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An expert performance approach to the study of individual differences in self-regulated learning activities in upper-level college students

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ABSTRACT

One of the hallmarks of adolescent and adult development of expert performance is its self regulation. This paper reviews different approaches to assessing the use of self-regulated learning (SRL) strategies in high-school and college students and their ability to predict academic performance. The current study assesses the use of SRL strategies with interviews and diaries and their relation to grade point average (GPA) in sixty upper-level college students majoring in science. Their diaries revealed that students with high, average, and low GPAs (assessed before the start of the semester) differed in overall use of SRL strategies and in the use of particular strategies during specific weeks. Methods of assessing and understanding differences in adult self-regulation and subsequent academic performance are evaluated and discussed.

Contents

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The expert performance approach attempts to explain how individuals attain superior performance for representative tasks in the associated domain of expertise. Research on a wide range of domains of expertise including music, sports, and games (Ericsson, Charness, Feltovich, & Hoffman, 2006; for a review, see Ericsson, 2006a) has shown how individuals start their training in early childhood and continue with increased levels of practice during adolescence and early adulthood. In particular, expert performers have been found to differ in their accumulated amount of *deliberate practice:* goal-directed activities designed to improve specific aspects of performance through self-evaluation and gradual refinement of performance with feedback (from teachers or coaches and, eventually, through self-assessment) (Ericsson, 2006b; Ericsson, Krampe, & Tesch-Römer, 1993). One of the most salient changes of the structure of the learning activities during this extended training is the increased role of learner, who eventually takes over the responsibility for monitoring performance and self regulating learning from their parents and teachers as they reach adulthood (Ericsson, 1996; Glaser, 1996). Several contemporary researchers (Alexander, 2004; Zimmerman, 2001, 2006, 2008; see also Willingham, 2004) have drawn connections between the attainment of academic goals in school settings and the pursuit of expertise in more traditional domains, such as sports and music.

Our general premise is that advanced college students taking upper-division courses in their science major satisfy the characteristics of adult learners (Merriam, Caffarella, & Baumgartner, 2007). They have reached physical maturity and are legally adults. They are motivated to learn as they are electing courses that are known to be challenging. Finally, they are acquiring more specialized knowledge that build on previously attained fundamentals in order to advance to the next stage of knowledge or expertise. We believe that the study of self-regulated learning in challenging upper-division college courses in science will provide new insights into the factors that contribute to variability in the acquisition of expertise in academic domains.

Despite the vast amount of research on the acquisition of superior performance in traditional domains of expertise, there have been few investigations to date using an expert performance approach to examine factors contributing to individual differences in school performance, as measured by grade point average (GPA) (e.g., Plant, Ericsson, Hill, & Asberg, 2005). There have, however, been several investigations from a very influential and related approach — the self-regulated learning (SRL) approach. Investigations from the SRL approach have proliferated over the last two decades (Karoly, Boekarts, & Maes, 2005; Pressley, 1995; Winne, 1995). The SRL approach evolved from social cognitive theory (Bandura, 1969, for a review, see Zimmerman, 1990), which rejected learning as a passive storage of experience and proposed the importance of self-regulated strategies to learn desired behaviors. Zimmerman defines SRL as "self-generated thoughts, feelings and actions which are systematically oriented towards the attainment of academic goals" (Schunk & Zimmerman, 1994, p. 9). In a more recent review, Zimmerman stated that SRL is "the degree to which students are metacognitively, motivationally, and behaviorally active participants in their own learning process" (Zimmerman, 2008, p. 167).

These definitions share characteristics with the notion of *deliberate practice* activities in other domains. Initially, deliberate practice activities are designed by a coach or teacher, but eventually, motivated individuals design their own practice activities based on self-assessed weaknesses and effective methods for improving them (for a review, see Ericsson, 2006b). Similarly, study activities are initially assigned and monitored by a parent or teacher, but eventually students begin to study independently to attain self-monitored academic goals (Zimmerman, 2008). Initiation and completion of deliberate practice activities also require voluntary effort. Thus, most deliberate practice activities can be viewed as self-generated activities aimed toward the attainment of performance goals. Furthermore, several studies have shown that deliberate practice activities have metacognitive and motivational components, in addition to the behavioral component of engaging in practice (for a review, see Ericsson, 2006b). Metacognitive awareness is a key component in deliberate practice, as aspiring experts must self-assess accurately in order to set appropriate goals and design optimal subsequent deliberate practice activities (Ericsson et al., 1993). Furthermore, unlike mindless repetition or playful activities, engaging in deliberate practice also requires motivation as these activities (much like many challenging studying activities) are not as inherently enjoyable as alternative social activities (Deakin & Cobley, 2003; Ericsson, 2006b).

The current paper examines self-regulated learning in adults from the perspective of the expert performance approach (Ericsson & Smith, 1991; Ericsson & Ward, 2007). We discuss the measurement of self-regulated learning to examine individual differences among motivated adult learners using both traditional methods and those adopted by the expert performance approach. We also compare methods of measuring the development of self-regulated learning, and we relate this to subsequent academic performance. Finally, we discuss the development of self-regulated learning in successful adult learners and how this relates to deliberate practice and the acquisition of expert performance.

First, an outline of an expert performance approach to the study of superior school performance at the college level is presented. Next, we review and discuss contributions from the SRL approach along with some issues raised from the perspective of the expert

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performance approach. Finally, the current investigation is outlined and presented, and implications for future investigations are discussed.

1. Superior school performance at the college level: an expert performance approach

The expert performance approach to the study of high ability and exceptional performance focuses on measurable, reproducible superior performance (for a reviews, see Ericsson, 2006a, 2006b; Ericsson, Roring, & Nandagopal, 2007). In contrast to many influential approaches to the study of learning and skill acquisition in the laboratory (Prins, Veenman, & Elshout, 2006), the expert performance approach searches for robust evidence of performance differences in everyday and professional life. Specifically, this approach searches for reproducible superior performance identified under relatively controlled conditions meant to represent everyday life and professional scenarios, such as competitive athletic performance, medical diagnosis, chess tournaments, and standardized tests. This superior performance is then typically, but not always, captured and reproduced with representative tasks in the laboratory to allow experimental identification and process tracing of the underlying mechanisms. Finally, this approach also seeks to identify goal-directed training activities, where past or current engagement is correlated with the observed superiority of performance.

Techniques for examining past and concurrent training activities include structured interviews, diaries, and think-aloud protocols (for reviews, see Chi, 2006; Deakin, Côté, & Harvey, 2006; Ericsson, 2006a; Sosniak, 2006). Using such methods, several investigations have found that it is not the total duration of any type of engagement in domain-related activities that influences improvement in performance, but the duration of engagement in *deliberate practice* activities (for a review, see Ericsson, 2006a). In many of the studied domains, such as chess, music, and individual sports, the practice activities that are associated with increased performance are not social, such as playful or competitive interactions, but solitary. In fact, future elite performers seek out quiet interruption-free environments with access to necessary training resources. Similarly, with respect to school performance in college, Plant et al. (2005) showed that the total amount of time that college students reported studying was essentially unrelated to grades, but once controlling for previous academic achievement variables, such as high school GPA and SAT (formerly the Scholastic Assessment Test) scores, the duration of studying under quiet conditions was correlated with college GPA. However, although seeking out a solitary environment for analyzing chess games, for practicing with a musical instrument, or for studying for a test is a precondition for deliberate practice, spending time in that environment does not assure full-time engagement in deliberate practice. Based on the high correlation between reported duration in this type of solitary activity and objectively measured performance in many other domains (Ericsson, 2006b) we hypothesize that there are similar activities with a higher probability of engaging in deliberate practice, where the frequency and duration are correlated to higher than average school performance. Plant et al. (2005) found such a correlation between duration of study activities with certain characteristics (i.e. in a solitary environment) but it *cannot* be said that the study examined specific deliberate practice activities.

