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KNOWING BY DOING

When Metacognitive Monitoring Follows Metacognitive Control

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Larn Jacoby's attributional theory of memory implies, along with the James-Lange view, that subjective experience can follow from, rather than be responsible for, objective performance. Research will be reviewed suggesting that metacognitive judgments are based sometimes on the feedback from control operations. This occurs when the regulation of effort is data-driven. In that case, metacognitive judgments (e.g., judgments of learning, confidence) decrease with the amount of effort invested in each item. When effort is goal-driven, in contrast, metacognitive judgments increase with amount of effort. The occurrence of both types of relationship within the same task highlights the delicacy of the attribution processes that have been emphasized by Jacoby and his associates, which con- tributes to the accuracy of peoples monitoring of their own knowledge and performance.

One of the long-standing issues in psychology concerns the cause-and-effect relation between subjective experience and behavior. This issue has been articulated by William James (1884) with respect to the relationship between emotional feelings and behavior. He raised the question whether we run away because we are afraid or we are afraid because we run away. The James-Lange theory, which assumes that emotional feelings are based on the feedback from bodily reactions, has gained empirical support. Several studies indicated that participants can be induced to experience specific emotional feelings by making them adopt certain behavioral expressions or body postures (e.g., Niedenthal, 2007; Strack & Neumann, 2000). In the area of memory, Kelley and Jacoby (1998) took their work to support the insight owed to the James-Lange view of emotion, concluding that "subjective experience can involve an attribution or unconscious inference about effects on performance and so follow from, rather than be responsible for, objective performance" (pp. 127-128).

In this chapter I review results that have some bearing on this thesis. These results concern specifically the relationship between metacognitive monitoring and metacognitive control. Underlying the growing interest in metacognition is the assumption that metacognitive feelings are not mere epiphenomena but exert causal effects on the regulation of cognitive processes and behavior. However, some very early work that I conducted suggested that monitoring may actually be based on the feedback from control operations. That suggestion came from a curious observation about the relationship between study time (ST) and judgments of learning (JOLs) during the self-paced study of paired associates A well-replicated finding is that participants spend more time studying normatively difficult items than normatively easy items (for reviews see Dunlosky -.&Ariel 2011; Son & Metcalfe, 2000).The standard explanation of this observation is that learners attempt to compensate for the difficulty of the more difficult items by investing extra time studying these items, possibly attempting to attain the same degree of mastery ("norm of study," see Dunlosky & Hertzog, 1998) across items However, my results (1983, unpublished) indicated that participants in a self- paced condition yield higher recall and JOLs for the normatively easy items than for the normatively difficult items, and the difference between the two types of items in both recall and JOLs was practically the same as that demonstrated by a fixed ST group, for which presentation time was the same across all items

These results were perplexing in two respects. First, they were inconsistent with the well-established finding that recall increases with the total amount of ST available for each item. I discussed this result with Tom Nelson who turned out to have similar perplexing findings which he later published under the heading "labor-in-vain" effect (Nelson & Leonesio, 1988).

The second perplexing aspect of the results is that they raise the question why do learners bother to regulate their ST according to the perceived difficulty of the item if they "know" (as suggested by their JOLs) that this is futile? 111 fact, when learners were presented with the same list of items for four self-paced trials, they invested more ST in the difficult than in the easy items and continued to make relatively low JOLs for the difficult items.

Several experiments that were intended to clarify the problem did not yield instructive results until many years later it suddenly occurred to me that the cause-and-effect relationship between JOLs and ST may actually be in the opposite direction: JOLs are based on ST rather than ST being deliberately regulated with the goal attaining a desired level of mastery. The idea was that in a typical self-paced learning, JOLs are data-driven rather than goal-driven.

Data-Driven Regulation and Its Effects on JOLs

Underlying data-driven regulation is the idea that in self-paced learning you give each item what it takes. It is not that you look at an item and say "this is a difficult item; I should invest relatively more time studying it." Rather, it is by spending a great deal of time attempting to commit an item to memory that you realize that the item is “difficult” and is not very likely to be recalled. Thus, the amount of ST invested in an item is essentially determined by the item itself, or by the learner—item interaction: Learners spend as much time and effort as the particular item “calls for” in a bottom-up fashion. Their JOL is then based retrospectively on the *memorizing effort heuristic* according to which the more effort needed to study an item, the less likely it is to be recalled.

