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Judgments of Learning Depend on How Learners Interpret Study Effort

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In self-paced learning, when the regulation of study effort is goal driven (e.g., allocated to different items according to their relative importance), judgments of learning (JOLs) increase with study time. When regulation is data driven (e.g., determined by the ease of committing the item to memory), JOLs decrease with study time (Koriat, Ma'ayan, & Nussinson, 2006). We induced learners to interpret differences in their study time (Experiment 1) or in another learner's study time (Experiment 2) as reflecting either differences in data-driven regulation or differences in goal-driven regulation. This manipulation was found to moderate the relationship of both study time and rated effort to JOLs. The results were seen to support the idea that JOLs are based on study effort but the effects of experienced effort are mediated by an attribution that intervenes between the metacognitive regulation of effort and the monitoring of one's learning. The results invite an attributional theoretical framework that encompasses both data-driven and goal-driven regulation and incorporates the option of attributing experienced effort to either or both of the 2 types of regulation.

Keywords: metacognition, judgments of learning, attribution, fluency, study time

There has been a great deal of work on processing fluency and its effects on judgment and subjective experience. This work has spanned different research domains including memory, decision making, metacognition, and social psychology (see Alter & Oppenheimer, 2009; Koriat, in press; Schwarz, in press; Unkelbach & Greifeneder, 2013). Several studies suggest that fluent processing can result from many sources, such as repeated presentation (C. M. Kelley & Lindsay, 1993; Whittlesea, 1993), the readability of text (Novemsky, Dhar, Schwarz, & Simonson, 2007), or semantic coherence (Topolinski, Likowski, Weyers, & Strack, 2009). Fluent processing, in turn, can affect a wide range of judgments and feelings such as familiarity (Whittlesea, 1993), frequency (Reber & Zupanek, 2002; Tversky & Kahneman, 1973), liking (Tamir, Robinson, Clore, Martin, & Whitaker, 2004), truth (Hansen, Dechêne, & Wänke, 2008; Reber & Unkelbach, 2010), intelligence (Oppenheimer, 2006), and fame (Jacoby, Woloshyn, & Kelley, 1989).

How can fluency have such diverse effects? To address this question, several researchers invoked the notion of attribution. According to Jacoby and his associates (e.g., Jacoby, Allan, Collins, & Larwill, 1988; Jacoby & Dallas, 1981; Whittlesea, Jacoby, & Girard, 1990), although fluency can derive from a variety of sources, the subjective experience that ensues from fluent processing depends on the specific source to which fluency is attributed. For example, fluent processing deriving from a previous exposure to a stimulus may be attributed to the past, resulting in the subjective experience of familiarity, but it may also be attributed to properties of the stimulus (e.g., Jacoby et al., 1988, 1989). Other researchers proposed that the effects of processing fluency depend on the interpretation of fluency in accordance with one's naive theory (Schwarz, 2004; Unkelbach, 2006) and that these effects can be prevented by manipulations that render experienced ease nondiagnostic (Haddock, Rothman, Reber, & Schwarz, 1999; Novemsky et al., 2007).

Monitoring One's Own Learning

The present study concerns metacognitive judgments, specifically, judgments of learning (JOL) during study. Discussions of the bases of metacognitive judgments generally agree that processing fluency is one of the dominant determinants of metacognitive judgments. Thus, JOLs have been claimed to depend on the ease with which the studied items are encoded or retrieved during learning (Benjamin, Bjork, & Schwartz, 1998; Koriat & Ma'ayan, 2005; Undorf & Erdfelder, 2011, 2013). Feeling-of-knowing (FOK) judgments have been claimed to rest on the familiarity of the cue that prompts recall (Metcalfe, Schwartz, & Joaquim, 1993;

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Reder, 1987) or on the amount and ease with which partial information about the elusive memory target comes to mind (Koriat, 1993, 1995; see Koriat & Levy-Sadot, 2001). Confidence in one's answer has also been assumed to depend on the ease with which the answer is retrieved (Ackerman & Zalmanov, 2012; C. M. Kelley & Lindsay, 1993).

Koriat, Ma'ayan, and Nussinson (2006; see Koriat, in press), however, stressed the distinction between data-driven and goal-driven effort as determinants of metacognitive judgments. The dimension of data-driven effort is roughly aligned with the dimension of fluent versus disfluent processing. Like fluency (or disfluency), data-driven effort refers to the amount of effort required by the task in a bottom-up fashion. Goal-driven effort, in contrast, refers to the amount of effort that the person willfully invests in a task in a top-down fashion, in accordance with a variety of goals. Goal-driven effort has been investigated in research areas that emphasized the effects of self-control on behavior. It has been studied, for example, in the area of attention and performance (Kahneman, 1973; Navon & Gopher, 1979; Posner & Snyder, 1975). It has also been discussed in attribution theories of achievement motivation (Bandura, 1997; Rotter, 1990; Salomon, 1984; Weiner, 1985) under the assumption that the amount of effort invested in a task is one of the factors to which learners can attribute their success or failure in that task. In the area of memory and metacognition, the role of goal-driven effort has been brought to the fore by demonstrations indicating that learners have some degree of control over which items they will recall and which they will forget (Bjork, Bjork, & Anderson, 1998; Castel, Lee, Humphreys, & Moore, 2011). Goal-driven regulation has been emphasized by theories of self-regulated learning (see Pieschl, Stahl, Murray, & Bromme, 2012), which assume that learners flexibly adapt their learning process to external task demands. The *agenda-based regulation* model of Ariel, Dunlosky, and Bailey (2009; see Ariel & Dunlosky, 2013) assumes that learners develop an agenda in which they try to allocate study time (ST) in an optimal manner that minimizes ST and maximizes goal achievement.

What is important about the distinction between data-driven and goal-driven effort is that the two types of effort are expected to exert diametrically opposed effects on metacognitive judgments and performance. Consider self-paced learning. Koriat et al. (2006; see also Koriat, Ackerman, Adiv, Lockl, & Schneider, 2014) proposed that the allocation of study effort between items is typically data driven: Learners spend as much time as the item calls for. Their JOL is then based on ST under the memorizing effort heuristic that easily learned items are better remembered than items that require greater effort to learn. Indeed, across items, JOLs generally decrease with ST, consistent with the idea that ST is used by the learner as an index of fluency (Koriat et al., 2006; Undorf & Erdfelder, 2011, 2013).

In contrast, when the regulation of effort is goal driven, learners continue to invest more effort in the studied material until they reach a targeted degree of mastery (*norm of study*; see Dunlosky & Herzog, 1998). For example, when different incentives are attached to the recall of different items, learners invest more ST in the high-incentive than in the low-incentive items (Ariel & Dunlosky, 2013; Ariel et al., 2009; Dunlosky & Thiede, 1998; Soderstrom & McCabe, 2011), and their JOLs increase accordingly with increased ST (Koriat et al., 2006).

Both a positive and a negative ST-JOL relationship have been demonstrated within the same task for both college students and ninth graders (Koriat et al., 2006, 2014). In these studies, participants were awarded different incentives to the successful recall of different items. The manipulation of incentive between items resulted in a positive ST-JOL relationship: Learners invested more ST and reported higher JOLs for the high-incentive than for the low-incentive items. At the same time, however, a negative ST-JOL relationship was observed within each incentive level, so that the more ST was invested in an item, the lower the JOL associated with that item. Thus, JOLs differed markedly for items with the same ST depending on the specific combination of data-driven and goal-driven sources of ST.

A similar pattern was observed for confidence in problem-solving tasks: Participants spent more time solving high-incentive than low-incentive problems and expressed higher confidence in the solution of the high-incentive problems (Ackerman, 2013; Koriat et al., 2006). However, within each incentive level, confidence correlated negatively with solution time.

Attribution of Study Effort

The sensitivity of JOLs to the opposite implications of study effort according to the source of that effort suggests an attribution process that intervenes between ST regulation and metacognitive monitoring. Presumably, learners partition the amount of study effort invested in each item into a data-driven component and a goal-driven component. The former component then contributes toward reducing one's JOLs, whereas the latter component contributes toward enhancing one's JOLs (see Koriat et al., 2014). Koriat and Nussinson (2009) provided evidence in support of the reality of the postulated attribution mediating JOLs. They asked learners to adopt a facial expression that creates a feeling of effort and induced them to attribute that effort either to data-driven or to goal-driven regulation. Under typical self-paced conditions in which regulation is generally data driven, participants who were asked to contract the corrugator muscle during study (mental effort group) made lower JOLs than did those who were asked to raise their eyebrows (control group). In contrast, in a second experiment that induced attribution of effort to goal-driven regulation, the opposite pattern was observed. In that experiment, participants studied items under time pressure and were instructed to modify their facial expression according to their intended willful control, contracting the corrugator or raising their eyebrows only when studying items on which they wanted to concentrate. Here, the mental-effort group expressed higher JOLs for the chosen items than did the control group.

In this study, we attempted to obtain further evidence in support of the attribution that is assumed to mediate between the regulation of study effort and metacognitive monitoring. In particular, we examined whether learners, after having invested a certain amount of time studying a particular item, can be biased to attribute that effort to data-driven or goal-driven regulation. If so, differences in effort framing as reflecting either data-driven effort or goal-driven effort would be expected to moderate the relationship between ST and JOLs.

Experiment 1

Participants in Experiment 1 studied a list of paired associates under self-paced conditions and indicated their JOLs after each study trial. However, prior to providing JOLs, they answered a question that was intended to bias their attribution of ST either to data-driven or to goal-driven regulation. For the data-driven effort framing, participants were asked to rate the amount of study effort that the item required. For the goal-driven effort framing, in contrast, they were asked to rate the amount of study effort that they chose to invest in the item. A list of unrelated paired associates was used to minimize the effects of judged difficulty of the items on JOLs (see Koriat, 2008), so as to bring to the fore the effects of effort attribution. ST was used as an objective but approximate measure of effort, whereas effort ratings were used as a more direct measure of the subjective feelings. The analyses will examine how JOLs vary with both ST and effort ratings in the two effort framing conditions.