A search for study activities with more specific attributes that correlate with superior school performance would be of particular importance to potential educational interventions and training techniques. The analysis of student learning in studies adopting the SRL approach has identified more specific SRL strategies that students engage in, which are promising as correlates of superior school performance. To date, most of the empirical studies of SRL strategy use have relied on questionnaires administered only on a single occasion (for reviews, see Muis, Winne, & Jamieson-Noel, 2007; Zimmerman, 2008). In some notable exceptions, researchers have collected interviews (Kitsantas, 2002; Ley & Young, 1998; Sundre & Kitsantas, 2004; Zimmerman & Martinez-Pons, 1986, 1988, 1990). Next, we discuss these interview studies, which attempted to assess study strategies during the course of a semester or school year.

2. Contributions from the self regulated learning approach

In their pioneering study, Zimmerman and Martinez-Pons (1986) developed a theory-based interview, the self regulated learning interview schedule (SRLIS, see Appendix A), to assess variability in SRL strategies for two groups of adolescent learners (high school students). The high-achieving group was approximately 2 standard deviations better in English and Mathematics achievement compared to the other group. Zimmerman and Martinez-Pons (1986) interviewed the students about what methods they "used to participate in class, to study, and to complete their assignments" (p. 617) for six hypothetical learning contexts. They identified 14 SRL strategies, which they defined as "actions directed at acquiring information or skill that involve agency, purpose (goals), and instrumentality self-perceptions by a learner" (p. 615) (for definitions and examples of the 14 strategies see Appendix B). They found that the two groups of students differed significantly in the presence of specific strategies (whether or not students reported using a type of strategy — henceforth referred to as 'strategy presence'), frequency of reporting strategies (the number of times a strategy was mentioned across contexts — henceforth referred to as 'strategy frequency') and strategy consistency (students' estimates of how often each strategy is used, on average).

There are a small number of studies that have extended Zimmerman and Martinez-Pons (1986) results by using the SRLIS to study SRL strategies among adult learners, namely regular college students. Kitsantas and Sundre (Kitsantas, 2002; Sundre & Kitsantas, 2004) examined studying behavior among adult learners (college students), assessing only strategy presence (i.e. the authors did not examine strategy frequency or consistency). In both studies, Kitsantas and Sundre (Kitsantas, 2002; Sundre & Kitsantas, 2004) found that high-achieving students used more SRL strategies overall than low-achieving students, similar to the results obtained by Zimmerman and Martinez-Pons (1986, 1990) for adolescent learners. Kitsantas (2002) modified the SRLIS by asking students to recall their studying behaviors before, during, and after the midterm for a specific course (psychology of personality) during a single interview session. She found significant differences in the reported SRL strategies for students performing in the top quartile on a midterm compared to those performing in the lowest quartile. Most interestingly, Kitsantas (2002) also found significant differences when college students were asked about which strategies they would use as a function of different time points during the semester. For example, more high-achieving students reported engaging in "seeking information" and "organizing and transforming" *before* the midterm, and "keeping records and monitoring" *after* the midterm. Moreover, Kitsantas (2002) found that total number of SRL strategies reported across contexts accounted for a significant proportion of the variance in midterm performance (adjusted $R^2 = .201$).[1]

2.1. Towards the identification of activities contributing to current academic performance

From a theoretical perspective it is important to systematically compare different methods for assessing SRL strategies in adult

[1] In the second study published by Kitsantas and colleagues (Sundre & Kitsantas, 2004), the authors did not analyze specific strategy usage and instead summed strategy use across contexts for a measure of self-regulated learning strategy usage.

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learners, such as college students. In a review Boekaerts and Corno (2005) argued that pioneering research on SRL strategies was based on the assumption that these strategies reflected "a relatively stable individual inclination to respond to a range of learning situations in a typical way" (p. 207), or *aptitude* (Zimmerman, 2008). According to this traditional view, students' self-regulatory learning ability could be abstracted across situations and assessed by their verbal reports elicited by questionnaires and structured interviews. However, Boekaerts and Corno (2005) argue that some subsequent research, based on smaller descriptive studies of adolescent learners (high-school students), has documented evidence for a more complex and situated elicitation of SRL strategies which depends on the particular *event* (i.e. the course, teachers' expectations, and motivational factors see also Zimmerman, 2008). In the case of college courses, we would need to consider that especially superior students' strategies are likely to change across the semester in response to upcoming midterms and finals (Kitsantas, 2002; Vanderstoep, Pintrich, & Fagerlin, 1996).

In the current study we compared the assessment of SRL strategies for the same group of adult learners with different methods in order to evaluate the ability of data from these methods to account for differences in academic performance and to address issues of the generality and stability of SRL strategies. At one end of the generalizability continuum, SRL strategies are compared to aptitudes — i.e., relatively stable in their use across contexts. Toward the other extreme, the frequencies and durations of SRL strategy use are flexible and depend on the type of encountered event. Our study explored different methods – a structured interview and a diary procedure – to assess SRL strategies for the same students in the same semester. Under the assumption that SRL strategies can be compared to general aptitudes, the SRLIS would be a very time effective method to identify variability in strategy use between college students with different GPAs. To test the idea that SRL could be best described as an event rather than an aptitude, we also compared the interviews with diary measures. Although there have been a few diary studies examining SRL strategies, they have been aimed at measuring the effects of SRL training interventions in children and adolescents (middle-school students) (Stoeger & Ziegler, 2008) and college students (Schmitz & Wiese, 2006) rather than examining typical studying strategies used by upper-level college students (for a review, see Zimmerman, 2008). While the aforementioned studies requested that students write about specific SRL-related activities in their diaries, the current study requests that students keep a concurrent diary of all their activities during the time awake. Once the diaries have been collected by researchers each entry is analyzed and coded for evidence of SRL strategies. Additionally, by collecting diaries for three different weeks – before, during and after the midterm – we incorporated Kitsantas' and Sundre's (Kitsantas, 2002; Sundre & Kitsantas, 2004) approach of examining the effects of learning contexts on strategy use.

In the current study, we examined undergraduate bioscience majors enrolled in challenging courses typically taken by students interested in pursuing a career in the sciences. From an expert performance approach and according to recent SRL proponents (Alexander, 2004; Zimmerman, 2001, 2006, 2008; see also Willingham, 2004), these students have made active decisions to embark on the road to acquiring expertise in the biological sciences. We also apply the theoretical framework of the SRL approach to encode different *specific study strategies* and extend the results obtained by Plant et al. (2005). Specifically, the current study analyzed diaries to estimate strategy presence, frequency and the duration (in hours) for each of three diary weeks. Thus, the current study is an integration of the expert performance and SRL approach. Specifically, we hypothesize that engagement in these strategies will be closely related to previous conceptions of SRL and deliberate practice: goal-directed, motivated, and metacognitively informed activities designed to improve specific aspects of performance. Further, we use concurrent measures, such as those described in recent reviews (e.g. Zimmerman, 2008), which are the methodological techniques successfully used to measure deliberate practice activities to examine SRL strategies.

In sum, the current study goes beyond previous studies conducted by expert performance and self-regulated learning approaches by: (1) comparing methods of measuring self-regulated learning activities in adult learners; (2) examining the development of self-regulated learning in adult learners; (3) comparing trait versus state conceptions of self-regulated learning, and (4) discussing the profile of successful self-regulated learners and how this relates to acquisition of expert performance.