The data-driven regulation brings to the fore the monitoring function of ST, and implies a control—>monitoring (CM) model in which the output from metacognitive control serves to inform metacognitive monitoring. The CM model is consistent with William James’ view that we are afraid because we run away. It is also consistent with the general view advanced by Kelley and Jacoby (1998) that subjective experience follows rather than precedes performance.

It should be stressed that in data-driven regulation, JOLs are assumed to rest not on ST as such, but on subjective effort. However, ST is a good indicator of data-driven study effort (see Koriat, Ma’ayan, & Nussinson, 2006).The proposition that JOLs are based on memorizing effort should not come as a surprise to many writers who, like Jacoby, emphasized the importance of processing fluency as a determinant of metacognitive judgments (Jacoby & Whitehouse, 1989). However, with the exception of Jacoby and his associates, most of these writers have not been aware of the important metatheoretical implication of fluency- based feelings and judgments: Subjective experience can be based on the feedback from control operations.

Evidence for control-based monitoring comes from several studies in which JOLs were found to *decrease* with the amount of ST invested in an item. In Experiment 1 of Koriat et al. (2006), the memorization effort heuristic was found to have some validity: The more ST was allocated to an item the less likely was the item to be recalled four months later. Also, when JOLs were solicited a few trials after study, the JOL-ST negative correlation decreased in comparison with when JOLs were immediately made after study. This result suggests that the subjective experience gained from the effort invested in studying an item fades away with the passage of time. Delayed JOLs are in fact more strongly correlated with retrieval fluency (as indexed by the latency of retrieving a target in response to a cue dui mg study) than with encoding fluency (as indexed by ST) (Koriat & Ma’ayan, 2005).

The negative ST—JOL and ST-recall relationships were obtained even when only unrelated pairs (pairs with little normative association between the mem- hers) were used (Koriat, 2008a). These relationships are somewhat counter-intuitive. However, a similar relationship, which challenges the adage “Easy-comes-easy-goes”, was obtained when participants studied a list of paired associates for several study-test cycles (Koriat, 2008a; Koriat, Ackerman, Lockl, & Schneider, 2009a). In these studies, only the pairs that participants had failed to recall on the preceding test phase were presented and then tested in each cycle.

The study—test cycles were terminated when participants achieved perfect recall Performance on a subsequent recall task that took place after a short interval decreased with the number of trials to acquisition. Thus, the more often an item was studied (and tested) the *lower* was its recall likelihood. Furthermore. JOLs made at the end of each trial suggested the operation of the *easily learned, easily remembered* (ELER) heuristic: Items that require fewer trials to acquisition ate associated with higher JOLs than those requiring more trials. These results were taken to suggest that metacognitive judgments incorporate knowledge about the internal ecology of cognitive processes, much as the perception of the external world embodies knowledge about the ecological structure of the environment. They incorporate the implicit knowledge that items that are mastered more easily by the learner are more likely to be remembered in the future. What is important to stress is that trials to acquisition are determined by the interaction between the item and the learner's orientation and background, and hence reflects data-driven regulation.

It is interesting to note that participants do not spontaneously apply the memorizing effort heuristic when they make recall predictions for another learner. In Koriat and Ackerman's (2010b) study, participants observed a learner allegedly studying paired associates under self-paced instructions, spending different amounts of time on different items. Their recall predictions for that learner failed to evidence a negative ST—JOL relationship. Only when participants studied paired associates themselves and made JOLs in a first phase of the experiment did they demonstrate a negative ST—JOL relationship in making recall predictions for another person in a second phase.