Method

Participants. Forty-two Hebrew-speaking University of Haifa undergraduates (six men) participated in the experiment. They were divided randomly between the goal-driven and the data-driven conditions of the experiment.

Materials. A set of 120 Hebrew words was used to form a list of 60 paired associates. This list had been used in a previous study (Koriat, 2008). In constructing the list, an attempt had been made to avoid pairs with clear associative links between the two members.

Apparatus and procedure. The experiment was conducted on a personal computer. A practice task was used to familiarize the participants with the task of effort attribution. In that task, they were asked to imagine that they were studying for an exam. Participants in the goal-driven condition were told that when studying for an exam, there are usually topics to which one chooses to allocate more study and others in which one chooses to invest less study. Participants in the data-driven condition, in contrast, were told that when studying for an exam, there are topics that call for a greater amount of study effort and others that call for less study effort. Four brief stories in Hebrew (a five-line paragraph each) were presented in turn. Participants were instructed to study each paragraph as long as they needed so that they could later answer questions about it and to press the left mouse key when they were through studying. The paragraph then disappeared, and participants in the goal-driven condition were asked to rate the amount of study effort they had chosen to invest in the paragraph on a vertical scale with a column of radio buttons marked from 1 (*I chose to invest little study*) to 9 (*I chose to invest a great deal of study*). In contrast, participants in the data-driven condition were asked to rate the amount of study effort that the paragraph required, using a similar scale from 1 (*The paragraph required little study*) to 9 (*The paragraph required a great deal of study*). Participants entered their ratings using the mouse. The rating scale was replaced with a JOL question: "Chances to answer correctly (0%–100%)?" Participants were asked to indicate the chances that they would be able to answer correctly a question about the paragraph by sliding a pointer on a horizontal slider using the mouse. The use of different scales (1–9 vs. 0–100) and different visual formats (vertical vs. horizontal) for the effort ratings and JOLs was intended to strengthen the distinction between the two judgments. At the end of the study task, participants were presented with four open-ended test questions, one about each of the paragraphs.

For the experiment proper, the participants were told that they would have to study 60 paired associates so that later, on the test phase, they would be able to recall the second word in each pair when the first was presented. They were instructed to study each pair for as long as they needed and press the left mouse key when they were through studying. They were encouraged to generate an association between the two words in each pair because doing so may help them recall the second word in response to the first word. The two words appeared side by side, and following the keypress, they were replaced by a vertical effort-rating scale (similar to the one used in the practice phase), and participants were asked to make their rating on this scale as they had done in the practice phase. The vertical scale was then replaced with the question "Chances to recall (0%–100%)?" and participants indicated their JOLs representing their assessed chances of recalling the second word when presented with the first word at test. They did so again by sliding a pointer on a horizontal slider using the mouse. When the study phase ended, participants were asked to make an aggregate estimate. The prompt, which appeared on the computer screen, was, "You were presented with 60 word pairs. How many of them do you think you will remember?"

In the test phase, the stimulus words were presented one after the other, in a random order. Participants had 8 s to say the response aloud, after which a beep was sounded and the next stimulus word was presented. Participants' responses were entered by the experimenter on a keyboard.

At the end of the experiment, participants were asked to indicate whether they would be more likely to recall the pairs in which they invested a great deal of study or those in which they invested little study.[1]

Results

ST. In all of the analyses, all responses for which STs were below or above 2.5 standard deviations from each participant's mean were eliminated (2.62% of all responses).[2] ST averaged 14.60 s (SD = 7.52) for the data-driven condition and 15.13 s (SD = 12.32) for the goal-driven condition, $t(40) = 0.17$. Thus, the effort framing that was primed by the effort rating did not seem to affect overall ST regulation.

The relationship between ST and effort rating. We first examine the relationship between ST and rated effort. We analyzed the results in the same way as we did in the previous studies, dividing items for each participant into those with below-median

[1] Two individual-differences tests were administered at the end of the experiment. All participants filled out Dweck's questionnaire (Dweck, Chiu, & Hong, 1995) assessing beliefs in fixedness as opposed to malleability of intelligence, personality, moral character, and the world (entity theory vs. incremental theory). In addition, 29 participants completed Rotter's locus of control questionnaire (Rotter, 1966) assessing extrinsic versus intrinsic locus of control. We expected the scores on these two questionnaires to predict the extent to which effort framing affects the relationships between ST, effort ratings, and JOLs. No significant effects were observed to support this expectation.

[2] Including outlier responses in the analyses had a negligible effect on the results.

ST (short) and those with above-median ST (long). Effort ratings for the two types of items are plotted in Figure 1 for the two conditions. A two-way analysis of variance (ANOVA), Condition × ST (short vs. long), yielded $F(1, 40) = 20.23$, mean square error (MSE) = 3.48, $p < .0001$, $\eta_p^2 = .34$, for condition; $F(1, 40) = 46.44$, $MSE = 0.33$, $p < .0001$, $\eta_p^2 = .54$, for ST; and $F < 1$ for the interaction. Effort ratings were overall higher for the data-driven condition than for the goal-driven condition. However, they increased with ST for both the data-driven condition, $t(20) = 4.75$, $p < .0001$, and the goal-driven condition, $t(20) = 4.90$, $p = .0001$. This increase can also be seen in the within-person Pearson correlation between ST and rated effort, which averaged .35, $t(20) = 5.93$, $p < .0001$, for the data-driven participants, and .42, $t(20) = 8.58$, $p < .0001$, for the goal-driven participants.

The relationship between ST and JOLs. We turn next to an examination of the ST-JOL relationship, which is the focus of this study. Figure 2A presents mean JOLs for short STs (below-median) and long STs (above-median) for the two conditions. A two-way ANOVA, Condition × ST (short vs. long), yielded $F < 1$ for condition; $F(1, 40) = 6.15$, $MSE = 37.19$, $p < .05$, $\eta_p^2 = .13$, for ST; and $F(1, 40) = 4.75$, $MSE = 37.19$, $p < .05$, $\eta_p^2 = .11$, for the interaction. For the data-driven condition, JOLs decreased with increasing ST, $t(20) = 3.29$, $p < .005$, whereas for the goal-driven condition, JOLs were not affected by ST, $t(20) = 0.22$, $p = .84$.

This pattern is also reflected in the within-person ST-JOL Pearson correlation. As expected, data-driven participants demonstrated a negative correlation between ST and JOLs: −.27, $p < .0001$. The correlation was negative for 18 participants and positive for three participants, $p < .005$, by a binomial test. This result suggests reliance on the memorizing effort heuristic that more effort implies lower chances of recall (Koriat, 2008; Koriat et al., 2006, 2014). Goal-driven participants, in contrast, exhibited a nonsignificant correlation, −.02, which differed significantly from that demonstrated by the data-driven participants, $t(40) = 3.01$, $p < .005$. We might have expected this correlation to be positive, but previous results (Koriat et al., 2006, 2014) suggest that a data-driven attribution is more dominant in interpreting differences between same-incentive items. Possibly the negative ST-JOL correlation that is typically observed was offset by the effort ratings, which induced a goal-driven interpretation of invested effort.

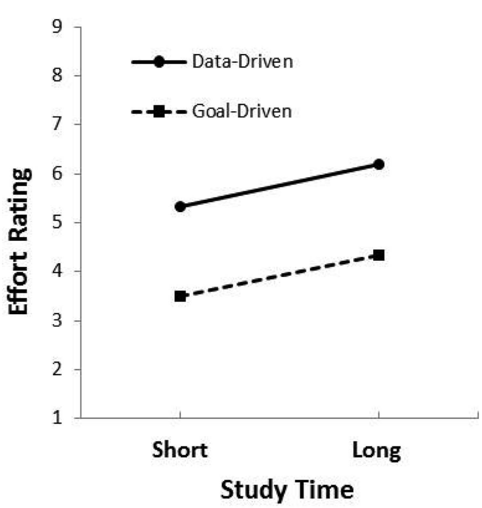

Figure 1. Mean effort ratings for below-median (short) and above-median (long) study time for the data-driven and goal-driven effort framing conditions (Experiment 1).

The relationship between rated effort and JOLs. How did JOLs vary with perceived effort? To examine this question, the results were also analyzed by dividing the items for each participant into those that received below median effort ratings (low effort) and those that received above-median effort ratings (high effort). JOLs for the two types of items are plotted in Figure 2B for each of the two conditions. A two-way ANOVA, Condition × Rated Effort (low effort vs. high effort), yielded $F(1, 40) = 1.07$, $MSE = 510.21$, $p < .32$, $\eta_p^2 = .03$, for condition, and $F(1, 40) = 8.48$, $MSE = 100.72$, $p < .01$, $\eta_p^2 = .17$, for rated effort. The interaction, however, was highly significant, $F(1, 40) = 37.24$, $MSE = 100.72$, $p < .0001$, $\eta_p^2 = .48$. For the data-driven condition, JOLs decreased with rated effort, $t(20) = 7.02$, $p < .0001$, whereas for the goal-driven condition, they tended to increase with rated effort, $t(20) = 2.03$, $p < .07$.

We also examined the within-person correlation between JOLs and rated effort. For the data-driven condition, JOLs decreased with rated effort. The average Pearson correlation between rated effort and JOLs was negative, −.71, $p < .0001$. This correlation was negative for 20 participants and positive for one participant, $p < .0001$, by a binomial test. In contrast, for participants in the goal-driven condition, the JOL−effort correlation was positive and significant, .26, $p < .05$. The correlation was positive for 14 participants and negative for seven participants, $p = .13$, by a binomial test. The correlation for the data-driven participants differed significantly from that demonstrated by the goal-driven participants, $t(40) = 7.90$, $p < .0001$.