2.2. Outline of the current study

The focus of the current study is on the reproducible superior performance of obtaining higher than average academic performance (course grades in college among students pursuing a science major). The performance involves studying a new set of materials and then mastering that material by integrating it with earlier acquired knowledge as specified by the instructor. We refer to the ability to get high grades in a series of different courses as 'expert school performance', and it is measured by cumulative GPA. In the current study, we recruited students on the basis of cumulative GPA prior to the start of the semester (preGPA). PreGPAs were used as a measure of academic standing (or in expert performance terms, level of expertise) prior to the start of the semester. At the undergraduate level the knowledge in a new course requires continued mastery and thus our measure of superior school performance measures accumulated knowledge in addition to the generality of ability to learn material in the different courses taken by a given science major.

The current study uses methodology from the SRL approach to study developing expertise in bioscience students. We examine reproducibly superior science performance using expert performance methodologies (daily diaries) to examine SRL strategies across time-points.

2.2.1. Hypothesis set #1: the use of SRL strategies is stable and can be assessed by SRLIS for upper-level college science students

First, we wanted to examine traditional SRLIS methodologies in upper-level bioscience students. The first hypothesis examined the prediction that there would be significant differences in SRL strategies reported in the SRLIS for high- and low-achieving groups of upper-level college students majoring in science differing in their preGPAs.

2.2.2. Hypothesis set #2: event-based assessment of use of SRL strategies matches estimated use of strategies from SRLIS

We tested the hypotheses that event or state-based estimates of strategy use (i.e. strategies reported in diaries) would be correlated with trait-based estimates of strategy-use (i.e. strategies reported in the SRLIS). Thus, we hypothesized that the estimates for strategy presence would be highly correlated (i.e. the SRLIS and the diaries).

2.2.3. Hypothesis set #3: event-based assessment of SRL strategies, their stability across the target semester and the predictability of academic performance

We predicted that: a) there would be significant differences according to preGPA groups in the use of specific strategies estimated in diaries from the three weeks at different times during the semester; b) estimated strategy use from the diaries would reveal a more detailed pattern of differences if each diary week was analyzed separately, and c) variables corresponding to strategy-use differences would significantly predict subsequent performance, semGPA. Specifically, we hypothesized significant differences between preGPA groups in the *presence* of reported strategies as well as the *extent* (frequency and duration of application) for the three diary weeks across the semester, and that these differences would predict subsequent

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academic performance (c.f. Kitsantas, 2002; Sundre & Kitsantas, 2004). This finding would be consistent with the expert performance view that aspiring experts must continually evaluate their current performance and contexts (often with feedback from teachers and coaches) and modify their practice activities accordingly to obtain optimal performance outcomes (Ericsson, 2006b).

2.2.4. Hypothesis set #4: groups of strategies

We wanted to examine the extent to which differences in the large number of reported SRL strategies between preGPA groups reflected differences in a small number of components comprised of theoretically related individual strategies. Additionally, grouping variables reduces the number of individual analyses and improves statistical power. Thus, variables were collapsed according to categories discussed by Zimmerman and Martinez-Pons (1986). There were six categories of strategies: self-regulating, organizing, seeking information, mnemonic usage, seeking social assistance and reviewing (see also Appendix B). We predicted that analyses with these six categories would be similar to those with each SRL strategy. Thus, the results of analyses with groups of strategies are presented alongside each of the other sets of analyses, and then comparisons between analyses with individual strategies and those with groups of strategies will be discussed.

3. Method

3.1. Participants

Participants were Bioscience majors recruited from seven relatively high-enrollment, challenging classes (animal behavior, cell structure and function, conservation biology, genetics, immunology, plant biology and virology) as identified by the Dean of Arts and Sciences. During the first class period of the semester, students filled out eligibility questionnaires, which requested information about estimated GPA, year in college, major and contact information. Approximately 200 of the 300 students attending filled out the questionnaire, and participation was restricted to the 160 Bioscience majors who had completed at least two semesters (30 units) of college. According to their estimated GPA, students were categorized into high-achieving (GPA > 3.7), average-achieving (GPA >= 3 and <= 3.7) and low-achieving students (GPA < 3). Twenty-five eligible students were randomly chosen and contacted from each achievement level, of which 70 (93%) attended the initial interview. Of these students, 3 dropped the class that they were recruited from and 7 students dropped out of the study prior to diary completion (of these students, two were high-achieving, three were average-achieving, and two were low-achieving).

Of the 60 (80%) remaining students, 22 met the criterion for being high-achieving, 17 for average-achieving and 21 for low-achieving. Estimated GPA was verified with the students' permission from academic records. However, three of the 60 participants were newly transferred students. These students' data were not included in the analyses where cumulative GPA (preGPA) was the between-subjects variable. Recruitment of students based on their reported GPA was considered successful, as the correlation between estimated and actual GPA was high ($r(57) = .92$, $p < .01$). Mean GPA at intake was 3.29 ($SD = .54$, range = 2.27–4.00). Mean SAT-verbal score was 567.58 ($SD = 85.42$, range = 360–750), mean SAT-math score was 586.03 ($SD = 75.45$, range = 400–750) and mean SAT-total was 1153.02 ($SD = 144.66$, range = 770–1480) Fifty-eight of the 60 remaining participants completed the diaries for all three diary weeks (16 males and 42 females, mean age = 19.50 SD = .99). Students were paid for their participation ($15 per hour for approximately 4 h) and given a monetary bonus ($15) for completing all parts of the study ($75 in potential earnings).

The sample size in the current study was relatively small compared to other studies using questionnaires or one-time interviews. Participants completed both interviews and diaries, which made the current study rather data intensive. Furthermore, to reduce volunteer bias and increase motivation for participating for approximately 4 h, participants were paid for their participation. Thus, while the sample size reflects constraints in laboratory resources (i.e. hours in the semester, monetary, etc.), we hypothesized that collecting data from seven days at three different weeks during the semester would give us more data to calculate more reliable estimates of strategy use than those derived from studies based on a single interview or one-time questionnaire and thus perhaps reducing the need for studying many participants.

3.2. Materials

3.2.1. SRLIS interview

The SRLIS was designed to be as similar as possible to the version used in Zimmerman and Martinez-Pons (1990) study with eight learning contexts. The wording of some questions was, however, modified slightly to be more applicable to adult college students (e.g. the word 'professor' was used instead of 'teacher', and 'teaching assistants' were mentioned instead of 'adults') (see Appendix A).

Interviews were coded by two researchers independently according to the 15 SRL strategies (14 SRL strategies plus one category for 'other', as described in Zimmerman & Martinez-Pons, 1986 — see Appendix B). Multiple strategies were tallied and summed across eight contexts. For each strategy, strategy presence (whether or not a strategy was reported during the entire interview) and strategy frequency (how many times a particular strategy was mentioned across the interview) were recorded. Strategies were then collapsed into six categories for analyses: self-regulating (including the variables self-assessing, goal-setting and planning, keeping records and monitoring, environment restructuring, and self-consequences), organizing, seeking information, mnemonic usage (memorizing), seeking social assistance (including the variables seeking assistance from peers, tutors, and professors) and reviewing (including the variables reviewing previous problems, notes, and textbook).[2]

3.2.2. Daily diaries

The daily diary template was a computerized text file containing a table with a row for each of 15-minute time periods over 24 h (midnight to midnight). Each row had column headings for detailed information, such as 'time', 'location', and 'activity'. Participants were instructed to fill out each row, being as specific as possible (except with private activities). With regard to studying activities, students were requested to indicate when and where they were studying, with whom, and what materials they were using.

