurement occasions during the lecture and non-lecture period. Breitwieser et al. (2021) tested 96 medical students over the course of 40 days during exam preparation. The authors used morning and evening diaries and obtained 2,932 measurement occasions in total. Theobald and Bellhäuser (2021) tested 56 students from various fields of study (e.g., economics, political science, teacher training, and social sciences) over the course of 30 days during exam preparation. The authors used morning and evening diaries and obtained a total of 1,133 measurement occasions.

All studies used advanced multilevel methods to account for the clustering of measurement occasions (level 1) in students (level 2). This methodology allows the disentanglement of daily intraindividual variation from interindividual differences in SRL (Bolger et al., 2003). Taken together, the studies in this special issue include a large number of datapoints from a representative sample of the student population to test intraindividual and interindividual differences in SRL.

Intraindividual and Interindividual Variation in SRL Over Time

All studies revealed substantial intraindividual variance in SRL over time, as indicated by the intraclass correlations (ICCs). The results revealed that the variance on level 2 (the student level) was generally lower than the variance at level 1 (the daily level) for the main dependent variables: Procrastination (ICC = .23; Bäulke et al., 2021), goal achievement (ICC = .36; Breitwieser et al., 2021), intrinsic and extrinsic motivation (ICC between .30 and .49; Bellhäuser et al., 2021), and negative affect (ICC = .42; Theobald & Bellhäuser, 2021). These results indicate that, for instance, all students procrastinated from time to time, and even high-achieving students sometimes failed to achieve their goals. The results further suggested that extrinsic and intrinsic motivation as well as negative affect showed some stability over time, as indicated by significant autoregressive effects (see Bellhäuser et al., 2021; Theobald & Bellhäuser, 2021).

Two studies (Bäulke et al., 2021; Theobald & Bellhäuser, 2021) further revealed time trends over the survey period. Both studies focused on the critical phase at the end of the semester when students typically prepare for their exams. Bäulke et al. (2021) showed that students procrastinated less as the exam date came closer (see Wäschle, Allgaier, et al., 2014, for a similar result). The results from Theobald and Bellhäuser (2021) complemented this finding as they found an increase in time investment over the survey period. This increase was, however, accompanied by higher negative affect. Together, these results indicate that students tended to postpone their studying, which resulted in a high workload and negative affect shortly before the exam.

In sum, the results of the four studies demonstrate that (1) SRL is dynamic, as it substantially varies within subjects, and (2) SRL depends on the situation in which it is assessed (e.g., during exam preparation or lecture vs. non-lecture time).

Predicting SRL Processes and Outcomes

Table 1 provides an overview of all predictor and outcome variables that were assessed in the studies. We thereby differentiate between variables that were assessed at the daily level (within-subject or *state* variables) and variables that were assessed at the student level (between-subject or *trait* variables). Table 1 further provides an overview on the main findings of the studies. Therefore, we will focus on describing the key contributions of each study, before we discuss the implications of the findings for SRL models and assessment in the next paragraphs.

Bäulke et al. (2021) assessed personality traits (conscientiousness and neuroticism) and interindividual differences in motivation regulation strategies to predict daily procrastination during the critical exam preparation phase. A novel contribution is that the authors suggest a mechanistic explanation for the relation between personality trait and procrastination – that is, a mediation via motivation regulation strategies.

Table 1. Overview of predictor variables, outcome variables, and main results

Study	Predictor (daily level)	Predictor (student level)	Outcome variable (daily level)	Outcome variable (student level)	Main results
Bäulke, Daumiller, & Dresel (2021)		Motivational regulation Neuroticism Conscientiousness	Procrastination		Procrastination decreased as the exam date came closer Students high in neuroticism and low in conscientiousness reported higher levels of procrastination Motivational regulation mediated the link between conscientiousness and procrastination
Bellhäuser, Mattes, & Liborius (2021)	Extrinsic motivation Intrinsic motivation Planning Self-efficacy Time investment Effort Concentration Procrastination Satisfaction	Study load Extrinsic motivation Intrinsic motivation Study satisfaction	Intrinsic motivation Extrinsic motivation		A higher satisfaction with the study day (on day *t*) predicted more intrinsic motivation and less extrinsic motivation on the next day (*t* + 1) Higher procrastination and a higher time investment (on day *t*) were related to more extrinsic motivation on the next day (*t* + 1) For the remaining predictors, results were mixed and differed for lecture and non-lecture periods
Breitwieser, Neubauer, & Brod (2021)	Volitional control	Volitional control	Goal achievement	Exam performance	The daily assessment of volitional control predicted daily goal achievement over and above retrospectively reported volitional control Neither daily nor retrospectively reported volitional control predicted final exam scores
Theobald & Bellhäuser (2021)	Planning Time investment (intended & actual) Affect Goal attainment		Planning Time investment (intended) Affect		Better planning strategies predicted lower negative affect Falling short of one's time schedule predicted more negative affect Negative affect (on day *t*) predicted higher intended study time the next study day (*t* + 1) Lower goal attainment (on day *t*) predicted more planning strategies the next study day (*t* + 1)