Participants in the two conditions did not differ in their estimate of the number of items to be recalled: Aggregate JOLs averaged 20.52 for data-driven participants and 17.05 for goal-driven participants, $t(40) = 1.04$, $p = .30$.

The effects on recall. Whereas Figure 2A and Figure 2B present the results for JOLs, Figure 2C and Figure 2D present the respective results for recall. Focusing first on the ST-recall relationship (see Figure 2C), a two-way ANOVA, Condition × ST, on recall yielded $F < 1$ for condition, ST, and the interaction.

Turning next to the results in Figure 2D, a Condition × Rated Effort ANOVA on recall yielded $F < 1$ for both condition and rated effort, but $F(1, 40) = 11.94$, $MSE = 130.90$, $p < .005$, $\eta_p^2 = .23$, for the interaction. The interactive pattern for recall is similar to that observed for JOLs, suggesting a good calibration of JOLs as far as the effects of effort ratings are concerned.

Interitem differences. Although all the pairs were unrelated, we examined whether systematic differences between the items transpire across the two conditions. Mean ST, JOL, rated effort and recall were calculated for each item for each of the two conditions. The Pearson intercorrelations between the eight variables across the 60 items are presented in Table 1.

It is interesting that the correlation between the mean ST allocated to each item in the two conditions was .53. The stability of interitem differences in ST across the two conditions underscores the finding that the effects of ST on JOLs varied with the interpretation of ST. Table 1 includes also the results for Experiment 2, which will be discussed in the General Discussion section.

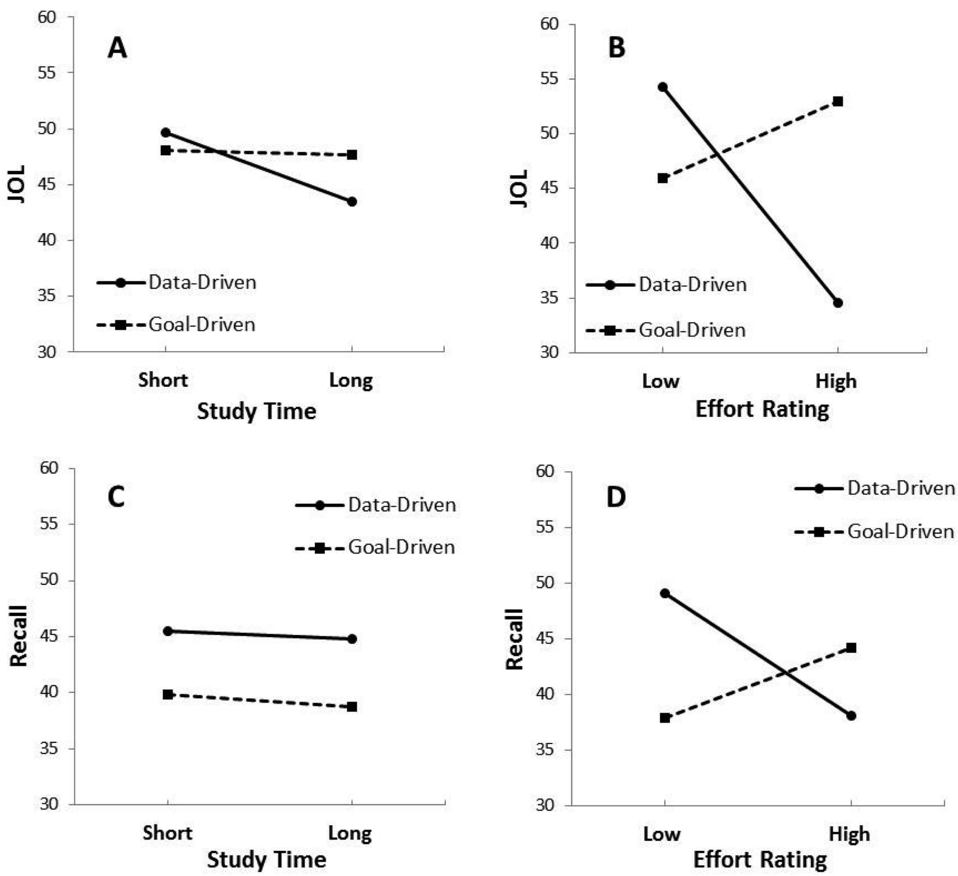

Figure 2. Mean judgments of learning (JOL; A and B) and recall (C and D) for the data-driven and goal-driven effort framing conditions. A presents mean JOLs for below-median (short) and above-median (long) study time, whereas B presents mean JOLs for below-median (low) and above median (high) effort rating. C and D present the respective results for recall.

Self-report results. Only 34 participants responded to the question whether more study would be associated with better recall or worse recall. The distribution of the ratings was exactly the same for the data-driven and goal-driven participants: Eight participants in each condition indicated that more study would be associated with better recall, and eight participants indicated that it would be associated with worse recall (one participant in each condition indicated "no difference").

Discussion

The results of Experiment 1 support the assumption that an attribution process mediates the regulation of effort during self-paced study and its effects on metacognitive monitoring. Because study effort often reflects the joint effects of data-driven and goal-driven regulation, an attribution process has been postulated in which participants partition the total amount of effort invested into two components, attributing each to its source. On the basis of that partitioning, they arrive at an overall recall prediction by drawing the opposite implications of data-driven and goal-driven effort for JOLs. Koriat et al. (2014) demonstrated that fifth and sixth graders could not respond differentially to data-driven and goal-driven efforts when the studied items differed in both difficulty and incentive for recall. However, they did evidence an adultlike pattern under a partitioning procedure that helped them separate between the contribution of data-driven regulation and that of goal-driven regulation to ST. Experiment 1 indicates that adult participants, after having invested a certain amount of effort studying a particular item, can be biased to interpret study effort as reflecting data-driven or goal-driven regulation. The biased interpretation affected the ST-JOL correlation as well as the correlation between rated effort and JOL.

The results for effort ratings yielded stronger effects of effort framing than those obtained for ST. This observation is consistent with the proposal that although ST is a relatively good indicator of effort, JOLs do not rest on ST as such, but on subjective effort (Koriat et al., 2006). Another factor that may have contributed to the weaker effects observed for ST than for rated effort is the delay in JOL elicitation that occurred as a result of the intervening effort rating task. Indeed, delaying the elicitation of JOLs has been found to reduce the negative ST-JOL correlation in self-paced learning, possibly because it reduced reliance on study effort as a cue for JOLs (Koriat et al., 2006; Koriat & Ma'ayan, 2005).

Note, however, that for both measures—ST and rated effort—the effects of the data-driven effort framing were stronger than

Table 1
Correlations Across Items Between the Means of Dependent Variables in Experiments 1 and 2

Variable	Experiment 1								Experiment 2					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Data-driven study time	—													
2. Data-driven effort	.79	—												
3. Data-driven JOL	−.75	−.89	—											
4. Data-driven recall	−.30	−.32	.34	—										
5. Goal-driven study time	.53	.53	−.48	−.08	—									
6. Goal-driven effort	.20	.12	−.21	−.14	.39	—								
7. Goal-driven JOL	−.61	−.71	.67	.43	−.54	−.17	—							
8. Goal-driven recall	−.26	−.26	.27	.82	−.20	−.18	.43	—						
9. Data-driven effort, other	.61	.59	−.48	−.29	.32	.03	−.48	−.20	—					
10. Data-driven JOL, other	−.69	−.71	.62	.39	−.37	−.02	.60	.27	−.88	—				
11. Goal-driven effort, other	.06	−.01	−.06	.00	−.04	−.10	−.17	−.09	.17	−.17	—			
12. Goal-driven JOL, other	−.46	−.57	.59	.39	−.27	.01	.50	.28	−.53	.68	−.12	—		
13. Study time, self	.53	.55	−.52	−.21	.51	.17	−.55	−.29	.49	−.46	.22	−.24	—	
14. JOL, self	−.80	−.80	.75	.38	−.53	−.19	.75	.31	−.59	.71	−.08	.63	−.65	—

Note. JOL = judgment of learning.

those of the goal-driven effort framing. Indeed, it has been argued that in self-paced learning, participants typically rely on data-driven effort as a basis of JOLs (Begg, Duft, Lalonde, Melnick, & Sanvito, 1989), and this was found even when item difficulty was controlled for (Undorf & Erdfelder, 2013). Nevertheless, the goal-driven manipulation was successful in producing a positive relationship between rated effort and JOLs.

Experiment 2

The results of Experiment 1 support the idea that the monitoring of one's own learning is mediated by the attribution of study effort to data-driven or goal-driven regulation. In Experiment 2, we examined whether this is also the case for the monitoring of another person's learning. Apart from its theoretical interest (see Carruthers, 2009), the extension of investigation to the monitoring of others' learning has the methodological advantage that ST can be manipulated experimentally, independent of factors such as item difficulty, that may affect self-controlled ST (see Undorf & Erdfelder, 2011). In a previous study, Koriat and Ackerman (2010) had participants watch a video depicting a female student studying paired associates, allegedly investing different amounts of time studying each item. For each item, they assessed the likelihood that the student would recall the target word at test. All participants also took part in a self condition either before or after the other condition. In that condition, they studied paired associates under self-paced instructions and made JOLs after each item. The study yielded two main findings. First, JOLs correlated negatively with ST for the self condition, in line with data-driven attribution. This was true whether the self condition preceded or followed the other condition. In contrast, for the other condition, the ST-JOL correlation was close to zero whether or not the pairs allegedly studied were presented. Second, when the other condition followed the self condition, a negative ST-JOL correlation was found in the other condition as well, suggesting that participants could transfer the insight derived from their own study experience to the interpretation and prediction of another person's performance. This result suggests a shift in effort attribution.