Studying activities across courses were coded according to the 15 SRL strategies described in Zimmerman & Martinez-Pons (1986, see Appendix B). For each diary week, each strategy was given a presence value (whether or not a strategy was reported at least once), frequency value (number of times a strategy was reported during the diary week) and total duration value (total time a strategy was used in hours). Three of the 15 SRL strategies were not included in any diary analyses: 'self-consequences' and 'environment structuring'

[2] Both diary and interview strategies were coded by two independent researchers. Inter-rater reliability was calculated for all interview strategies, and it was determined that all strategies had interclass correlations above (two-way, random) .90. Inter-rater reliability was also calculated for the 12 diary strategies with significant GPA group differences ($p < .01$). It was determined that all but three strategies had interclass correlations (two-way, random) above .90. Presence of seeking assistance from peers during the midterm week had an interclass correlation above .80, and presence of organizing and seeking information had interclass correlations above .75. There was only one strategy with significant GPA group differences at the $p < .01$ level, frequency of organizing and transforming, which had an interclass correlation above .85.

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were difficult to assess from the entries in diaries, and the strategy 'other' was not used as participants were contacted within 24 h to clarify activities that could not be coded. Similar to the interview analyses, strategies were collapsed into 6 categories: self-regulating, organizing, seeking information, mnemonic usage, seeking social assistance, and reviewing. Also, similar to Kitsantas' studies (Kitsantas, 2002; Sundre & Kitsantas, 2004), a variable corresponding to total number of strategies reported (out of 12 possible strategies) was also recorded and included as a strategy variable in the analyses. Each diary entry was coded by two researchers independently[2].

3.3. Procedure

At the first meeting, which occurred towards the beginning of the semester, participants were administered the SRLIS (Zimmerman & Martinez-Pons, 1986, 1990). Participants were then instructed in how to complete the daily diaries. Participants were sent the daily diary template at the beginning of the three diary weeks by email. Participants were instructed to fill out their diaries *each* evening and send them to the primary investigator via e-mail everyday, between midnight and 9 am, for seven days. If students sent diaries late, reminders were sent and the students were warned to send diaries within 24 h. According to these rules, two students were unable to complete all three diary weeks. There was no significant difference between preGPA and semGPA groups according to students that provided late entries (in each case, $F(2, 57) < 1$, $p > .05$). If any studying activity reported in the diary was unclear (e.g., 'studying' with no further description), the participant was contacted via e-mail or phone by the principal investigator and the item was clarified within 24 h. In order to clarify, participants were instructed to give details as to what course they were studying for, what materials were being used, how these materials were being used, and how long they were studying for. Although several of the students were asked for clarifications, particularly in the first week, no students' diary entries were eliminated due to failure to respond to request for clarifications in a timely manner. The schedule of diary completion was planned according to class schedule, such that participants completed one week of diaries during a midterm test in the class from which they were recruited and two weeks during which there were no midterms in that class (i.e., week 1 = beginning of the semester, week 2 = midterm week, week 3 = end of the semester).

4. Results

The current study had four sets of hypotheses, and the analyses associated with each are addressed in turn.

4.1. Hypothesis set #1: the use of SRL strategies are stable and can be assessed by SRLIS for upper-level college science students

4.1.1. Strategy presence scores

Individual ANOVAs of each of the 15 strategies with preGPA groupings as a between-groups factor were conducted for each type of strategy to examine group differences in individual strategies more closely. None of the strategies differed significantly between groups (in each case, $p > .01$). Similar analyses were conducted for each of the 6 categories of strategies, but no significant differences between groups were observed (in each case, $p > .01$).

4.1.2. Strategy frequency scores

When similar analyses were conducted for the 15 variables coding for frequency of strategy use, there were no strategies reported during the SRLIS that differed significantly between groups (in each case, $p > .01$). Additionally, similar analyses conducted for each of the 6 categories of strategies also yielded no significant differences between groups (in each case, $p > .01$).

Contrary to our first hypothesis, in the current sample of upper-level college science students the strategies in SRLIS did *not* reveal significant differences between preGPA groups at the $p < .01$ level. Our analyses of individual strategies and the six categories of strategies uniformly failed to find any significant differences between groups.

4.2. Hypothesis set #2: event-based assessment of use of SRL strategies matches estimated use of strategies from SRLIS

As described in the methods section, only 12 of the 15 SRL strategies could be assessed from the diaries. To compare the information about strategy use from the diaries to those derived from the SRLIS, we first averaged the information across the three diary weeks to yield a single, dichotomous score for each study strategy's presence (e.g. for 'reviewing the textbook', we determined whether or not the participant engaged in the strategy across the three weeks and scored the strategy as '1' for present and '0' for absent). For diary frequency variables, we averaged information across the three weeks to reveal an average score for each study strategy. The agreement of the measures of strategy presence and frequency assessed from the two interviews and the aggregated diaries was evaluated by calculating correlation coefficients.

The strategy presence for 'reviewing notes' and 'reviewing textbook' in the diaries was at 100%, making it impossible to compute any correlation with the SRLIS. An analysis of the phi correlations (for comparison of dichotomous variables) between the variables derived from the SRLIS and the diary data for each of the 10 remaining strategies revealed no significant correlations (in every case, $p > .05$).

When comparing estimates of strategy frequency for the SRLIS and the diaries, it was revealed that only one strategy was positively correlated between measures — organizing and transforming, $r\ (58) = .375$, $p < .01$. Thus, contrary to our initial hypotheses from the second set of hypotheses, it was revealed that almost all the corresponding diary and interview variables were not significantly correlated.

When conducting the same analyses with 6 categories of strategies, we created dichotomous variables that collapsed across the three time-points and across strategies. For example, with the 'reviewing' strategy, participants were awarded '1' if they engaged in any reviewing strategy across the three weeks examined and '0' if they did not. Similar results to the individual analyses were obtained, such that there were no significant correlations except for organizing and transforming ($r\ (58) = .375$, $p < .01$). The result for organizing and transforming was identical to that from the analysis of the individual strategies because the category of organizing and transforming consisted of data on a single strategy.

4.3. Hypothesis set #3: event-based assessment of SRL strategies, their stability across the target semester and the predictability of academic performance

To go beyond the results based on averages across the three diary weeks and examine specific strategy-use more closely across time-points, repeated measures ANOVAs were conducted to assess the significant group differences in reported strategy usage across the three weeks. Separate analyses were performed for each strategy, with strategy-use across weeks as the within-subjects variable and preGPA groupings as the between-subjects variable. Only main effects and interactions significant at the $p < .01$ are reported. The effects on the presence, frequency, and duration of study strategies will be reported in separate sections for diary week, preGPA grouping, and their interactions.

4.3.1. Significant main effects of diary week on strategy use

Main effects of week reflect a tendency for students across the three GPA groups to change their study strategies at the three diary

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Table 1
Means, standard deviations, F-values, and effect sizes (partial eta-squared) for significant main effects of week reported in the diaries.

Variable	Week 1		Week 2		Week 3		Overall		F-value	Effect size
	M	SD	M	SD	M	SD	M	SD		
Presence of organizing and transforming	0.43	0.07	0.69	0.06	0.67	0.06	0.59	0.04	6.37	0.11
Presence of reviewing notes	0.82	0.05	0.98	0.01	0.81	0.05	0.87	0.26	5.04	0.09
Frequency of reviewing notes	3.00	0.43	6.18	0.46	4.36	0.59	4.51	0.35	14.08	0.21
Frequency of studying	20.8	1.52	26.4	1.33	23.65	1.59	23.62	1.16	4.18	0.07
Duration of reviewing notes	2.56	0.37	5.84	0.54	4.19	0.59	4.2	0.38	15.88	0.23

Table 2
Means, standard deviations, F-values and effect sizes (partial eta-squared) for significant main effects of PreGPA group.