Breitwieser et al. (2021) systematically compared the predictive power of retrospective and daily self-reports of volitional control for daily goal achievement and a more distal performance measure (exam performance). A major strength of this article is that the authors used intraindividual and interindividual differences in volitional control to predict objective daily goal achievement (assessed via log files).

Bellhäuser et al. (2021) revealed feedback loops between daily study satisfaction and intrinsic and extrinsic motivation, and compared those dynamics for lecture and non-lecture periods. A key contribution is that the authors unveiled daily fluctuations in study motivation and related them to intraindividual differences in SRL on the preceding day.

Theobald and Bellhäuser (2021) tested how students plan and regulate their study time and assessed their negative affect during the examination phase. The findings support key assumptions of SRL models: Students evaluated whether they met their time schedule, which predicted affective self-reactions and strategic regulation in the next study session.

In sum, the findings of the studies in this special issue demonstrated that (1) SRL strategies are related to a multitude of outcome variables on the daily level (e.g., goal achievement, affect, procrastination, or motivation), and (2) SRL outcomes are, in turn, related to SRL on the subsequent day in terms of a feedback loop. The results, thus, underline the conclusion that SRL is a process that varies within individuals over time.

SRL as a Process: A Research Agenda

Implications for SRL assessment

All of the articles clearly demonstrate the advantages of assessing SRL using learning diaries, which underlines findings from previous diary studies (e.g., Liborius et al., 2019; Schmitz & Wiese, 2006; Wäschle, Allgaier, et al.,

2014). All studies revealed high intraindividual differences in SRL over time, which cannot be captured by retrospective self-report questionnaires that are only assessed once. The study by Breitwieser et al. (2021) underlines this point most distinctively: The authors showed that daily-assessed volitional strategies predicted goal achievement over and above retrospective trait questionnaires. Hence, these studies add to previous calls to view SRL as a dynamic process (e.g., Klug et al., 2011).

We propose three targets for further research on SRL assessment. First, there is a need for more standardized measurement procedures to assess daily SRL. Although all studies developed their daily questionnaires based on well-established trait questionnaires or adopted them from previous diary studies, a standardized daily SRL inventory is missing. Standardized questionnaires would offer the possibility to compare results between studies more easily. This would further facilitate the replication of findings across diary studies, which, to the best of our knowledge, has not been done so far. Additionally, researchers could share their data and materials, which would constitute as important step toward testing the replicability of the findings across studies. For instance, it would be important to test whether findings are replicated if researchers assess similar constructs but with slightly different questionnaires. Taken together, more research is needed to develop standardized SRL questionnaires for daily assessment – ideally including norms for various student populations.

Second, the studies revealed that SRL requirements vary over the semester. For instance, SRL is especially required when students prepare for an exam, or during non-lecture periods that offer few external guidance. Hence, besides the daily assessment, future research should test the role of SRL at various times during the semester.

Third, the studies revealed high variability in SRL within individuals, corroborating previous findings (e.g., Schmitz, 2006; Schmitz & Skinner, 1993). These intraindividual differences in SRL predicted daily fluctuations in affect, motivation, procrastination, and goal achievement. However, one study that tested the relation between volitional strategies and a more distal, objective outcome measure (exam performance) did not find any effects (see Breitwieser et al., 2021, this issue). One explanation is that aggregated daily self-report measures reveal the general level of volitional strategies over a certain time period. However, this aggregated measure does not tell us if the volitional strategies were applied appropriately and at the right time. Going one step further, the relation between volitional strategies and learning success may even vary between students. For instance, while some students need to apply volitional strategies regularly to avoid distractions, others may not need to apply volitional strategies at all because they avoid distracting situations in the first place (Inzlicht et al., 2021). This example illustrates why (aggregated) daily measures of SRL may not always be good predictors of more distal outcome measures. It is thus crucial to investigate whether and how daily fluctuations in SRL (within persons) can explain more distal individual differences between persons.