Undorf and Erdfelder (2011) obtained similar results without video watching. Their participants studied word pairs or watched pairs presented to other learners using the same STs as those used by real participants. Like Koriat and Ackerman (2010), they compared self (learning) first with other (observing) first. The ST-JOL correlation was negative for the self condition regardless of phase order, and it was also negative for the other condition when the studied pairs were displayed. In contrast, when the studied pairs were concealed, the correlation tended to be positive for the other-first condition but was negative when the other task followed the self task. By concealing the word pairs, Undorf and Erdfelder were able to show that ST, as an index of encoding fluency, affects JOLs independent of item difficulty. Their subsequent study (Undorf & Erdfelder, 2013) provided even stronger support for this conclusion. In that study, after experiencing self learning, participants made JOLs for others when the pairs were displayed. It is important to note that in the other condition, ST for about half of the items was swapped so that items with short STs were presented for long durations, whereas items with long STs were presented for short durations. Their results suggest that ST contributes to JOLs over and above item difficulty.

The task used in Experiment 2 of the present study was similar to that used in the other condition of Experiment 2 of Koriat and Ackerman (2010), in which the pairs allegedly studied were presented on the screen. The main difference was that an effort rating task preceded the solicitation of JOLs. As in Experiment 1, these ratings were intended to induce a data-driven or a goal-driven effort framing.

Experiment 2 had an ancillary aim. Because of the self-paced feature of Experiment 1, it may be argued that the effort framing induced in that experiment actually affected not only the interpretation of study effort but also the very regulation of ST (at least in the later trials). That is, the instructions to attribute study effort to data-driven or goal-driven regulation may have influenced the very policy of ST allocation. It is therefore important to examine whether the effects of effort framing are obtained in Experiment 2, in which ST is experimentally manipulated rather than self-determined.

Finally, Experiment 2 also examined the possibility that the effort framing induced in the other condition could affect the interpretation of one's own study effort in a self condition that followed the other condition. Thus, in the second part of the experiment, all participants took part in a self task in which they studied a new list of paired associates. No effort rating task preceded JOLs in this task. At the end of the experiment, participants answered a few questions, as detailed below.

Method

Participants. Fifty-six Hebrew-speaking (38 women) University of Haifa undergraduates participated in the experiment. They were divided randomly between the data-driven and the goal-driven conditions of the experiment.

Materials. The same list of 60 word pairs as in Experiment 1 was used, but it was divided to form two lists of 30 unrelated paired associates. One list was used in the other task and the other list was used in the self task, with the assignment of the two lists to the two tasks counterbalanced across participants.

For the other task, the same 5-min video was used as in Koriat and Ackerman (2010). The video depicted a female student, named Ella, performing the self-study task. She was filmed while she actually studied a list of paired associates that appeared on the screen. The video depicted her holding a mouse, facing the screen of a laptop computer. In addition participants were able to see the paired associates that the student allegedly studied (see Figure 3).

Apparatus and procedure. The experiment was conducted on a personal computer. The same practice task as in Experiment 1 was used: Participants studied the four paragraphs and provided effort ratings according to their condition, either data-driven study effort or goal-driven study effort. After the practice task, the other task was presented. Participants were given an explanation of the paired-associates task. They were then told that they would see a video of Ella studying 30 paired associates under the instruction that she can spend as much time as she needs to study each pair, but she should try to maximize her recall while keeping the total time invested in studying the entire list as short as possible. Participants were instructed to watch Ella studying and to estimate for each studied item either the amount of study effort that it required from her (in the data-driven condition) or the amount of study effort that she chose to invest (in the goal-driven condition). They then judged the likelihood that she would recall the target word at test in response to the cue word.

The ST invested by the student in each item was experimentally manipulated. This was done by randomly cutting segments of the original video that were either 5 s long (short) or 10 s long (long).

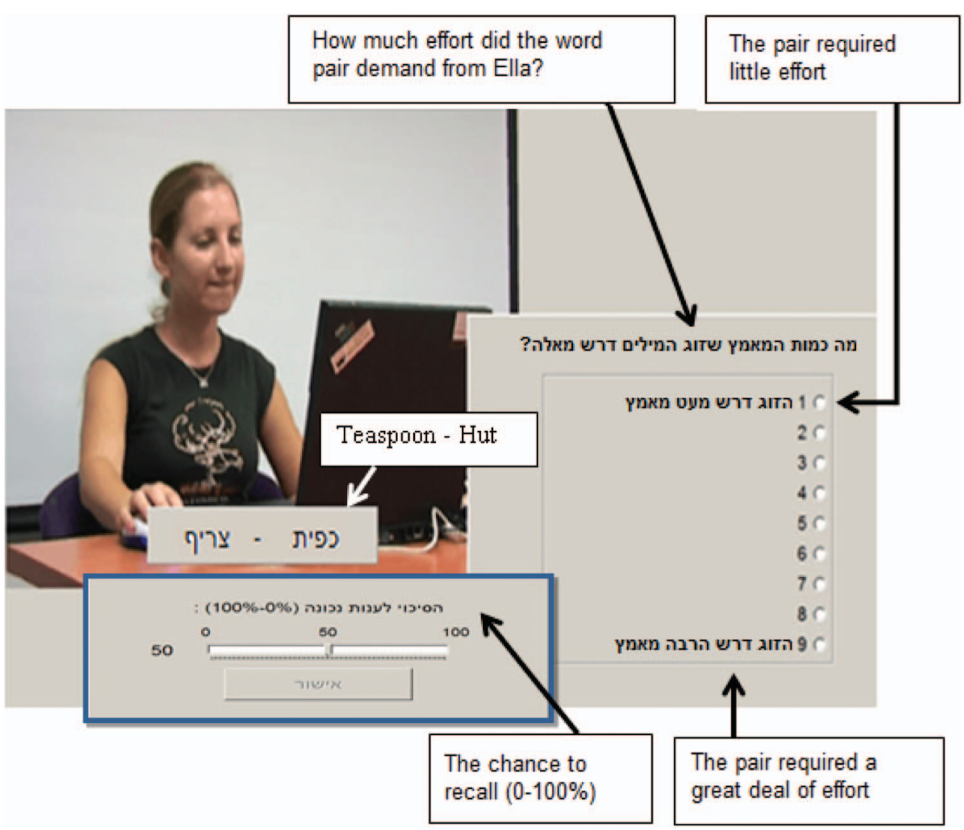

Figure 3. An example of a frame from the display used in Experiment 2 in the other condition. The display shows the last frame from the video, the effort rating scale, and the judgment of learning (JOL) slider. The boxes include the English translation of the Hebrew titles. The individual who appears in this figure gave consent for the use of her likeness.

The assignment of short and long STs to each paired associate was counterbalanced across participants, and the order of short and long STs was random except that in each set of six successive items, three items were short and three items were long.

At the end of each item, the video was stopped, and a panel was added at the right hand side of the screen with the same vertical scales of effort rating used in Experiment 1. Participants in the data-driven condition were asked, "How much effort did the item demand from Ella?" and those in the goal-driven condition were asked, "How much effort did Ella choose to invest?"[3] After participants made the effort rating, a horizontal JOL rating scale appeared, with the title "Her chances to recall (0–100%)?" Participants were instructed to judge the likelihood that Ella would recall the target word, by sliding a pointer on a horizontal slider as in Experiment 1. When the study phase was over, participants provided an aggregate JOL: They estimated the number of words that Ella would recall at test.

When the other task ended, participants were presented with the self task. They were told that they would have to study 30 paired associates so that they would be able to recall the second word in each pair when the first was presented. The rest of the instructions and the procedure were similar to those of Experiment 1 with the exception that no effort ratings were solicited, so that the procedure was the same for all participants.

Finally, a short questionnaire was presented orally by the experimenter. The questions required explaining the bases of one's JOLs in the other and self tasks and the bases of the effort ratings in the other task.

Results

We begin by the analysis of the results from the other task and then present the results of the self learning task.

The relationship between other's ST and effort ratings. Effort ratings averaged 4.76 for the data-driven condition and 5.05 for the goal-driven condition, $t(54) = 1.15$, $p = .26$. The results did not replicate the unexpected difference observed in Experiment 1 of higher effort ratings for the data-driven than for the goal-driven condition.

Figure 4A presents mean rated effort for short (5 s) and long (10 s) STs for the data-driven and goal-driven conditions. For the data-driven condition, the difference between short and long STs yielded $t(27) = 7.00$, $p < .0001$. The respective difference for the goal-driven condition yielded $t(27) = 11.10$, $p < .0001$. A two-way ANOVA, Condition (data driven vs. goal driven) × ST (short vs. long), yielded $F(1, 54) = 7.09$, $MSE = 0.60$, $p < .05$, $\eta_p^2 = .12$, for the interaction. Thus, regardless of effort framing, participants associated longer ST with greater effort, and this is true for judgments of one's own behavior (Experiment 1) as well as for judgments of another person's behavior (Experiment 2). Here, however, the relationship between ST and rated effort was stronger for the goal-driven effort framing.

The relationship between other's ST and JOLs. JOLs were higher for the data-driven participants than for the goal-driven participants (see Figure 4, panel B), but the results disclose a similar interaction as that observed in Experiment 1. A two-way ANOVA, Condition × ST (short vs. long), on these results yielded $F(1, 54) = 2.18$, $MSE = 256.19$, $p < .16$, $\eta_p^2 = .04$, for condition, $F(1, 54) = 1.04$, $MSE = 60.45$, $p < .32$, $\eta_p^2 = .02$, for ST, and $F(1, 54) = 12.88$, $MSE = 60.45$, $p < .001$, $\eta_p^2 = .19$, for the interaction. As expected, data-driven participants demonstrated higher JOLs for short STs ($M = 66.17$) than for long STs ($M = 59.40$), $t(27) = 3.50$, $p < .005$. The ST-JOL relationship was negative for 21 participants and positive for seven participants, $p < .01$, by a binomial test.