The Effects of Data-Driven Regulation on Confidence Judgments

The idea that metacognitive monitoring may be based on the feedback from control operations underlies some of the work on confidence judgments. That work has documented an inverse relation between confidence and response latency (e g. Kelley & Lindsay, 1993; Koriat, 2008b, 2012; Loftus, Donders, Hoffman, & Schooler, 1989; Mitchum & Kelley, 2010; Robinson, Johnson, & Herndon. 1997). This relation has been interpreted to imply that once an answer or a solution has been retrieved or selected, the confidence in that answer or solution is based on the feedback from the process leading up to the answer or solution. As with the memorizing effort heuristic, the assumption is that the greater the effort and the longer the deliberation needed to reach an answer or a solution, the lower the confidence in the correctness of the answer or solution. Research by Kelley and Lindsay (1993) helped support the causal link between response time and confidence: When response speed was enhanced through priming, confidence judgments also increased accordingly. Lindsay and Kelley (1996) also showed that providing participants with recall cues that caused nonstudied words to come easily to mind at test created illusions of familiarity, as evidenced by a high likelihood of “know” judgments.

This research is consistent with the view of confidence judgments as reflecting control-based monitoring. Furthermore, they underscore the retrospective nature of metacognitive judgments: Possibly, the time to reach an answer or a solution is affected by a variety of factors that are inherent in the question or the problem (or in the interaction between the person and the specific question or problem). Once an answer or a solution has been reached, the amount of effort and time expended can then serve as a cue for the feeling of certainty. The implication is that monitoring follows control operations.

It has also been suggested that response latency may mediate the accuracy of confidence judgments. On the one hand, confidence judgments in an answer increase with the speed of choosing or retrieving that answer. On the other, response speed is diagnostic of the accuracy of the answer (e.g., Hertwig, Herzog, Schooler, & Reimer, 2008). Both of these effects have been found even for second-grade children (Ackerman & Koriat, 2011; Koriat & Ackerman, 2010a). Thus, the accuracy of confidence judgments in monitoring performance is partly mediated by reliance on latency as a cue for correctness (Kelley & Lindsay, 1993; Robinson et al., 1997).

Knowing by Doing

Control-based monitoring involves what I call “knowing by doing.” It is by attempting to study an item that we know whether we are likely to recognize or recall the item in the future. Similarly, it is by attempting to retrieve an answer or solve a problem that we know whether the answer or solution is correct. The same is generally true of feeling-of-knowing (FOK) judgments: Koriat (1993) proposed that these judgments can be based on the feedback from the search for the elusive memory target—the number of partial clues that come to mind and the ease with which they come to mind. The implication is that it is by searching for a memory target, that participants “know” whether an unrecallable target is available in memory.

Control-based metacognitive judgments represent experience-based judgments, as distinct from theory-based or information-based judgments (Kelley & Jacoby. 1996; Koriat & Levy-Sadot, 1999). Whereas information-based judgments involve an analytic, deliberate inference that is intended to yield an educated judgment, experience-based judgments rely on mnemonic cues that derive online from task performance (Kelley & Jacoby, 1998). These cues are devoid of declarative content. The implication is that experience-based metacognitive judgments are by-products of the ordinary processes of learning, remembering, and thinking. They are parasitic on object-level cognitive operations rather than reflecting the operation of a dedicated process (see Koriat, Nussinson, Bless, & Shaked, 2008).

Goal-Driven Regulation

In the previous analyses I focused on the monitoring function of cognitive effort. The cognitive effort invested in studying an item or in solving a problem is assumed to serve as a cue for metacognitive judgments such that greater effort is seen to be diagnostic of poorer future memory performance. However, effort clearly has a control function: Students know that if they want to get a higher grade in an exam they should spend more time and effort preparing for that exam. Indeed, it is the control function of ST that has been commonly emphasized in most previous research on self-paced learning.

Koriat et al. (2006) proposed that the control function of effort is characteristic of *goal-driven* regulation, for example when the allocation of ST is used as ɩstrategic tool for regulating memory performance in accordance with different goals. Indeed, discussions of the self-management of learning have emphasized the ability of learners to deploy cognitive strategies and resources adaptively to optimize performance (see Bjork, Dunlosky, & Kornell, 2013).

