2

A Cognitive and Metacognitive Analysis of Self-Regulated Learning

Philip H. Winne
Faculty of Education, Simon Fraser University

The mind is a storehouse for knowledge. The world affords people uncountable opportunities to learn many things but not all opportunities are taken up—people are selective—they self-regulate learning. To examine how people self-regulate what and how they learn, I first present several core ideas.

KNOWLEDGE HAS A KEY ROLE IN LEARNING

Fundamentally, there are three kinds of inputs to learning. The first is knowledge. Examples are: what “Au revoir” means, rules for reducing fractions, and a feeling of relief when my book club chooses a science fiction novel. Knowledge is produced when people selectively link information into a complex network. Knowledge also provides inputs to various cognitive operations and metacognitive operations. These are described later.

A second input to learning is information. Information is potential knowledge if it can be coherently articulated with knowledge. Examples could be: the plot of Macbeth, syncopation in music, and the principle of refraction.

The third input to learning is experience. Examples are: sounds, such as those perceived when someone speaks; squiggles you see that may or may not represent a character or icon in a human symbol system; and sensations, such as eagerness or apprehension in a new situation. Experience affords opportunities to construct information by interpreting sensations in terms of knowledge alongside other information in mind but not yet made into knowledge, not yet learned.

Implications

Distinctions between knowledge, information, and experience have two important implications. First, knowledge plays roles in transforming experience into information and information into knowledge. Without knowledge, experience would be gibberish, sensation without sense.

Second, learners must operate on experience to construct information and operate on information to forge knowledge. Retrieving knowledge from memory is key to these events.
Other cognitive operations are applied to articulate knowledge with new experiences and new information.

Regarding metacognition and self-regulated learning (SRL), cognitive operations have two additional key roles. First, executing cognitive operations generates experience a learner can inspect, such as how much effort was applied and whether it was successful. Second, cognitive operations can be controlled. These are the topics of metacognition and agency, respectively, that are central to SRL.

COGNITION HAS LIMITED CAPACITY

The “work” of building information from experience, and cognitively and metacognitively operating on information and knowledge occurs in a hypothetical mental location called working memory. Working memory has limited capacity. Only a very small selection of all the potentially available experience, information and knowledge can be grist for cognitive and metacognitive operations. A learner in biology class is (hopefully) not attending to dust motes floating in the air, wondering why an attractive girl didn’t accept his invitation to a party or mentally imaging a game-winning slap shot. These and other ideas are available but not focal in working memory.

Implications

Limited capacity for cognitively and metacognitively operating on mental content has several corollaries. First, learners bundle content into larger packages. These are variously called chunks, schemas, or frames when content is declarative knowledge about how chocolate tastes, the definition of “commutative” in mathematics, or the organization of common features in a textbook—title page, table of contents, pages, glossary, etc. Another kind of knowledge package is a production. It organizes steps for completing activities under particular conditions—when to say “Please,” how to plot a quadratic inequality, and steps in researching a term paper.

Second, learners often suffer errors in complex or time-limited tasks. Some are errors of omission when relevant experience, information or knowledge escapes the learner’s purview. Others are errors of commission. Learners invent content they never experienced or apply it only because it has been common in past similar situations.

Third, because working memory can be overwhelmed and because information or knowledge can be lacking, learners are motivated to regulate which content they select to work with and which operations they apply. These implications of limited capacity support an inference that SRL is inherent in learning activities (Winne, 1995). SRL is natural and learners do it whether taught about it or not.

KNOWLEDGE IS A FORM OF COGNITION

Extensive, coordinated, automated knowledge plays critical roles in cognition that produces knowledge. To unpack this claim, consider two formats for knowledge about domains as diverse as history, astronomy, music, composition and thinking skills: declarative knowledge and procedural knowledge.

The declarative format for representing knowledge (literally, presenting the knowledge again) describes what a topic is and what is known, predicted, favored or inferred about it. Examples include: statements of likes and dislikes, definitions, elaborations, analogies,
metaphors, explanations, judgments, organizing frameworks such as schemas and outlines (e.g., the standard form of a fugue), and a list of members in a category (e.g., inert gases). Knowledge can be probabilistic—there is an 80% chance of rain today. A method can be described by steps to summarize efficiently: delete unimportant information, delete redundant information, use a superordinate term to describe a cluster of information, and create a topic sentence (Brown & Day, 1983).