In contrast, goal-driven participants exhibited the opposite trend, with short STs yielding somewhat lower JOLs ($M = 56.43$) than long STs ($M = 60.21$), $t(27) = 1.71$, $p < .10$. The positive ST-JOL relationship was demonstrated by 17 participants, whereas 11 participants yielded a negative relationship, $p < .27$, by a binomial test.

We also examined the within-person ST-JOL correlation. This correlation averaged −.22 for participants in the data-driven condition, $t(27) = 4.14$, $p < .0005$, and .12 for participants in the goal-driven condition, $t(27) = 1.99$, $p < .07$. The difference between the two correlations was significant, $t(54) = 4.25$, $p < .0001$.

The relationship between rated effort and JOLs. How did JOL vary with perceived effort? The results were first analyzed by dividing the items for each participant into those that received below median effort ratings (low effort) and those that received above-median effort ratings (high effort). JOLs for the two types of items are plotted in Figure 4C for each of the two conditions. A two-way ANOVA, Condition × Rated Effort (low effort vs. high effort), yielded $F < 1$ for condition and $F(1, 54) = 10.17$, $MSE = 105.37$, $p < .005$, $\eta_p^2 = .16$, for rated effort. The interaction, however, was highly significant, $F(1, 54) = 39.74$, $MSE = 105.37$, $p < .0001$, $\eta_p^2 = .42$. For data-driven participants, JOLs decreased with rated effort, $t(27) = 8.01$, $p < .0001$, whereas for goal-driven participants, JOLs increased with rated effort, but not significantly so, $t(27) = 1.93$, $p < .07$.

For the data-driven participants, the within-person correlation between rated effort and JOLs averaged −.60, $p < .0001$. The correlation was negative for 27 out of 28 participants, $p < .0001$, by a binomial test. In comparison, for goal-driven participants, this correlation was positive, .21, $p < .05$, and differed from that observed for the data-driven participants, $t(54) = 6.90$, $p < .0001$. The correlation was positive for 21 participants and negative for seven participants, $p < .01$, by a binomial test.

Participants in the two conditions did not differ in their estimate of the number of target words to be recalled: Aggregate JOLs averaged 15.25 for data-driven participants and 14.96 for goal-driven participants, $t(54) = 0.28$, $p < .79$.

ST and effort ratings for self. We turn next to the results for the self task, which followed the other task. Responses for which STs were below or above 2.5 standard deviations from each participant's mean were eliminated (1.79%; see footnote 2). Mean ST was 10.78 s ($SD = 5.24$) for participants in the data-driven condition and 9.73 s ($SD = 5.22$) for participants in the goal-driven condition.

It was hypothesized that the effort framing induced in interpreting another person's study effort might transfer to the interpreta-

[3] Although the instructions for the effort-framing task specified "study effort," as in Experiment 1, we found it clearer for participants to use the terminology "amount of effort" in the presented panel rather than "amount of study" as we did in Experiment 1.

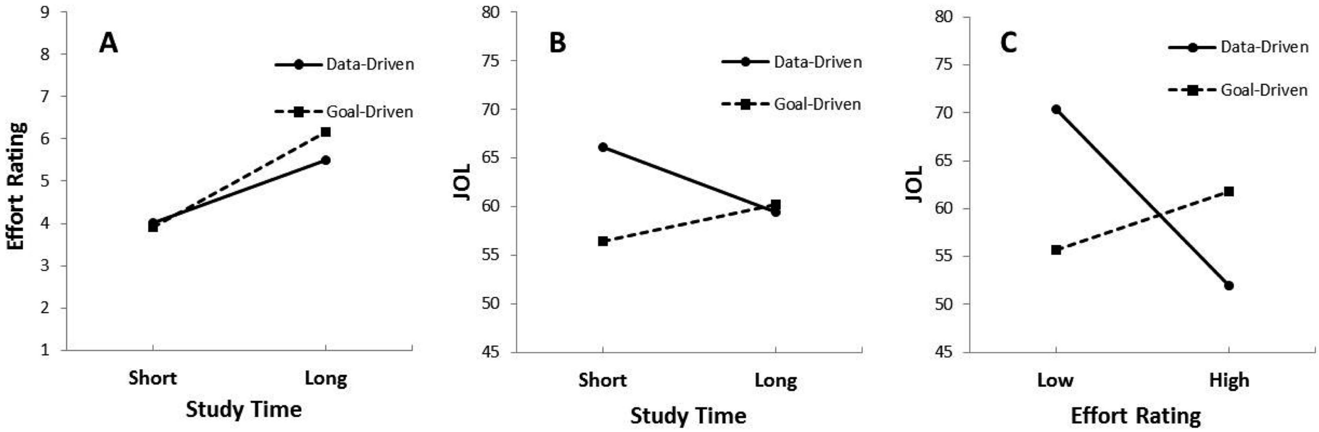

Figure 4. The relationships observed in Experiment 2 for the data-driven and goal-driven effort framing conditions. A presents mean effort ratings for below-median (short) and above-median (long) study time; B presents mean JOLs for below-median (short) and above-median (long) study time; and C presents mean JOL for below-median (low) and above median (high) effort rating.

tion of one's own study effort. If so, we would expect JOLs in the self task to decrease more strongly with ST for participants who were induced to adopt a data-driven effort framing in the other task than for those who were induced to adopt a goal-driven effort framing. The pattern observed for the self task (see Figure 5) is consistent with this prediction, but the interaction was not significant. The results presented in Figure 5 were obtained by dividing the items for each participant into those with below-median ST (short) and those with above-median ST (long). JOLs for short and long STs were then averaged separately for participants who had received data-driven instructions in the other task and those who had received goal-driven instructions. A two-way ANOVA, Task $\times$ ST (short vs. long), yielded $F < 1$ for task and $F(1, 54) = 44.99$, $MSE = 50.68$, $p < .0001$, $\eta_p^2 = 0.45$, for ST. JOLs decreased significantly with increasing ST for participants in the data-driven condition, $t(27) = 5.13$, $p < .0001$, as well as for those in the goal-driven condition, $t(27) = 4.33$, $p < .0001$. The interaction was not significant, $F(1, 54) = 2.03$, $MSE = 50.68$, $p = .16$, $\eta_p^2 = .04$.

We also examined the within-person ST-JOL correlation for the self task. This correlation averaged $-.35$ for participants who had been primed with a data-driven effort framing in the other task and $-.25$ for those who had been primed with a goal-driven effort framing, $t(54) = 1.43$, $p < .17$. Thus, there was no carryover effect from the other task to the self task.

Somewhat strangely, the relationship between recall and ST was stronger for goal-driven participants, averaging 46.76 and 38.38 for the short-ST and long-ST items, respectively. The respective means for the data-driven participants were 53.88 and 51.48.

Interitem differences. Table 1 includes the correlations across items between the variables in Experiment 2, as well as those obtained with the variables in Experiment 1. Note that *item* is defined in terms of the specific word pair that appeared on the screen. Therefore, for Experiment 2, the means for each word pair were calculated either across 28 participants (ST Self, JOL Self) or across the 14 participants in the appropriate condition (effort rating and JOL for the other data-driven and goal-driven conditions). The results suggest reliable interitem differences that were consistent across the two experiments, as will be discussed in the General Discussion section.

Self-report results. The participants rated the effort that Ella invested in learning (2.4) to be higher than their own effort (2.1), $t(55) = 2.65$, $p < .05$, with no effect for the condition. No differences were found between the two conditions in the answers regarding the bases for JOL and effort ratings either for other or for self.

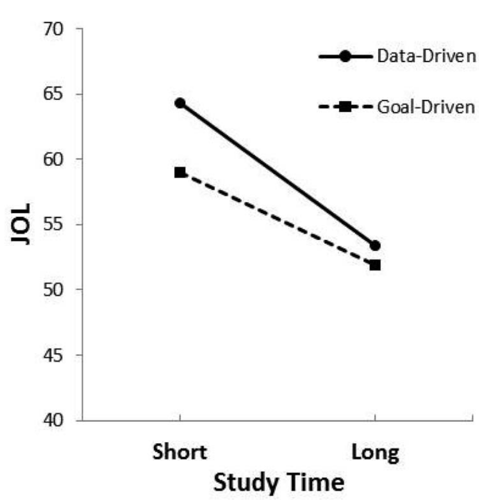

Figure 5. Average judgment of learning (JOL) in the self phase of Experiment 2 for participants in the data-driven and goal-driven effort framing conditions.

Discussion

The results for the other task of Experiment 2 were very similar to those of Experiment 1. Overall, the results suggest that the effort framing adopted in watching another learner's self-paced study moderates the relationship between JOLs and study effort. In the previous study on the monitoring of another person's learning

(Koriat & Ackerman, 2010), JOLs were found to decrease with increasing ST only for the self condition but not for the other condition. In Experiment 2 here, in contrast, participants who were induced to interpret ST as representing goal-driven regulation tended to expect another person's recall to increase with ST (see Figure 4B). As in Experiment 1, the effects of effort framing were stronger for effort ratings than for ST. Although effort ratings were found to increase with ST for both goal-driven and data-driven conditions (see Figure 4A), a clearer crossover interaction was observed for the effects of effort ratings on JOLs (see Figure 4C) than for the effects of ST on JOLs (see Figure 4B), with a significant increase in JOL in the goal-driven condition. This pattern suggests that the critical moderating mechanism underlying the monitoring of one's own learning or of another person's learning is the attribution of subjective effort to data-driven or goal-driven regulation.