Variables	Low achieving		Average-achieving	High-achieving	Overall				F-value	Effect size
	M	SD	M	SD	M	SD	M	SD		
Presence of organizing and transforming	0.37	0.07	0.71	0.07	0.7	0.07	0.59	0.04	7.57	0.23
Presence of seeking information	0.13	0.07	0.38	0.07	0.56	0.06	0.35	0.04	10.13	0.28
Presence of reviewing textbook	0.7	0.05	0.94	0.05	0.94	0.05	0.86	0.03	7.19	0.22
Number of strategies	4.9	0.3	6.21	0.32	7.06	0.28	6.06	0.18	13.57	0.34
Frequency of seeking information	0.2	0.28	0.88	0.3	1.73	0.26	0.93	0.16	7.94	0.23
Frequency of reviewing notes	2.59	0.61	5.56	0.65	5.38	0.56	4.51	0.35	7.34	0.22
Frequency of studying	17.33	2.01	24.6	2.13	28.91	1.86	23.62	1.16	7.74	0.22

weeks depending on the time during the semester (for means, standard deviations, F-values and effect-sizes of significant main effects, see Table 1). There were two significant main effects of week for strategy presence: organizing and transforming (with significant contrasts such that the strategy was used by more students in week 2 and 3 than week 1) and reviewing notes (with significant contrasts such that the strategy was used by more students in week 2 than in week 1 or 3).[3] There were significant main effects of week for all six categories of strategy. In the case of self-regulating and organizing, contrasts were significant such that the strategies were used by more students during both weeks 1 and 2 than week 3, but there were no significant contrast between weeks 1 and 2. For the remaining strategy categories (seeking information, mnemonic usage, reviewing, and seeking social assistance), there were significant contrasts such that strategies were used by more students during week 1 than week 2 or week 3, but there were no significant contrasts between weeks 2 and 3.

There were also two significant main effects of week for strategy frequency: reviewing notes differed across weeks (with significant contrasts such that the strategy was used more frequently in week 2 than in week 3) and the total frequency of studying (with significant contrasts such that the total frequency of strategies was greater in week 2 than in week 1). Similarly, the same two significant main effects of week emerged for strategy frequency of categories: the reviewing category differed across weeks (with significant contrasts such that the strategy was used more frequently in week 2 than in week 1 or 3) and the total frequency of studying (with significant contrasts such that the total frequency of studying was greater in week 2 than in week 1).

Finally, there was one main effect of week for strategy duration: reviewing notes (with significant contrasts such that the strategy was engaged in for the longest duration during week 2, followed by week 3 and week 1). Similarly, the duration of the category of reviewing yielded a significant main effect of week, with similar significant contrasts.

4.3.2. Significant main effects of groups differing in preGPA

A main effect of preGPA group reflected general preGPA group differences averaged across weeks (for means, standard deviations, F-values, and effect sizes of significant main effects in partial eta-squared, see Table 2). There were four significant main effects of group for strategy presence: organizing and transforming, seeking information, reviewing textbook, and the number of strategies used. In each case, contrasts between high- and low- and average- and low-achieving students were significant, such that both high- and average-achieving students engaged in the strategies more than low-achieving students. Analysis of the strategy categories revealed similar significant main effects of the organizing strategy (with similar significant contrasts).

There were also three significant main effects of groups for strategy frequency: seeking information, reviewing and overall frequency of studying. In each case, contrasts between high- and low- and average- and low-achieving students were significant—with the exception of seeking information, where only the contrast between high- and low-achieving students was significant. Similarly, there were three significant main effects of group for strategy frequency of category: organizing, seeking information, and reviewing. There were no significant contrasts in the organizing category, but for each of the other categories high-achieving students used the strategies more frequently than low achieving students.

There were no significant main effects of group for duration of any strategy or category at the $p<.01$ level.

4.3.3. Significant interactions between week and preGPA grouping

A week-by-preGPA interaction reflected the tendencies of certain preGPA groups to use specific strategies during specific weeks (for means, standard deviations, F-values, and effect sizes of significant interactions in partial eta-squared, see Table 3). There was only one significant week by preGPA interaction for the strategy presence, namely in number of students that reported seeking assistance from peers (with high-achieving students engaging in the strategy more than low-achieving students during week 2 and low-achieving students engaging more in seeking assistance than average-achieving students during week 3). A similar interaction was found with the frequency of the category of seeking assistance, with a similar pattern of significant contrasts.

There was also only one significant week by preGPA interaction for both strategy frequency and strategy duration, namely in the seeking assistance from peers (with low-achieving students engaging in the strategy more than average-achieving students during week 3 in both cases). Similar interactions were found with frequency

[3] All significant contrasts were corrected using Bonferroni adjustments (9 contrasts for interactions and 3 contrasts for main effects).

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Table 3
Means, standard deviations, F-values and effect sizes (partial eta-squared) for week-by-preGPA group interactions.

Variables	Low achieving		Average-achieving		High-achieving		Overall		F-value	Effect size
	M	SD	M	SD	M	SD	M	SD		
Presence of seeking assistance from peer — week 2	0.22	0.11	0.38	0.12	0.67	0.1	0.43	0.05	4.03	0.13
Presence of seeking assistance from peer — week 3	1.32	1.57	0.17	0.41	0.52	0.78	0.69	1.14	4.03	0.13
Frequency of seeking assistance from peer — week 3	1.61	0.31	0.18	0.33	0.74	0.29	0.84	0.14	4.34	0.14
Duration of seeking assistance from peer — week 3	1.32	0.25	0.17	0.27	0.52	0.23	0.72	0.12	4.61	0.15

and duration of engaging in seeking social assistance categories, with similar contrasts.

4.3.4. Total duration of studying

A recent study from our lab examined time-use in college students and found no significant difference between amount of time spent studying and GPA (Plant et al., 2005). The current study confirmed these results overall. However, when ANOVAs were performed with total hours spent studying in a given week as dependent variables and preGPA grouping as the independent variable, there was a significant difference between groups for week1, a non-midterm week towards the beginning of the semester, $F(2, 56) = 7.112$, $p < .01$, $\eta_p^2 = .20$, with significant contrasts between both high- and average- and high- and low-achieving students ($M = 24.77$, $SD = 7.90$ for high-achieving students, $M = 17.51$, $SD = 8.89$ for average-achieving students and $M = 14.87$, $SD = 9.66$ for low-achieving students).

In sum, we found support for our predictions from the analysis of the third set of hypotheses. Additionally the results of the strategy category analyses were very similar to the individual strategy analyses. We will discuss this further in the discussion section.

4.4. Hypothesis set #4: groups of strategies

In order to examine the extent to which differences in the large number of reported SRL strategies between preGPA groups reflected differences in a small number of components comprised of theoretically related individual strategies, we collapsed individual strategy variables according to categories discussed by Zimmerman and Martinez-Pons (1986). We predicted that analyses with these six categories would be similar to those with each SRL strategy. Indeed, the analyses were largely similar, with few differences in significant main effects and interactions. With so few differences, it would appear to be more efficient and statistically sound (in terms of power and number of analyses) to use categories instead of individual analyses. Thus, we examined the differences in the amount of variance in subsequent performance explained by individual strategies and categories of strategies.

4.4.1. Predicting subsequent performance

In order to determine how much of the overall performance (as measured by semGPA) is accounted for by strategy usage, linear regressions were conducted with semGPA as the dependent variable. Strategies were entered as independent variables. The variables with significant ($p < .01$) main effects of GPA and week-by-GPA interactions entered stage-wise into the regression equation (for a list of strategies and correlations between strategies, see Table 4). The analysis revealed that strategies accounted for 51% of the variance, $F(12, 45) = 3.90$, $p < .001$. Next, a similar analysis was conducted with strategy categories. Five variables were chosen because of their significant ($p < .01$) main effects of GPA and week-by-GPA interactions: frequency of organizing, seeking information, reviewing, and seeking social assistance and presence of organizing (for each strategy, week 1 frequency/presence was entered). The analysis revealed that strategies accounted for 10.8% of the variance, $F(5, 54) = 2.42$, $p < .05$. When frequency/strategy overall variables were entered rather than the week 1 variables, the amount of variance accounted for increased to 21.8%, $F(5, 54) = 4.30$, $p < .01$.