Unlike data-driven regulation, the signature of goal-driven regulation ^ 2 *positive* relationship between the amount of time and effort invested and metacognitive judgments. Thus, for any given item, end-of-study JOLs are expected to increase as more ST is invested in that item. Similarly, for any given problem, confidence in the correctness of the solution should generally increase the more time is invested in reaching that solution. Such a positive relationship is expected when ST or solution time are goal driven, regulated by the person in accordance with specific goals that are extrinsic to the item or problem in question.

Goal-driven regulation is best studied when different incentives are attached to the recall of different items or to the solution of different problems Indeed, when different incentives or values were attached to different items, learners generally allocated more ST to the high-incentive than to the low-incentive items, and in parallel made higher JOLs for the high-incentive items (e.g Castel, Murayama, Friedman, McGillivray, & Link, 2013; Dunlosky & Thiede, 1998, Soderstorm & McCabe, 2011). Such was also the case for college students in Experiment 5 of Koriat et al. (2006). In that experiment, half of the paired associates in a list were awarded a 1 -point incentive for their recall, and the remaining items were awarded a 3-point incentive. The incentive associated with each item was announced before the presentation of the item for self-paced study Participants invested more ST in the 3-point items than in the 1-point items, and in parallel reported higher JOLs for the former items. Similarly, in Experiment 7 of that study, participants spent more time solving problems associated with a 5-point incentive than those associated with a 1-point incentive, and in parallel expressed stronger confidence in the solution of the former items than in the solution of the latter problems. Thus, a positive relationship was observed between amount of effort and metacognitive judgments.

These results are consistent with a monitoring—►control (MC) model in which $T allocation is used by the learner as a strategic tool toward the achievement of specific goals. Presumably, participants continue to invest more effort in the item until they reach a desired level of ST or a desired level of confidence, so that the amount of effort invested is modulated by metacognitive judgments. Of course, many other findings in the literature are consistent with the idea that monitoring guides and drives control operations (e.g., Dunlosky &Thiede, 1998; Koriat -&Goldsmith, 1996; Kornell & Metcalfe, 2006; Nelson & Leonesio, 1988). In terms of the issue raised by William James, the MC model is consistent with the idea that we run away because we are afraid.

The Combined Effects of Data-Driven and Goal-Driven Regulation

Koriat et al. (2006) argued that the CM and MC models are not mutually exclusive, and indeed, they found evidence for both types of ST-JOL relationships within the same task. As just noted, in their Experiment 5, the manipulation of incentive resulted in a *positive* relationship between JOLs and ST. At the same time, however, a *negative* ST-JOL relationship was obtained within each incentive level, so that the more ST was invested in an item, the *lower* was the JOL associated with that item, suggesting that the allocation of ST between same-incentive items is data driven.

Precisely the same pattern was observed in Experiment 7 for the relation- ship between confidence judgments and response latency in a problem-solving task (Koriat et al., 2006). As just noted, participants invested more time in the problems that were associated with a higher incentive than m those that were associated with a lower incentive, and in parallel, expressed greater confidence in the solutions of the former problems than in those of the latter problems (MC model). However, for all problems with the same incentive level, confidence decreased with solution time, suggesting that confidence was based on the feedback from task performance (CM model; see Kelley & Lindsay, 1993).

These results suggest that the two models considered by William James (1884) with respect to the cause-and-effect relation between emotional feelings and emotional behavior are not mutually exclusive. Whereas the effects of goal- driven regulation are consistent with the feeling-affects-behavior model, the data driven regulation is consistent with the behavior-affects-feeling model. The CM and MC models can coexist within the same situation, as illustrated above, but they can also occur sequentially: A metacognitive judgment that is based 011 the feedback from a control operation can exert its own effects on subsequent behaviors. Evidence for such a concatenated CM—MC chain was reported by Koriat and Levy-Sadot (2001) for FOK judgments and by Koriat and Ackerman (2010a) for confidence judgments.