As noted earlier, in the self condition of Experiment 1, ST was under the control of the participant. Therefore, the possibility exists that the effects of effort framing were due to the instructions affecting the very regulation of ST rather than only to the attribution of ST to goal-driven or data-driven regulation. In Experiment 2, in contrast, ST was experimentally manipulated. The similarity between the results of the two experiments suggests that the critical process is effort attribution rather than effort regulation. The results of Experiment 2 also underscore the distinction between ST regulation and effort attribution: Once a learner has invested a certain amount of ST, that ST can be attributed to data-driven or goal-driven regulation.

With regard to the self task, the difference between the data-driven and goal-driven participants in the ST-JOL relationship was in the expected direction but was not significant. In the previous studies by Koriat and Ackerman (2010) and Undorf and Erdfelder (2011), there was a carry-over effect from the self task to the other task: A negative JOL-ST correlation was obtained for the other task when that task followed a self task. Perhaps the experience gained from the monitoring of one's own learning can affect the interpretation of another person's behavior but not vice versa.

General Discussion

The Effects of Processing Effort on Metacognitive Judgments

In the present study, we capitalized on the intriguing observation that memory performance tends to increase with mental effort when the regulation of mental effort is goal driven but decreases with mental effort when the regulation is data driven. JOLs were found to mirror this pattern, suggesting that participants take into account the effects of mental effort according to its presumed source. Thus, when ST is data driven, even third graders evidence decreased JOLs with increasing ST (Koriat, Ackerman, Lockl, & Schneider, 2009). In contrast, for goal-driven regulation, when different incentives are attached to the recall of different items, JOLs increase with ST in comparing low- and high-incentive items (Ariel et al., 2009; Dunlosky & Thiede, 1998; Koriat et al., 2006, 2014).

A particularly challenging situation for the monitoring of one's own learning is when variation in ST is due to the joint effects of data-driven and goal-driven regulation. For college students and ninth-grade children (but not for younger children), JOLs were found to mimic closely the results observed for recall (Koriat et al., 2014): For items assigned different incentives, the ST-JOL relationship was positive in comparing low- and high-incentive items. At the same time, a negative relationship was obtained for each level of incentive. These results suggest the operation of a delicate attribution that intervenes between ST regulation and monitoring: The variation in effort is partitioned between data-driven and goal-driven regulation. The component that is attributed to data-driven effects contributes then toward reducing one's JOLs, whereas the component attributed to goal-driven regulation contributes toward enhancing one's JOLs.

It is interesting to compare this pattern with what follows from the attributional theory of achievement motivation (Weiner, 1985). Two of the factors to which people may attribute their success or failure are task difficulty and effort. High task difficulty, which corresponds roughly to high data-driven effort, is one of the factors to which learners typically attribute their failure: Students may blame their low grade in an exam to the difficulty of the exam. High effort, in turn, which corresponds specifically to high goal-driven effort, is one of the factors to which learners may attribute their success. Thus, effortful processing is assumed to correlate with a lower likelihood of success when it is due to the task but to a higher likelihood of success when it is due to the person's internal control.

The Mediating Role of Effort Attribution

In this study, we examined whether participants studying an item (Experiment 1) or observing another person studying an item (Experiment 2) can be induced to interpret the effort invested as reflecting data-driven or goal-driven regulation. The interpretation induced was expected to moderate the relationship between ST and JOLs.

In Experiment 1, the effort-framing manipulation was found to affect the relationship between ST and JOLs. Whereas the data-driven framing yielded the typical negative ST-JOL relationship, the goal-driven framing yielded no such relationship. A very similar pattern was observed in Experiment 2 for the monitoring of another person's learning.

In both experiments, the relationship between effort rating and JOL was affected in the same way by the effort-framing manipulation, as was the ST-JOL relationship. Effort ratings, however, yielded a clearer crossover interaction than that obtained for the ST-JOL relationship. It was proposed that the weaker effects observed for ST may have been due to the delay in JOL elicitation (because of the intervening effort rating task) because the ST-JOL correlation is weaker when JOLs are delayed (see Koriat et al., 2006; Koriat & Ma'ayan, 2005). In addition, however, rated effort would seem to capture the amount of experienced effort better than ST would. Indeed, Robinson, Johnson, and Herndon (1997) also found subjective confidence to be more strongly related to subjective reports of effort than to response latency, although effort rating and response latency were interrelated.

An important observation is that in both experiments, the effort framing manipulation seemed to affect the correlation between effort ratings and JOLs as well as the correlation between ST and JOL over and above the effects that are due to the intrinsic properties of the studied items. Evidence for the latter effects has been reported in previous studies (see Begg et al., 1989). For example, many studies demonstrated strong effects of item difficulty on both ST and JOLs: Learners spend more time studying difficult items than easy items (see Son & Metcalfe, 2000, for a review) and give higher JOLs to the latter items. In the present study, we tried to minimize the effects of item difficulty by using unrelated paired associates, but there were nevertheless consistent between-item differences. It can be seen in Table 1 that the ST-JOL correlation was negative (−.75) in the data-driven condition of Experiment 1, as expected. However, this correlation was also negative for the goal-driven condition of that experiment (−.54). These correlations are possibly due to interitem differences in intrinsic properties of the items. Indeed, mean ST in the data-driven condition of Experiment 1 correlated .53 across items with mean ST in the goal-driven condition of that experiment and .53 with ST for the self condition of Experiment 2. The respective correlations for mean JOL were .67 and .75. The reliable contribution of the intrinsic properties of the items may be mediated by theory-based or experience-based processes (see Koriat, 1997; Mueller, Tauber, & Dunlosky, 2013). Yet, the manipulation of effort framing exerted an effect on the relationship between ST and JOLs over and above the effects of these intrinsic characteristics of the items. These results document the multiplicity of processes underlying metacognitive judgments (see Undorf & Erdfelder, 2013).

Particularly impressive are the results of Experiment 2, in which ST was experimentally dissociated from whatever effects the intrinsic properties of the stimuli could have on JOLs. Undorf and Erdfelder (2011, 2013), who also examined the monitoring of another person's learning, disentangled the effects of ST from those of item difficulty by concealing the items studied or by manipulating ST independent of item difficulty. In our Experiment 2, the items allegedly studied were presented for STs that were randomly determined for each item, and effort framing was experimentally manipulated independent of the pairs presented. Inspection of Table 1 suggests that despite the dissociation between ST and item difficulty, a reliable contribution of interitem differences to JOLs for other remained. Nevertheless, the effort-framing manipulation exerted an effect on JOLs over and above the effects of these differences.

Comparing the Effects of Data-Driven and Goal-Driven Framing

In both experiments, the results for the data-driven condition were more consistent with our predictions than those for the goal-driven condition. Thus, in the data-driven effort framing, JOLs correlated negatively with both ST and rated effort. In contrast, for the goal-driven condition, the expected positive relationship of JOLs with ST and rated effort was not clearly observed. In fact, inspection of Table 1 indicates that in Experiment 1, the ST-JOL correlation was negative across items not only for the data-driven condition but also for the goal-driven condition. Thus, by and large, items that took longer to study were associated with lower JOLs overall, as had been found in previous studies (e.g., Koriat et al., 2006).

Why is data-driven attribution more dominant? Previous research has shown that ease of processing tends to be attributed to the dimension on which attention is focused. For example, when asked to judge whether target words are old or new, attention is focused on prior experience with the stimulus, and therefore enhanced fluency is likely to result in a feeling of familiarity (see Unkelbach & Greifeneder, 2013, for a review). Also, in a study by Mandler, Nakamura, and Van Zandt (1987), participants were asked to compare two shapes, one of which had been presented earlier. Those who were asked which of the two shapes was brighter judged the old shape to be brighter, whereas those who were asked which of the two shapes was darker judged the old shape to be darker. It is possible that learners typically focus on item difficulty in making JOLs and hence, under self-paced learning, they are more likely to attribute effort to data-driven rather than to goal-driven regulation. Indeed, learners were found to rely on data-driven effort as a basis of JOLs even when item difficulty was controlled for (Undorf & Erdfelder, 2013). Therefore, the framing of effort as goal driven was successful mostly in reducing the negative ST-JOL relationship but not in reversing that relationship.

What Is the Process Underlying the Attribution of Effort?

Several observations provide some clues to the nature of the process underlying the attribution of effort to data-driven or goal-driven regulation. First, as noted earlier, the effects observed in Experiment 1 could derive from the effort-framing query affecting the very regulation of ST. However, because ST was experimentally manipulated in the other condition of Experiment 2, the effect observed in that condition seems to be due to biasing the interpretation of ST. This seems to be the case also of the monitoring of one's own learning in Experiment 1. The results support the idea that attribution possibly occurs at a postregulation stage.

Second, a question of interest is whether the attribution of effort occurs unconsciously. Jacoby and his associates proposed that subjective experience is shaped by a process in which fluent processing is attributed unconsciously to a particular source (Jacoby & Dallas, 1981; C. M. Kelley & Rhodes, 2002; Whittlesea et al., 1990). Possibly, the effects of effort framing on JOLs in the present study were also mediated by a process that was largely unconscious. Koriat et al. (2006) proposed that the memorizing effort heuristic is applied unconsciously to yield a sheer subjective feeling that can serve as the basis of recall predictions (see Koriat, 2000; Koriat & Levy-Sadot, 1999).

Koriat and Ackerman (2010), however, suggested that under certain conditions, participants can apply the memorizing-effort heuristic deliberately and consciously. As mentioned earlier, when monitoring another person's learning, participants did not apply this heuristic, but did so when the other condition followed a self condition (see also Undorf & Erdfelder, 2011). It is important to note that the transfer from the self condition to the other condition occurred only when JOLs were solicited in the self condition but not when participants were not required to make JOLs. These results were taken to suggest a shift from experience-based to theory-based judgments: Learners gain insight about the ST-JOL relationship that underlies JOLs for themselves and then apply that insight in making JOLs for others.