In order to determine which individual strategies predicted subsequent performance best, a step-wise regression analysis was conducted with semGPA as the dependent variable and the 12 selected variables from the diaries described above as independent variables. The results of this analysis revealed that three variables accounted for 45.8% of the variance $F(3, 54) = 15.098$, $p < .01$ ($R^2 = .456$, adjusted $R^2 = .426$): presence of seeking information, presence of reviewing the textbook, and presence of seeking assistance from peers during the midterm week (see Table 5). When a similar analysis was

Table 4
Means, Standard Deviations, and zero-order correlations for variables with significant main effects of preGPA group and week-by-preGPA group interactions.

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12
Var 1	0.59	0.04												
Var 2	0.35	0.04	.35*											
Var 3	0.86	0.03	.45*	0.04										
Var 4	6.06	0.18	.53*	.54*	.40*									
Var 5	0.43	0.05	0.04	0.22	0.09	.38*								
Var 6	0.69	1.14	−0.17	−.34*	−0.01	0.01	0.23							
Var 7	0.93	0.16	.35*	.81*	0.03	.55*	0.13	−0.33						
Var 8	4.51	0.35	.43*	−0.01	.37*	.37*	0.03	−0.06	0.03					
Var 9	0.84	0.14	−0.22	−0.33	−0.12	−0.05	0.15	.68*	−0.28	−0.04				
Var 10	0.72	0.12	−0.21	−0.31	−0.13	−0.09	0.12	.67*	−0.28	−0.07	.94*			
Var 11	23.62	1.16	.63*	.43*	.45*	.85*	.34*	0.01	.46*	.51*	0.01	−0.05		
Var 12	19.43	9.77	.37*	.35*	0.25	.63*	0.25	0.08	.35*	.37*	0.06	0.04	.65*	
preGPA	3.29	0.54	.41*	.52*	.39*	.54*	.36*	−0.21	.41*	.36*	−.30*	−.35*	.46*	.38*
semGPA	3.09	0.84	.39*	.46*	.43*	.46*	.40*	−0.13	.35*	0.22	−0.28	−0.27	.46*	0.28

Note. Var 1 = presence of organizing and transforming, Var 2 = presence of seeking information, Var 3 = presence of reviewing textbook, Var 4 = number of Strategies, Var 5 = presence of seeking assistance from peers during midterm, Var 6 = presence of seeking assistance from peers late, Var 7 = frequency of seeking information, Var 8 = frequency of reviewing notes, Var 9 = frequency of seeking assistance from peers late, Var 10 = duration of seeking assistance from peers late, Var 11 = frequency of studying, Var 12 = duration of studying early. Correlation between preGPA and semGPA, $r = .67$, $p < .0$.

* $p < .01$.

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Table 5
Regression results — diary and modified SRL variables predicting semGPA.

Model	B	SE	Beta
Constant	1.33	.33	
Var 2	.95	.26	.38
Var 3	1.39	.36	.39
Var 5	.48	.17	.29

Notes. Var 2 = presence of seeking information, Var 3 = presence of reviewing textbook, Var 5 = presence of seeking assistance from peer during midterm, total $R^2 = .456$, adjusted $R^2 = .426$.

conducted with the category variables, using the frequency/presence overall variables, the results of the analysis revealed that two variables accounted for 24.4% of the variance, $F(2, 57) = 10.55$, $p < .01$, seeking information and reviewing.

To examine whether categories accounted for a similar proportion of the variance as using individual strategies, the two category variables from the stepwise regression described were entered into a regression equation, followed by the three individual strategy variables. Then, the category variables were removed from the regression equation. The results revealed that the addition of the individual strategy variables added significant variance to the category variables, F_{change} $(3, 52) = 5.32$, $p < .01$, $R_{change} = .160$. However, the removal of the category variables did not result in a significant change in variance accounted for. Thus, while using the category variables did reveal for significant differences in preGPA groups accounting for a significant proportion of the variance in subsequent performance, using individual strategies accounted for significantly more variance.[4]

4.4.2. Intellectual capacity and SRL strategies

In several of the results outlined, it seemed that there were significant differences between high- and low- and even average- and low-achieving students, but not between high- and average-achieving students, despite the clear differences in academic performance. One possibility is that intellectual capacities may differentiate between these students, giving high-achieving students an academic edge to outperform average-achieving students who are otherwise engaging in similar strategies.

It is well known that SAT scores correlate with GPA in college (Frey & Detterman, 2004, for a review, see Willingham, Lewis, Morgan, & Ramist, 1990). In the current study, the correlation between SAT-Total (SAT-T) and semGPA was $r(56) = .37$, $p < .01$. When an ANOVA was conducted comparing the SAT-T performance of GPA groups, there were significant differences between groups, $F(2, 55) = 4.95$, $p < .01$, however with post-hoc tests revealing significant differences between high- and low- and average- and low-achieving students only. Furthermore, SAT-T scores accounted a significant proportion of the variance in semGPA ($R^2 = .158$, adjusted $R^2 = .143$), $F(1, 56) = 10.474$, $p < .01$). When SAT-T was added after the significant SRL strategies described in the step-wise regression above, SAT-T was not associated with associated with a significant increase in the proportion of the accounted variance (around 3% increase), F_{change} $(1, 53) = 3.01$, $p > .05$.

5. Summary and general discussion

In our investigation of adult learners studying advanced semester-long courses in their area of major specialization we uncovered four distinct findings that support the essential role of self directed learning and the context sensitive use of particular SRL strategies (Zimmerman, 2008). First, the average engagement in particular SRL strategies across all groups differed across phases of the semester-long course. For example, overall students engaged in organizing and transforming and reviewing notes more frequently and for longer durations of time during the midterm week than other weeks.

Second, the analysis of the diaries identified individual differences in use of strategies that differentiated significantly between groups differing in the academic performance prior to the target semester (preGPA). Students who had attained higher grades in prior semesters were found to use a larger number of different strategies and were more likely to engage in strategies such as organizing and transforming, seeking information, and reviewing strategies more than low-achieving students.

Third, the analysis of the diary data identified differences in strategy use that differentiated between preGPA groups at specific time-points based on significant week-by-GPA group interactions. For example, we found that high-preGPA students sought more assistance from their peers during midterm weeks than low-achieving students, while towards the end of the semester, low-achieving students engaged in this strategy more than average-achieving students did. A similar result was found when examining the total amount of time spent studying. Our study found no overall significant relation between the total amounts of time spent studying and preGPA, consistent with several other investigations (for a review, see Plant et al., 2005). However, the diary data showed that high-preGPA students spent more time overall in study-related activities earlier on in the semester than *both* average- and low-achieving students. Later on in the semester, differences in the overall duration of studying were no longer significant.

Finally, in order to explore whether strategies could be grouped according to theoretical conceptions (and in order to reduce the overall number of analyses), we collapsed strategies into categories (following the recommendations by Zimmerman & Martinez-Pons, 1986) and conducted similar analyses to those performed with individual strategies. We found that the results from both analyses were largely similar, with a similar pattern of significant main effects and interactions. However, when comparing individual strategies and categories in their ability to predict subsequent performance, we found that while both predicted significant amounts of variance, individual strategies predicted significantly more variance. Thus, although it may be more convenient (or more statistically robust) to use categories instead of individual strategies in analyses, the use of individual strategies in our study was more informative and predictive of the outcomes of the semester-long courses.