It should be stressed that the idea of bidirectional links between monitoring and control is basic to the influential model of Nelson and Narens (1990). The model distinguished between two interrelated levels, an object level and a meu level. Control is conceptualized as a flow of information from the meta level to the object level that modifies the state of the object level. This is illustrated by the act of speaking into a telephone handset. Monitoring, in turn, is conceptualized as the flow of information from the object level to the meta level, analogous to listening to the telephone handset. Thus, the model stipulates that monitoring affects control and that control affects monitoring. However, in our conceptualization both of these directional links are part of the MC model. For example, the idea that self-regulated learning is driven by the attempt to reduce the discrepancies between perceived states and goals (Dunlosky & Ariel, 2011) implies that learners monitor their ongoing state and continue to invest more effort studying a particular item until they have reached a desired JOL level ("norm of study"). The CM model, in contrast, embodies the idea of "knowing by doing" It is the feedback from studying an item that serves as the very cue for monitoring. It is by studying an item that one knows whether the item will be recalled or not. Hence, the more ST one invests in studying an item, the lower is one's recall prediction.

The Role of Attribution

The occurrence of a positive and a negative ST—JOL relationship within the same situation implies an attribution process that intervenes between ST regulation and metacognitive monitoring. Jacoby and his associates (see Jacoby, Kelley, & Dywan, 1989; Kelley & Jacoby, 1990, 1998), have provided extensive evidence for the critical role of attribution in mediating the effects of processing fluency on subjective experience. The evidence comes from the occurrence of memory and perceptual errors. It was shown, for example, that fluent processing that steins from priming may be incorrectly attributed to the past, resulting in a memory illusion (Jacoby & Whitehouse, 1989). In turn, fluent processing emanating from the prior presentation of the stimulus may be misattributed to characteristics of the current stimulus (e.g., brightness or loudness; see Jacoby, Allan, Collins. & Larwill, 1988).

In the work presented in Koriat et al. (2006) and Koriat, Ackerman. Adiv, Lockl, and Schneider (2014), the evidence for the mediating role of attribution comes from people s ability to respond differentially to cognitive effort depending on its presumed source. Because the amount of effort invested in each items is conjointly determined by data-driven and goal-driven regulation, an attribution process was postulated in which variations in effort are attributed by the learner in different proportions to data-driven or goal-driven regulation before the implications for metacognitive judgments are determined. The component of ST that is attributed to data-driven effects then contributes toward reducing one's

JOLs, whereas the component that is attributed to the effects of goal-driven regulation contributes toward enhancing one's JOLs.

To support the reality of this process, Koriat and Nussinson (2009) 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 for which regulation tends to be data-driven, participants who were asked to contract the corrugator muscle during study (mental effort group) made lower JOLs than those who were asked to raise their eyebrows (control group). In contrast, in another experiment that induced 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 mental-effort participants expressed higher JOLs for the chosen items than control participants.