Comparing the Results for the Self and Other

The results for the self task (Experiment 1) and the other task (Experiment 2) were very similar, supporting the idea that similar processes underlie the monitoring of one's own learning and another person's learning. These results may have some bearing on the issue raised by philosophers and psychologists regarding the relationship between metacognition—knowing one's mind—and mindreading—understanding other minds (Carruthers, 2009; Dimaggio, Lysaker, Carcione, Nicolò, & Semerari, 2008; Proust, 2013). Note, however, that systematic differences between the self and other tasks were observed when these tasks appeared in the first block (Koriat & Ackerman, 2010; Undorf & Erdfelder, 2011): Only for the self task did JOLs decrease with ST.

A Hierarchy of Attributions?

We discuss in this final section the implication of our results for the concept of attribution. This concept occupies an important role in two theoretical contexts that are relevant to the present study. First, in the area of social cognition, attribution theories (Heider, 1958; H. H. Kelley, 1967; Weiner, 1985) have provided a general framework for the analysis of behavior. Second, attribution theories of fluency (Jacoby & Dallas, 1981; C. M. Kelley & Rhodes, 2002; Unkelbach & Greifeneder, 2013) have focused on the various ways in which fluent processing can affect subjective experience and behavior. Strangely enough, there has not been sufficient effort to combine insights from the two contexts.

In discussions of fluency, the concept of attribution has been invoked to account for the many different ways in which fluency affects judgments and feelings (See Alter & Oppenheimer, 2009). Unkelbach and Greifeneder (2013) proposed a three-phase model of the effects of fluency. First, fluency is experienced. Second, it is attributed to a certain source, for example, to the mental process of retrieval or to the distracting music (Schwarz et al., 1991). Finally, fluent processing is interpreted. Thus, even when fluency is attributed to the stimulus, it can be interpreted so as to yield a subjective experience of famousness, frequency, liking, or visual clarity.

However, this model, like all theorizing about fluency, focused specifically on differences in data-driven effort (which may be referred to as *effortfulness*) and did not consider the kind of effort that is deliberately invested by the person. Goal-driven effort, in contrast, occupies an important role in social cognition theories of attribution as a possible cause to which events can be attributed. Rotter (1990), for example, distinguished between an internal locus of control, when people believe that they control their own life events, and an external locus of control, when people believe that their life events are determined by external factors that are outside their control. Weiner's (1985) attributional theory of achievement, as noted earlier, includes two factors to which people can attribute their success or failure: effort and task difficulty. Effort is conceptualized as implying attribution to one's own agency (see Metcalfe & Terrace, 2013; Wegner, 2002) and thus corresponds to goal-driven effort. Task difficulty, in turn, corresponds roughly to data-driven effort. Whereas in Weiner's conceptualization, effort and task difficulty represent distal targets to which success or failure can be attributed, in discussions of fluency, effortful versus effortless processing represent the subject of attribution—what is being attributed.

So how can goal-driven effort be incorporated into a stage model like that of Unkelbach and Greifeneder? The first stage in that model is that fluency–disfluency is experienced, so the first question to ask is whether data-driven effort and goal-driven effort "feel" different. The differential effects of data-driven and goal-driven effort on JOLs (and confidence; see Ackerman, 2013; Koriat et al., 2006) suggest that learners can discriminate between the two sources of effort. The results of the present study, however, indicate that participants can nevertheless be induced to attribute their effort to data-driven or goal-driven regulation. Should these results imply a preliminary stage in Unkelbach and Greifeneder's model in which effort is attributed to data-driven regulation before it can be attributed to various external sources such as visual clarity or past exposure? Similarly, in Weiner's model, must effort be first identified as goal driven rather than data driven before one can perceive it as a cause for one's success in a task? If such is the case, this would imply a hierarchy of attributions. Alternatively, the attribution of effort to the task or to one's willful control may be part of the second stage in Unkelbach and Greifeneder's model. Clearly the consideration of data-driven and goal-driven effort within the same theory poses a challenge.

In sum, the present study examined the effects of the effort invested during self-paced study on the monitoring of one's own learning. The results supported the idea that the interpretation of the effort invested as reflecting data-driven or goal-driven regulation moderated the relationship of JOLs to both the amount of ST invested and the rated effort. The results provided further support for the attribution that has been assumed to intervene between the regulation of study effort and the monitoring of one's learning.

References

Ackerman, R. (2013). The diminishing criterion model for metacognitive regulation of time investment. *Journal of Experimental Psychology: General*. Advance online publication. doi:10.1037/a0035098

Ackerman, R., & Zalmanov, H. (2012). The persistence of the fluency–confidence association in problem solving. *Psychonomic Bulletin & Review, 19,* 1187–1192. doi:10.3758/s13423-012-0305-z

Alter, A. L., & Oppenheimer, D. M. (2009). Uniting the tribes of fluency to form metacognitive nation. *Personality and Social Psychology Review, 13,* 219–235. doi:10.1177/1088868309341564

Ariel, R., & Dunlosky, J. (2013). When do learners shift from habitual to agenda-based processes when selecting items for study? *Memory & Cognition, 41,* 416–428. doi:10.3758/s13421-012-0267-4

Ariel, R., Dunlosky, J., & Bailey, H. (2009). Agenda-based regulation of study-time allocation: When agendas override item-based monitoring. *Journal of Experimental Psychology: General, 138,* 432–447. doi:10.1037/a0015928

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: Freeman.

Begg, I., Duft, S., Lalonde, P., Melnick, R., & Sanvito, J. (1989). Memory predictions are based on ease of processing. *Journal of Memory and Language, 28,* 610–632. doi:10.1016/0749-596X(89)90016-8

Benjamin, A. S., Bjork, R. A., & Schwartz, B. L. (1998). The mismeasure of memory: When retrieval fluency is misleading as a metamnemonic index. *Journal of Experimental Psychology: General, 127,* 55–68. doi:10.1037/0096-3445.127.1.55

Bjork, E. L., Bjork, R. A., & Anderson, M. C. (1998). Varieties of goal-directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 103–137). Mahwah, NJ: Erlbaum.

Carruthers, P. (2009). How we know our own minds: The relationship between mindreading and metacognition. *Behavioral and Brain Sciences, 32,* 121–138. doi:10.1017/S0140525X09000545

Castel, A. D., Lee, S. S., Humphreys, K. L., & Moore, A. N. (2011). Memory capacity, selective control, and value-directed remembering in children with and without attention-deficit/hyperactivity disorder. *Neuropsychology, 25,* 15–24. doi:10.1037/a0020298

Dimaggio, G., Lysaker, P., Carcione, A., Nicolò, G., & Semerari, A. (2008). Know yourself and you shall know the other . . . to a certain extent: Multiple paths of influence of self-reflection on mindreading. *Consciousness and Cognition, 17,* 778–789. doi:10.1016/j.concog.2008.02.005

Dunlosky, J., & Herzog, C. (1998). Training programs to improve learning in later adulthood: Helping older adults educate themselves. In D. J. Hacker (Ed.), *Metacognition in educational theory and practice* (pp. 249–275). Mahwah, NJ: Erlbaum.

Dunlosky, J., & Thiede, K. W. (1998). What makes people study more? An evaluation of factors that affect people's self-paced study and yield "labor-and-gain" effects. *Acta Psychologica, 98,* 37–56. doi:10.1016/S0001-6918(97)00051-6

Dweck, C. S., Chiu, C., & Hong, Y. (1995). Implicit theories and their role in judgments and reactions: A world from two perspectives. *Psychological Inquiry, 6,* 267–285. doi:10.1207/s15327965pli0604_1

Haddock, G., Rothman, A. J., Reber, R., & Schwarz, N. (1999). Forming judgments of attitude certainty, importance, and intensity: The role of subjective experiences. *Personality and Social Psychology Bulletin, 25,* 771–782. doi:10.1177/0146167299025007001

Hansen, J., Dechêne, A., & Wänke, M. (2008). Discrepant fluency increases subjective truth. *Journal of Experimental Social Psychology, 44,* 687–691. doi:10.1016/j.jesp.2007.04.005

Heider, F. (1958). *The psychology of interpersonal relations*. New York, NY: Wiley. doi:10.1037/10628-000

Jacoby, L. L., Allan, L. G., Collins, J. C., & Larwill, L. K. (1988). Memory influences subjective experience: Noise judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 240–247. doi:10.1037/0278-7393.14.2.240

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110,* 306–340. doi:10.1037/0096-3445.110.3.306

Jacoby, L. L., Woloshyn, V., & Kelley, C. (1989). Becoming famous without being recognized: Unconscious influences of memory produced by divided attention. *Journal of Experimental Psychology: General, 118,* 115–125. doi:10.1037/0096-3445.118.2.115

Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice-Hall.

Kelley, C. M., & Lindsay, D. S. (1993). Remembering mistaken for knowing: Ease of retrieval as a basis for confidence in answers to general knowledge questions. *Journal of Memory and Language, 32,* 1–24. doi:10.1006/jmla.1993.1001

Kelley, C. M., & Rhodes, M. G. (2002). Making sense and nonsense of experience: Attributions in memory and judgment. In B. H. Ross (Ed.), *Psychology of learning and motivation: Advances in research and theory* (Vol. 41, pp. 293–320). San Diego, CA: Academic Press.

Kelley, H. H. (1967). Attribution theory in social psychology. In D. Levine (Ed.), *Nebraska symposium on motivation* (Vol. 15, pp. 192–238). Lincoln: University of Nebraska Press.