Implications for SRL Models and Ideas for Further Research

The findings from the studies in this special issue offer several implications for SRL models that open up avenues for further research. First, SRL is complex and involves many different subprocesses. The multitude of variables that were assessed by the studies in this special issue underlines this point. More research on intraindividual couplings between SRL strategies seems promising to build more informative and predictive models of SRL. For instance, how do specific SRL strategies in the forethought phase relate to learning behavior in the performance phase, and are these relations comparable across students? Building on current SRL models (e.g., Schmitz & Wiese, 2006; Zimmerman, 2002), future research should test the proposed temporal relations between variables in the forethought, performance, and reflection phases.

Second, future research should test how students regulate their strategies across study sessions in terms of a feedback loop. Students continually generate internal feedback about their learning progress and goal achievement, which encourages regulatory action. For instance, it has been found that time investment or the subjective evaluation of learning success predicts the next day‘s motivation and time investment (see Bellhäuser et al., 2021; Theobald & Bellhäuser, 2021, this issue). These regulatory processes could give rise to vicious and virtuous circles in SRL that have rarely been studied to date (for an exception, see Wäschle, Allgaier, et al., 2014). Hence, more research is needed to identify adaptive and maladaptive regulation patterns within and across study sessions.

Lastly, research on short-term day-to-day variability in SRL could offer deeper insights into long-term changes in students' SRL strategies, motivation, or well-being. For instance, do short-term changes in affect and time management predict long-term changes in stress and burnout? Do daily feelings of pressure and obligation predict long-term changes in students' intrinsic or

extrinsic motivation for studying? To answer those questions, more long-term research is clearly needed.

Implications for Interventions to Improve SRL

Results from the studies in this special issue uncovered notable gaps in the research on SRL interventions. First, all studies mentioned the possibility that learning diaries might have evoked reactivity effects. Learning diaries could serve as study reminders or could help students to monitor their learning and to reflect on their learning outcomes (Panadero et al., 2016). The idea that learning diaries might function as an intervention in itself is not new (see, e.g., Schmitz & Wiese, 2006). However, only a few studies tested the effectiveness of learning diaries as an intervention using well-controlled experimental designs (for exceptions, see, e.g., Bellhäuser et al., 2016; Dörrenbächer & Perels, 2016a). Results from these studies suggest that learning diaries might be especially effective if they are combined with a SRL training program.

Alternatively, or additionally, the learning diaries might be enriched by specific scaffolds that address particular cognitive or motivational subprocesses in order to support students' SRL. For example, Wäschle, Lachner, et al. (2014) implemented a line graph in students' weekly learning diaries that provided them with visual feedback on their current and past levels of procrastination. The researchers found in two experimental studies that the visual feedback increased students' metacognitive awareness, led them to formulate more specific personal learning goals, and substantially reduced their self-reported procrastination (see Wäschle, Lachner, et al., 2014). Nevertheless, although the semiautomated feedback approach by Wäschle, Lachner, et al. (2014) proved to be successful, learning diaries can largely vary in their content or the frequency and duration of application (e.g., once a day for 28 days in the study by Bäulke et al., 2021, vs. twice a day for 154 days in the study by Bellhäuser et al., 2021, this issue). Hence, more research is needed to find out if – or under which circumstances – learning diaries improve SRL.

Second, student characteristics that are assessed at the interindividual level, such as personality traits or general use of SRL strategies, could serve as screening variables to identify students who will likely show difficulties when self-regulating their learning. For instance, students low in conscientiousness and motivation regulation strategies may show higher levels of procrastination over the semester (see Bäulke et al., 2021, this issue; Theobald et al., 2018). Hence, interventions could use interindividual difference measures to identify students who would benefit from SRL training programs (Dörrenbächer & Perels, 2016b).

On the other hand, results revealed substantial intraindividual differences as well, meaning that all students sometimes struggle with self-regulating their learning. For instance, a lack of volitional strategies on a given day can increase the risk of goal failure on that day (Breitwieser et al., 2021, this issue). Research on feedback loops across study sessions revealed that low study satisfaction and negative affect can, in part, encourage adverse feedback loops (see Bellhäuser et al., 2021; Theobald & Bellhäuser, 2021, this issue). Together, these findings call for daily, adaptive interventions that help students to maintain their motivation during learning and to deal with goal failure and negative emotions in an adaptive way. For instance, visual feedback on the learning progress (Wäschle, Lachner, et al., 2014) could be complemented by daily instructional prompts or strategy suggestions. A student who missed a learning goal on a particular day could, for example, be prompted to reflect on reasons for goal failure or could be offered strategies to improve goal setting on the next day. The combination of feedback and strategy suggestions could thus help students to monitor their learning progress and to adaptively regulate their daily studying.

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