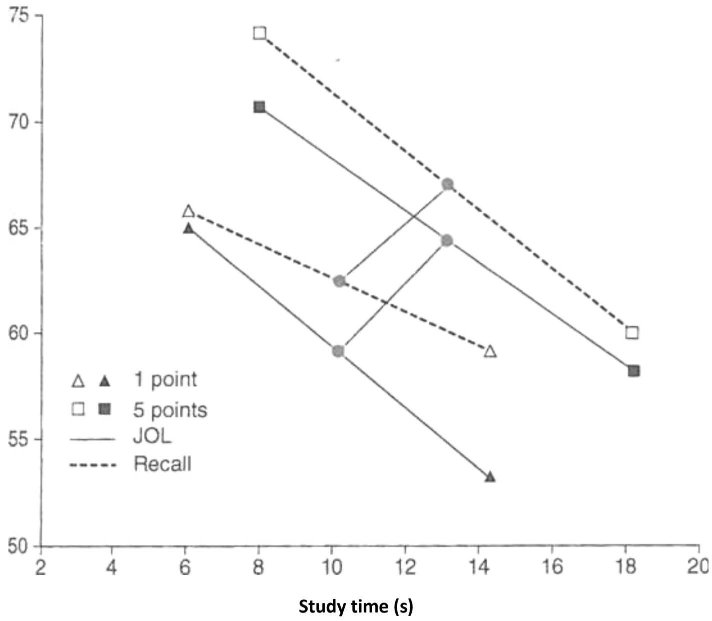

FIGURE 12.1 Mean judgment of learning and recall for 9th-graders for below-median and above-median study time for each incentive level. Plotted also (dotted lines) are mean JOL and recall as a function of mean study time for each incentive level. (Reproduced from "The effects of goal-driven and data-driven regulation on metacognitive monitoring during learning: A developmental perspective" by A. Koriat, R. Ackerman, S. Adiv, K. Lockl and W. Schneider, 2014, *Journal of Experimental Psychology: General.* Copyright © 2013 by the American Psychological Association. Reproduced with permission.)

Figure 12.1 presents mean JOLs and recall for 9th-graders for below- median and above-median STs for 1-point and 5-point incentives. Plotted also (dotted lines) are mean JOL and recall as a function of mean study time for each incentive level (Koriat et al., 2014; Experiment 4). The results replicate the positive and negative ST—JOL relationships obtained for college students in Koriat et al. (2006). However, they also demonstrate an impressive similarity between the pattern of results for JOLs and recall, indicating that the effects of STs on JOLs capture faithfully the respective effects on recall. Thus, young adults are sometimes very skillful in deriving the implications for recall of variations in ST by attributing these variations to their respective source— data-driven or goal-driven.

A Developmental Perspective on Data-Driven and Goal-Driven Regulation

Koriat, Ackerman, Lockl, and Schneider (2009b) examined the sensitivity of children's metacognitive judgments to data-driven and goal-driven regulation. Children in 3rd—6th grades yielded a decrease in JOLs with increasing ST, suggesting sensitivity to data-driven variation in ST. In contrast, children in 1st and 2nd grades did not evidence such a decrease, although they demonstrated a negative ST-recall relationship. These results suggest a developmental increase in the reliance on ST as a cue for JOLs. The within- person ST—JOL correlation suggested a further increase in that reliance until adulthood. Other results also indicated a developmental increase in children's sensitivity to response latency as a cue for confidence judgments (Koriat & Ackerman, 2010a).

However, the ability to respond differentially to data-driven and goal-driven variation in ST within the same task was found to develop much later. Children in Grades 5 and 6 exhibited a positive ST—JOL relationship for goal-driven regulation and a negative relationship for data-driven regulation but never in the same task. In contrast, the JOLs and recall of 9th graders and college students yielded differential co-sensitivity to data-driven and goal-driven variation. The 5th and 6th graders demonstrated such co-sensitivity only under a condition that helped them in partitioning the variation in ST into its data-driven and goal- driven components.

In sum, our results are consistent with two ideas that have been emphasized by Jacoby and his associates. The first is that subjective experience can follow rather than precede objective performance. The second is that the effects of performance-based cues (e.g., fluency, effort) on subjective experience are mediated by an attributional process. Our work additionally stressed the distinction between data-driven and goal-driven regulation, and highlighted the challenge that this distinction poses for people's online monitoring of then own performance.

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REMEMBERING

Attributions, Processes, and Control in Human Memory Essays in Honor of Larry Jacoby

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Andrew P. Yonelinas is a cognitive psychologist with expertise in quantitative modeling and memory disorders. He is an expert in memory models, measure- ment methodology, and quantitative analysis. He has published extensively on memory theory, measurement, and memory disorders associated with age-related changes including normal aging, stroke, cardiac arrest, and Alzheimer's disease. He developed a highly influential model of memory retrieval that has become the standard in the field and is featured in several textbooks.

Henry L. Roediger, III holds an endowed chair at Washington University in St. Louis, Missouri, USA, and is in the top echelon of researchers in cognitive psychology. He published highly influential work on "implicit" memory in the 1980s, and in the 1990s he and coauthor Kathleen McDermott popularized and greatly extended a procedure for fostering false memories that had initially been introduced in the 1950s by James Deese. The Deese—Roediger—McDermott or DRM method has been used in hundreds of published studies and it continues to be very popular today.

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