Koriat, A. (1993). How do we know that we know? The accessibility account of the feeling of knowing. *Psychological Review, 100,* 609–639. doi:10.1037/0033-295X.100.4.609

Koriat, A. (1995). Dissociating knowing and the feeling of knowing: Further evidence for the accessibility model. *Journal of Experimental Psychology: General, 124,* 311–333. doi:10.1037/0096-3445.124.3.311

Koriat, A. (1997). Monitoring one's own knowledge during study: A cue-utilization approach to judgments of learning. *Journal of Experimental Psychology: General, 126,* 349–370. doi:10.1037/0096-3445.126.4.349

Koriat, A. (2000). The feeling of knowing: Some metatheoretical implications for consciousness and control. *Consciousness and Cognition, 9,* 149–171. doi:10.1006/ccog.2000.0433

Koriat, A. (2008). Easy comes, easy goes? The link between learning and remembering and its exploitation in metacognition. *Memory & Cognition, 36,* 416–428. doi:10.3758/MC.36.2.416

Koriat, A. (in press). Knowing by doing: When metacognitive monitoring follows metacognitive control. In S. D. Lindsay, A. Yonelinas, C. M. Kelley, & H. L. Roediger (Eds.), *Remembering: Attributions, processes, and control in human memory: Essays in honour of Larry L. Jacoby. Hove,* United Kingdom: Psychology Press.

Koriat, A., & Ackerman, R. (2010). Metacognition and mindreading: Judgments of learning for self and other during self-paced study. *Consciousness and Cognition, 19,* 251–264. doi:10.1016/j.concog.2009.12.010

Koriat, A., Ackerman, R., Adiv, S., Lockl, K., & Schneider, W. (2014). The effects of goal-driven and data-driven regulation on metacognitive monitoring during learning: A developmental perspective. *Journal of Experimental Psychology: General, 143,* 386–403.

Koriat, A., Ackerman, R., Lockl, K., & Schneider, W. (2009). The memorizing effort heuristic in judgments of learning: A developmental perspective. *Journal of Experimental Child Psychology, 102,* 265–279. doi:10.1016/j.jecp.2008.10.005

Koriat, A., & Levy-Sadot, R. (1999). Processes underlying metacognitive judgments: Information-based and experience-based monitoring of one's own knowledge. In S. Chaiken & Y. Trope (Eds.), *Dual process theories in social psychology* (pp. 483–502). New York, NY: Guilford Press.

Koriat, A., & Levy-Sadot, R. (2001). The combined contributions of the cue-familiarity and the accessibility heuristics to feelings of knowing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 34–53. doi:10.1037/0278-7393.27.1.34

Koriat, A., & Ma'ayan, H. (2005). The effects of encoding fluency and retrieval fluency on judgments of learning. *Journal of Memory and Language, 52,* 478–492. doi:10.1016/j.jml.2005.01.001

Koriat, A., Ma'ayan, H., & Nussinson, R. (2006). The intricate relationships between monitoring and control in metacognition: Lessons for the cause-and-effect relation between subjective experience and behavior. *Journal of Experimental Psychology: General, 135,* 36–69. doi:10.1037/0096-3445.135.1.36

Koriat, A., & Nussinson, R. (2009). Attributing study effort to data-driven and goal-driven effects: Implications for metacognitive judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 1338–1343. doi:10.1037/a0016374

Mandler, G., Nakamura, Y., & Van Zandt, B. J. (1987). Nonspecific effects of exposure on stimuli that cannot be recognized. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 646–648. doi:10.1037/0278-7393.13.4.646

Metcalfe, J., Schwartz, B. L., & Joaquim, S. G. (1993). The cue familiarity heuristic in metacognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 851–861. doi:10.1037/0278-7393.19.4.851

Metcalfe, J., & Terrace, H. (Eds.). (2013). *Agency and joint attention*. New York, NY: Oxford University Press. doi:10.1093/acprof:oso/9780199988341.001.0001

Mueller, M. L., Tauber, S. K., & Dunlosky, J. (2013). Contributions of beliefs and processing fluency to the effect of relatedness on judgments of learning. *Psychonomic Bulletin & Review, 20,* 378–384. doi:10.3758/s13423-012-0343-6

Navon, D., & Gopher, D. (1979). On the economy of the human-processing system. *Psychological Review, 86,* 214–255. doi:10.1037/0033-295X.86.3.214

Novemsky, N., Dhar, R., Schwarz, N., & Simonson, I. (2007). Preference fluency in choice. *Journal of Marketing Research, 44,* 347–356. doi:10.1509/jmkr.44.3.347

Oppenheimer, D. M. (2006). Consequences of erudite vernacular utilized irrespective of necessity: Problems with using long words needlessly. *Applied Cognitive Psychology, 20,* 139–156. doi:10.1002/acp.1178

Pieschl, S., Stahl, E., Murray, T., & Bromme, R. (2012). Is adaptation to task complexity really beneficial for performance? *Learning and Instruction, 22,* 281–289. doi:10.1016/j.learninstruc.2011.08.005

Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola Symposium* (pp. 55–85). Hillsdale, NJ: Erlbaum.

Proust, J. (2013). *The philosophy of metacognition: Mental agency and self-awareness*. Oxford, United Kingdom: Oxford University Press. doi:10.1093/acprof:oso/9780199602162.001.0001

Reber, R., & Unkelbach, C. (2010). The epistemic status of processing fluency as source for judgments of truth. *Review of Philosophy and Psychology, 1,* 563–581. doi:10.1007/s13164-010-0039-7

Reber, R., & Zupanek, N. (2002). Effects of processing fluency on estimates of probability and frequency. In P. Sedlmeier & T. Betsch (Eds.), *Frequency processing and cognition* (pp. 175–188). Oxford, United Kingdom: Oxford University Press. doi:10.1093/acprof:oso/9780198508632.003.0011

Reder, L. M. (1987). Strategy selection in question answering. *Cognitive Psychology, 19,* 90–138. doi:10.1016/0010-0285(87)90005-3

Robinson, M. D., Johnson, J. T., & Herndon, F. (1997). Reaction time and assessments of cognitive effort as predictors of eyewitness memory accuracy and confidence. *Journal of Applied Psychology, 82,* 416–425. doi:10.1037/0021-9010.82.3.416

Rotter, J. B. (1966). Generalized expectancies for internal versus external control of reinforcement. *Psychological Monographs: General and Applied, 80*(1, Whole No. 609). doi:10.1037/h0092976

Rotter, J. B. (1990). Internal versus external control of reinforcement: A case history of a variable. *American Psychologist, 45,* 489–493. doi:10.1037/0003-066X.45.4.489

Salomon, G. (1984). Television is "easy" and print is "tough": The differential investment of mental effort in learning as a function of perceptions and attributions. *Journal of Educational Psychology, 76,* 647–658. doi:10.1037/0022-0663.76.4.647

Schwarz, N. (2004). Metacognitive experience in consumer judgment and decision making. *Journal of Consumer Psychology, 14,* 332–348. doi:10.1207/s15327663jcp1404_2

Schwarz, N. (in press). Metacognition. In E. Borgida & J. A. Bargh (Eds.), *APA handbook of personality and social psychology: Attitudes and social cognition*. Washington, DC: American Psychological Association.

Schwarz, N., Bless, H., Strack, F., Klumpp, G., Rittenauer-Schatka, H., & Simons, A. (1991). Ease of retrieval as information: Another look at the availability heuristic. *Journal of Personality and Social Psychology, 61,* 195–202. doi:10.1037/0022-3514.61.2.195

Soderstrom, N. C., & McCabe, D. P. (2011). The interplay between value and relatedness as bases for metacognitive monitoring and control: Evidence for agenda-based monitoring. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37,* 1236–1242. doi:10.1037/a0023548

Son, L. K., & Metcalfe, J. (2000). Metacognitive and control strategies in study-time allocation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 204–221. doi:10.1037/0278-7393.26.1.204

Tamir, M., Robinson, M. D., Clore, G. L., Martin, L. L., & Whitaker, D. (2004). Are we puppets on a string? The contextual meaning of unconscious expressive cues. *Personality and Social Psychology Bulletin, 30,* 237–249. doi:10.1177/0146167203259934

Topolinski, S., Likowski, K. U., Weyers, P., & Strack, F. (2009). The face of fluency: Semantic coherence automatically elicits a specific pattern of facial muscle reactions. *Cognition & Emotion, 23,* 260–271. doi:10.1080/02699930801994112

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology, 5,* 207–232. doi:10.1016/0010-0285(73)90033-9

Undorf, M., & Erdfelder, E. (2011). Judgments of learning reflect encoding fluency: Conclusive evidence for the ease-of-processing hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37,* 1264–1269. doi:10.1037/a0023719

Undorf, M., & Erdfelder, E. (2013). Separation of encoding fluency and item difficulty effects on judgements of learning. *The Quarterly Journal of Experimental Psychology, 66,* 2060–2072. doi:10.1080/17470218.2013.777751

Unkelbach, C. (2006). The learned interpretation of cognitive fluency. *Psychological Science, 17,* 339–345. doi:10.1111/j.1467-9280.2006.01708.x

Unkelbach, C., & Greifeneder, R. (2013). A general model of fluency effects in judgment and decision making In C. Unkelbach & R. Greifeneder (Eds.), *The experience of thinking* (pp. 11–32). New York, NY: Psychology Press.

Wegner, D. M. (2002). *The illusion of conscious will*. Cambridge, MA: MIT Press.

Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review, 92,* 548–573. doi:10.1037/0033-295X.92.4.548

Whittlesea, B. W. A. (1993). Illusions of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 1235–1253. doi:10.1037/0278-7393.19.6.1235

Whittlesea, B. W. A., Jacoby, L. L., & Girard, K. (1990). Illusions of immediate memory: Evidence of an attributional basis for feelings of familiarity and perceptual quality. *Journal of Memory and Language, 29,* 716–732. doi:10.1016/0749-596X(90)90045-2

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