In comparison to earlier SRL studies that assessed the kind of strategy-use that differentiated high-achieving students by questionnaires, our diary methodology provides a day-to-day description of the actual use of SRL strategies by adult students at the upper-division college level. First, the diary provides information on the *extent* to which students use specific strategies (i.e. frequency and duration of the associated study and learning activity). Second, we were able to determine *when* (at which point during the semester) students used strategies linked to superior academic performance. In combination, this specific information obtained about the actual use of strategies (i.e. what, how much, and when) predicted a large proportion of the variance in the current semester's GPA.

[4] Of potential interest, we conducted a principle components analysis (PCA). The Kaiser–Meyer–Olkin measure of sampling adequacy was good at .785. Three principle components emerged with Eigenvalues > 1.0. The first component (Component 1) evidenced loadings >.40 from activities including organizing and transforming, seeking information, reviewing variables and overall preparation variables (i.e. overall time spent studying during week 1, overall number of strategies used). This component accounted for 36% of the variance in responses, overall. The second component included variables associated with seeking assistance from peers and accounted for 23% of the variance in responses. The third component was harder to interpret, as it included loadings from seeking information variables as well as from reviewing variables, but the latter were negatively loaded and accounted for 13% of the variance in responses, overall. When participants' scores for each of the three components were entered stepwise into a regression analysis for predicting semGPA, only Component 1 accounted for significant variance $F(1, 56) = 30.261$, $p < .01$ ($R2 = .351$, adjusted $R2 = .339$).

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5.1. Reconciling our findings with earlier studies on self-regulated learning

When we used the SRLIS interview to assess the use of SRL strategies among our adult learners, we did not find individual differences related to academic performance. This finding may appear to be inconsistent with the findings by Zimmerman and Martinez-Pons (1986, 1990), who found significant correlations between strategies assess with the SRLIS interview and academic performance in their studies of high-school students. There are several possible reasons for the differences between our study and those by Zimmerman and Martinez-Pons (1986, 1990).

One potential explanation for our lack of significant findings was the relatively small size of our sample (60 students). However, although the sample size in the current study is small relative to several of the studies employing questionnaires, the sample size is comparable to the main studies using interviews (e.g. Kitsantas, 2002 — 62 students; Zimmerman & Martinez-Pons, 1986, 1988 — 80 students).[5] Indeed, power calculation based on our regression analysis using three significant predictors (seeking information, reviewing the textbook, and seeking assistance from peers) was comparable to those calculated from regressions presented in Kitsantas (2002) and Zimmerman and Martinez-Pons (1986) data (0.99 versus 0.96 and 1.00 respectively).

Our sample was collected differently from the studies by Kitsantas (2002) and Zimmerman and Martinez-Pons (1986, 1988), who studied a single class of students. In contrast, our sample consisted of students from several smaller advanced undergraduate classes. Given the small sizes of advanced bioscience classes in college it was necessary to recruit from several classes to obtain a sufficiently large sample of bioscience majors. However, our sample was quite homogenous and all participants had completed the class requirements in the first two years in the major for bioscience. A study examining and comparing SRL in a specific advanced college science course with much larger enrollments would address this issue, and such studies are under way.

Considering the fact that we found very robust results for differential use of SRL strategies based on the diaries, but not with SRLIS interview, we argue that the differences between the studies concerned the level of development and types of the learners. Zimmerman and Martinez-Pons (1986, 1990) assessed differences between high and low-performing students in high-school. In contrast, our study assessed a select group of advanced college students who were majoring in bioscience. In our college sample, even the low-performing college students represent a group of individuals who, a few years earlier, had high grades in high school. The college students in our study had earned acceptable high-school GPAs and SAT-scores in order to be admitted into university and at least *some* level of academic success in college in order to be enrolled in the upper-level science program. Thus, it is likely that this select group of advanced undergraduates would not differ in terms of their knowledge of available SRL strategies, which was the target of SRLIS interview.

There are interesting similarities with this finding and studies of the amount of engagement in deliberate practice in the acquisition of expert performance. For example, skilled individuals working toward a full-time professional career in music often agree about their ratings of relevance of different practice activities for improving performance, however, the observed differences in music performance among the skilled musicians could be accounted for by the amount of time they engaged in the deliberate practice activities during their careers (Ericsson et al., 1993). In contrast, observational studies of children, who are told to practice alone, show that the children do not engage in deliberate practice and seem to keep repeating errors in an almost mindless manner (McPherson & Renwick, 2001). Consistent with these observations of the poor quality of practice of many beginning music students, research has found that the amount of time music students spend practicing alone is not closely related to improvements in music performance (Lehmann, 1997). In a similar vein, in populations of performers that differ more in their skilled performance – include both amateurs and experts in chess – the ratings of relevance of activities have been found to differ as a function of attained skill (Charness, Krampe, & Mayr, 1996). Thus, deliberate practice activities, where accumulated engagement is correlated with attained chess skill are judged to be much more relevant for improving performance by the most skilled chess players than the least skilled chess players, which in turn may explain why less skilled players engage less in those effective deliberate practice activities.

The current study examined different methodologies for assessing SRL strategies in order to examine issues concerning the generality and stability of SRL strategy-use. As mentioned above, if SRL strategies were aptitude or trait-like, we would expect responses on interviews and diaries to be highly correlated. On the other hand, if SRL strategies differed according to context, or state-like, we would expect responses on interviews to be less predictive of overall performance than a more concurrent measure, such as diaries. Our findings support the latter interpretation and notions of developing expertise – that college students' strategy-use is flexible according to context.

5.2. Towards identification of deliberate practice activities in high-achieving science students

The findings from the analyses of our diary data show that the pattern of studying that differentiates high-achieving students from less accomplished students includes information regarding both frequency of strategy-use and time-point during the semester. Our results suggest that mere knowledge of a strategy does not appear to be sufficient when considering college students: timing and the extent to which strategies engaged in are essential, which is in line with both deliberate practice and SRL conceptions (e.g. Boekaerts & Corno, 2005; Ericsson, 2006a). Moreover, the strategy category analyses converged with our individual strategy analyses, revealing that studying early and using strategies such as organizing and transforming, seeking information from external sources, and seeking assistance from peers differentiated between preGPA groups of students and significantly predicted subsequent performance. Furthermore, these activities are best captured by online, concurrent measures, such as episodic interviews and diaries.

The relation demonstrated between these strategy use and grades at the college level suggests that interventions guiding low-achieving students (as identified by preGPA) to improve their study habits will increase the quality of students' learning and, ultimately, their performance on subject matter tests. Thus, future interventions and training programs should investigate methods such as guided study groups and tutorials to encourage college students to use the appropriate strategies at the relevant time periods during the semester.

5.3. Limitations and prospects of our study

Our investigation demonstrates the value of adopting data collection methods from the expert performance approach to monitor the use of SRL strategies in adult learners who are extending their knowledge by

[5] A potential limitation of our replication with college students is that, unlike Zimmerman and Martinez-Pons (1986) first study (but similar to a subsequent study Zimmerman & Martinez-Pons, 1990) our study did not request that students rate how consistently they used each strategy measure. Zimmerman and Martinez-Pons (1990) called this variable 'strategy consistency', and students were asked to rate their consistency on a 5 point scale (0 = never, 4 = always). On the other hand, Zimmerman and Martinez-Pons (1986, 1990) reported a similar pattern of significant results for their two other measures (strategy frequency and presence), which were not replicated with our current sample. We do agree, however, that further studies examining the SRLIS with upper-level college students should include this additional measure for a more complete replication and current studies conducted in our laboratory are also attempting to address this issue.

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taking advanced courses. Specific strategies and associated activities were used significantly more by high-achieving students, such as studying early, seeking information and organizing at a greater frequency. The development of such situated strategies over time is in line with conceptualizations from both expert performance and SRL conceptions of the development of superior performance (for reviews, see Boekaerts & Corno, 2005; Ericsson, 2006a; Zimmerman, 2008).