The procedural format represents knowledge that accomplishes tasks. It is modeled as **If-Then-Else productions** and patterned sets of productions that form **production systems**. While a procedure can be written out in declarative format, that is not procedural knowledge. Procedural knowledge means to carry out activities to accomplish a task. For example, If an article I’m reading contains a word I don’t understand—**Then I will stop reading to look up the word**’s definition. But, If my dictionary or my computer is not conveniently available (because I’m on the bus), **Else I will read on expecting the word’s meaning may become clear with further context**. Other examples of procedural knowledge include: applying grammatical rules to punctuate a complex sentence, factoring an algebraic expression, and reading between the lines to infer what a teacher expects in an essay.

A standard trajectory transforms declarative knowledge for action (a list of steps) into weakly articulated actions that absorb cognitive resources (the beginning of skilled performance) into smooth-flowing, automated action (expertise) that makes little demand on limited cognitive resources. This transformation requires extensive deliberate practice with feedback (Ericsson, Krampe, & Tesch-Römer, 1993). Automated production systems are workhorses learners use to tackle everyday tasks such as reading, texting, and taking notes. Interruptions and breakdowns in productions are primary occasions for SRL.

When a learner attends to a chunk of knowledge, other chunks of knowledge nearby in the memory network are activated, like a ripple effect. This process by which activation fans out is called **spreading activation**. Whereas procedures create new information, spreading activation brings dormant knowledge into focus in working memory.

Together, declarative and procedural knowledge comprise a huge proportion of what learners think about, how they think, and how they SRL. For example, when a learner studies a chapter, word meanings are activated without thought. Paragraph indentation signals shifts to new main ideas. Bold-style font is recognized as “important.” Phrases such as, “To summarize…,” trigger study tactics that, for example, may involve monitoring how thoroughly each item in the summary can be expanded to approximate what was originally presented in the chapter and how much effort that elaboration required. On the basis of these two results, the learner may regulate whether to restudy.

**Implications**

Declarative knowledge is sometimes wrongly considered inert, having no intrinsic effect. When a learner attends to an item of declarative knowledge, there are two effects. First, when a particular package of declarative knowledge occupies working memory, other knowledge cannot be attended to because of limited capacity. The scope of knowledge available at points in work on a task is directly proportional to the learner’s expertise regarding the task’s content. Second, attending to a particular item of knowledge activates other knowledge. For example, when a mathematical expression in experienced, spreading activation may trigger: (a) a method for trying to understand such expressions, such as dissecting them part by part; (b) a recollection that this “dissection” method recently worked well but only if no part of the mathematical expression is skipped; and, (c) as a result of these activated bits of knowledge, the learner has moderately high efficacy.
Procedural knowledge of the domain being studied accounts for a great deal of how learners engage with tasks and what they can regulate. Stated succinctly, how learners think is mostly what they know. Importantly, procedural knowledge extends beyond academic subjects to include rules and protocols for social interactions, as well as strategies for managing motivation and anxiety. Regarding SRL, a significant collection of production systems learners regulate is study tactics and learning strategies. These are cognitive tools for accomplishing everyday learning tasks.

**COGNITION IS VERY OFTEN IMPLICIT**

Most cognition is carried out without learners needing either to deliberate about doing it or to control fine-grained details of how it unfolds (Burgh & Williams, 2006; Koriat, 1997). Some researchers describe such cognition as “unconscious” but I prefer the label implicit. Because cognitive operations cannot be inspected directly, learners and researchers alike infer when they are used and qualities of their use by examining features of product(s) they create.

There is a second explanation for why productions and production systems appear implicit. It is that the mind “all by itself” activates information organized in the network of knowledge that is long-term memory (Anderson, 1991). This happens as a learner directs attention to incoming experiential data and mostly automatically interprets it in relation to prior knowledge. For instance, when an accomplished student of earth science views a diagram of the solar system, the student appears to “just know” which orbit is Saturn’s. This happens because activation spreads along pathways to reach schemas that organize knowledge about the sun, planets and their orbits, the asteroid and Kuiper belts, and more. All this knowledge is potentially available but, due to limits of cognitive capacity, only some of it receives focal attention.

As learners experience multiple learning opportunities every day over thousands of days throughout their lives, they build and reshape highly complex, utterly personal and yet socioculturally comparable networks of information. They elaborate and discriminate elements of knowledge by assigning values to attributes that describe it, such as familiarity or priority.

Learners can exercise some control to regulate where in their network of knowledge they “direct” their spreading activation. They do this by scanning content in working memory and monitoring what to attend to, which initiates spreading activation. Thus, some particular elements of experience, information and knowledge are momentarily favored. But spread per se needs no attention. It is inherent to the human cognitive system (Anderson, 1991).

**Implications**

Because so much of cognitive activity is implicit, learners are infrequently aware of their cognition. There are two qualifications. First, cognition can change from implicit to explicit when errors and obstacles arise. But, second, unless learners trace cognitive products as tangible representations—“notes to self” or underlines that signal discriminations about key ideas, for example—the track cognitive of events across time can be unreliable, a fleeting memory.

Lacking traces of cognition, learners rely on fallible memory to characterize their cognition and metacognition. They often reconstruct what might have been likely rather than retrieving accurate data about actual cognition. Also, because learners typically lack extensive and discriminating concepts for describing cognition, such as a cognitive psychologist would command, their accounts of cognition may be rudimentary and lack sharpness in features they describe. In short, learners not trained to introspect accurately about cognition are likely to make errors of omission and commission, and suffer biases in describing how they worked what
they thought about (Winne, Jamieson-Noel, & Muis 2002). When inputs to SRL are unreliable, regulation may have less than optimal effects.

LEARNING IS POTENTIALLY CONTINUOUSLY SELF-REGULATED

A self-regulating learner is theorized to be highly active cognitively and metacognitively. Although models of SRL differ in particulars (see other chapters), one common feature is that cognitive operations used in SRL often require effort. In general, people strive to regulate effort they invest in tasks.

Why does learning require effort? Theory and data suggest at least three main reasons. First, when a task calls for knowledge that the learner doesn’t have or can’t recall implicitly (by spreading activation), the learner must do cognitive work to fill this gap. Searching for information is a deliberate cognitive activity that learners perceive as effortful.

Second, learning often involves more knowledge than can be managed within working memory’s limited capacity. To offset forgetting and to keep track of knowledge, the learner may temporarily offload content into the environment, e.g., by drawing a concept map to summarize a system like the nitrogen cycle. Managing information and articulating it with knowledge is perceived as effortful.

Third, when cognition itself becomes a topic of cognition—when the learner is metacognitive—cognitive resources are spent to monitor, first, products of cognition for qualities they should have and, second, qualities of cognition used, such as effort. Standards used in monitoring absorb more of working memory’s limited capacity, so monitoring is perceived as effortful.

Implications

This view of cognition and metacognition has important consequences for SRL:

1. Learners self-regulate because they have options to choose different bundles of procedural knowledge as tools for working on a task.
2. Learners appear sometimes not to self-regulate because cognition seems to them and to observers to “run by itself.” This apparent absence of cognition is due to spreading activation across schemas and automated procedural knowledge. Notwithstanding, cognition is still self-regulated.
3. There is hope for a theory of SRL to unify disparate work on learning strategies, motivation, planning and other topics. This is because, to the extent knowledge and how learners use it can be modeled, it is possible to model the cognitive operations and metacognitive operations learners apply to work on tasks.

PRIMITIVE COGNITIVE OPERATIONS

Not all cognition can be founded on knowledge. We need to assume a set of “primitive operations” that are not knowledge. I consider a cognitive operation primitive if it is not helpful to disassemble into smaller parts. I proposed five primitive cognitive operations differentiated by information each takes as input and the product it generates (Winne, 1989, 2001). They are: searching, monitoring, assembling, rehearsing, and translating.
Searching is the operation by which a learner chooses to attend to particular information or knowledge that are predicted to link to other knowledge in memory. Once this input has the learner’s attention, the mind’s spreading activation returns “products”—knowledge—to the learner’s working memory.

Monitoring takes two kinds of information as its inputs. One is a set of standards. The other is a set of features the learner perceives to describe a target. In monitoring, the target’s features are compared to the standards. Monitoring produces an index of the match between the standards and a target’s features: Is a standard represented among the target’s features? If it is, to what degree does target’s feature match the standard?