The diary methodology offers some advantages over traditional interviews. There is an impressive body of research that has evaluated the validity of diaries against independent observations using video recordings (see Robinson, 1999, for a review). Appropriate diary collection might avoid some of the problems associated with the interviews, such as the low correlations between attitudes and predicted behaviors and the corresponding observed behaviors (Ericsson & Simon, 1993; Tourangeau, Rips, & Rasinski, 2000; see also Veenman, Prins, & Verheij, 2003; Winne & Jamieson-Noel, 2002). However, future research with diaries could be improved by including opportunities for explicit validation of the reported information by direct observations, indirect observation of studying and problem solving on the internet and/or "think aloud" protocols during study activities.

In order to obtain a better understanding of adult learning, an investigation of the motivational and metacognitive components of SRL is required. These particular factors were not directly measured in the current study. It could be argued that certain activities, such as studying early in the semester in the absence of imminent midterms and exams, could be an indirect measure of motivation, but further research is necessary to replicate those findings. Additionally, the diaries did not include information about metacognitive strategies, such as self-consequences and monitoring while learning (e.g. Azvedo, Guthrie, & Siebert, 2004; Winne & Jamieson-Noel, 2002; for a review, see Zimmerman, 2008). Combining longitudinal diary studies with intermittent examinations of individual students studying particular course-related materials while producing think-aloud protocols would address this problem, and such studies are also currently under way.

Until supplementary experiments and studies are conducted we cannot determine whether increased SRL strategy use causes higher academic performance or is merely correlated. However, we can consider alternative hypothetical mechanisms mediating the observed relations. For example, one criterion of deliberate practice is that the activity permits repetitions with immediate feedback. More systematic studying early in the semester would allow the higher achieving student several advantages. It would allow them to master material earlier, but perhaps more importantly to gain an overview of what they already know and which aspects they would need to allocate more study time and request help from teachers and peers well in advance of the first exams in the course. Only further studies identifying the detailed relations between developed knowledge structures and SRL strategies could permit clarification of these issues. Recent research has used diaries to examine the effectiveness of SRL training (Schmitz & Wiese, 2006; Stoeger & Ziegler, 2008). The current methodology can contribute to this body of research by uncovering specific strategies that are effective for adult learners (upper-level college students). However, to demonstrate that the engagement in such strategies will cause improvements in academic performance it will be necessary to demonstrate benefits using randomized trial studies to compare different training interventions.

Lastly, the current methodology needs to be extended to allow us to analyze the detailed processes of SRL strategy-use. This may reveal differences between average- and high-achieving students, who did not differ their reported SRL strategy-use or SAT scores in the current study but did differ significantly in their subsequent performance. For example, two students may both report reviewing their textbook for half an hour, but while one is merely reading the text, the other may be actively retrieving relevant examples (e.g. Chi et al., 1989). Studies examining think-aloud protocols while students are studying representative materials would address such issues, and such studies are currently being conducted by our labs (Nandagopal & Ericsson, 2010). A complementary approach would be to examine study activities that yield some directly observable output, such as preparation of homework assignments and solving problems online on a monitored website (e.g. Penn, Nedeff, & Gozdzik, 2000).

The current study has taken steps toward describing individual differences in the self-regulated learning of adults when they are facing a representative task of expanding their knowledge in their area of specialization (major). We believe that these advanced college students have developed important study skills that allow them to acquire new knowledge in their area of specialization in an effective manner. Further research on this group of advanced college students taking challenging science courses will have dual benefits. Our knowledge of how these students learn can help in the design of training interventions to improve the academic performance of less accomplished students. Furthermore, understanding how these advanced college students are capable of learning will increase our knowledge of adult learners throughout our society and how we can support their life-long learning. Specifically, we propose that a closer integration of the SRL and expert performance approaches will allow investigators to more fully understand effective studying and make important contributions towards improving instruction and supporting students' and adults' learning in our schools and colleges as well as in domains of professional expertise. A successful framework for understanding how to better develop school, college, and professional education should lead to an integration of the bodies of knowledge on effective learning across the life span.

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Appendix A. Self-regulated learning interview

This interview closely resembles Self-Regulated Learning Interview Schedule designed by Zimmerman and Martinez-Pons (1986). Some of the questions have been reworded in order to be more appropriate for college students.

1. Most teachers give important tests at the end of marking periods, and these tests greatly affect report card grades. Do you have a particular method for preparing for these tests? What if you were preparing for a particularly difficult test?
2. What if your professor says that you must write a short paper about a topic in your major area of study. Your score on this paper will affect your report card grade. In such cases, do you have any particular method to help you plan and write your paper? What if you were having difficulty with the topic?
3. Sometimes in college, students must work without the help of their professors or TA's. Is there a particular method you use when you don't understand question in your homework? What would you do if the assignment deals with a very difficult type of problem?
4. When completing homework assignments, do you have a particular method for checking your work after it is finished? What if it is a difficult assignment?

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5. When taking a test, do you have a particular method for obtaining as many correct answers as possible with a) multiple choice questions; b) short-answer; c) essay questions? What if it is a particularly difficult test question?
6. Many times, students have difficulty completing homework assignments because there are more interesting things they would rather be doing, such as watching TV, talking to friends, etc. Do you have any particular method for motivating yourself to complete your homework or studying under these circumstances? What if you were trying to meet a pressing deadline?
7. Some students find it easier to study or complete assignments if they can arrange a place where they can study. Do you have a particular method for arranging the place where you study? What if you are having difficulty concentrating on your schoolwork?

Appendix B. Self-regulated learning strategies and definitions (adapted from Zimmerman & Martinez-Pons, 1986)

Strategies	Category	Definition
1) Self-evaluating	Self-regulating	Statements indicating student-initiated evaluations of the quality of progress of their work. (i.e., 'I check over my work to make sure I did it right.')
2) Organizing and transforming	Organizing	Statements indicating student-initiated overt or covert rearrangement of instructional materials to improve on learning, e.g., 'I make an outline before I write my paper.'
3) Goal setting and planning	Self-regulating	Statements indicating students setting of educational goals or sub-goals and planning for sequencing, timing and completing activities related to those goals, e.g., 'First I start studying 2 weeks before exams, and I pace myself.'
4) Seeking information	Seeking information	Statements indicating student-initiated efforts to secure further task information from nonsocial sources when undertaking an assignment, e.g., 'Before beginning to write the paper, I go to the library to get as much information as possible concerning the topic.'
5) Keeping records and monitoring	Self-regulating	Statements indicating student-initiated efforts to record events or results, e.g., 'I took notes of the class discussion.' 'I kept a list of the words I got wrong.'
6) Environment restructuring	Self-regulating	Statements indicating student-initiated efforts to select or arrange the physical setting to make learning easier, e.g., 'I turned off the radio so I can concentrate on what I'm doing.'
7) Self-consequences (self-regulating)	Self-regulating	Statements indicating arrangement or imagination of rewards or punishment for success or failure, e.g., 'If I do well on a test, I treat myself to a movie.'
8) Rehearsing and memorizing	Mnemonic-use	Statements indicating student-initiated efforts to memorize material by overt or covert practice, e.g., 'In preparing for a math test, I keep writing the formula down until I remember it.'
9–11) Seeking social assistance	Seeking social assistance	Statements indicating student-initiated efforts to solicit help from peers (9), teacher (10), and adults (11), e.g., 'If I have problems with the math assignments, I ask a friend to help.'
12–14) Reviewing records	Reviewing	Statements indicating student-initiated efforts to re-read tests (12), notes (13), or textbook (14) to prepare for class or further testing, e.g., 'When preparing for a test, I review my notes.'

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