Assembling builds a network of links between previously separate items. Inputs are two items of knowledge. The output is a structure. Assembling accounts for the “shape” of memory’s network of knowledge. Links can be unelaborated, as when we have a feeling we can’t describe clearly. But most structures of knowledge are enriched with qualitative and quantitative features about links. A few examples are: this explains that (The government fell because the vote of no confidence was passed.); A precedes B (Lightning is seen before thunder is heard.); concept g inherited properties of concept G (A dog has fur, a 4-chambered heart, and births young alive because it is a mammal.); concepts k, j, and l belong to a set called M (Neon, argon, and krypton are inert gases.); and concept N has attributes p, q, r, s, and t which forms a schema (A fully argued case includes a claim, data, warrants for data, qualifiers on the claim, backing that supports the warrants, and rebuttals to counterarguments.).

Rehearsing takes information the learner is currently working on as input and repeatedly directs attention to it. The output is the same information or knowledge. Rehearsing allows learners to focus attention on information or knowledge that would otherwise decay or be “pushed aside” due to the limited capacity of working memory.

Translating reformats information or knowledge into another representation. An example is making a flow chart based on a text that describes how a bill becomes a law. Ideally, translating does not alter the input’s fundamental meaning but, in fact, different representations have different affordances. A list of populations of countries and a bar chart of those numbers can convey a different sense about how countries’ populations differ.

Consider a scenario illustrating the SMART operations. Ms. Clark draws a triangle with vertices labeled A, B, C. Angle \( \angle CAB \) is 90° and sides AC and AB are labeled to have length 4. She asks: “What is the tangent of angle \( \angle ABC \)” Alan automatically transforms these sounds and Ms. Clark’s diagram into information in working memory. He focuses attention on the concept “tangent” and search by spreading activation implicitly retrieves from memory the proposition, “Tangent equals opposite over adjacent.” He monitors this result and determines it describes a mathematical method with variables—opposite and adjacent—and an operation—division. To answer, he must find values for those variables. He focuses on “opposite” which spreading activation returns as having the value of 4. He repeats this for “adjacent.” Alan transforms “over” to the arithmetic production it represents, division, and automatically computes the result. He answers: “Ms. Clark, it’s 1.”

A BRIEF TOUR OF SELF-REGULATED LEARNING

Winne and Hadwin’s (1998; Winne, 2001) model characterizes SRL as unfolding over four weakly sequenced and recursive phases.
Phase 1: Defining the Task

Learners encounter tasks in a context of affordances and constraints. Some affordances and constraints are external, such as the clarity of the goal, time available and whether a peer can be asked for help. Others are internal, including knowledge about the topic, motivation to engage with it, consequences forecast on completing it successfully (or unsuccessfully), limited capacity, and tactics and strategies available for working on the task.

In this phase of SRL, learners can engage in metacognitive monitoring if they check their understanding about the task. Later, they may re-define the task as they work through it. Learners also exercise metacognitive control if they search for more information when a task’s parameters are fuzzy and they deem it worth the effort to clarify them.

Phase 2: Setting Goals and Plans

Having forged an understanding of the task, learners are ready to set goals and plan how to reach them. For example, if the learner judges she knows little about the topic, what will be an acceptable level of achievement? Should a brute force approach that emphasizes rehearsing new concepts be chosen or should a more effortful and potentially less predictably useful tactic be chosen, such as elaborating information as much as possible given limited knowledge? Here, metacognition shapes why and how the task will be engaged.

In this phase, theory describes learners as intensely but perhaps mostly implicitly engaged in weighing the utility of different options for goals and for plans about cognition they predict can achieve them.

Phase 3: Engagement

The learner is now poised to work on the task. Tactics are activated and products are constructed. As work progresses, a metacognitively active learner interleaves cognition applied to the task with metacognition “on the fly.” Products are “quality checked” against standards established in Phase 2. Also, attributes of cognitive experience may be monitored for properties such as effort.

Phase 4: Large-Scale Adaptation

At points of the learner’s choosing, usually at the end of a task, the entire approach to work may be evaluated. The objective is to make similar tasks easier in the future, more likely to turn out well, and more satisfying. Salomon and Perkins (1989) called this forward reaching transfer.

METACOGNITION IN SRL

Throughout the phases of SRL, learners have opportunities to metacognitively monitor properties of information, declarative and procedural knowledge, and their cognitive experience. Matches and differences between features of targets and standards for those targets imply options about what to do next, i.e., how to exercise metacognitive control. The next sections examine metacognitive monitoring and metacognitive control in SRL.
METACOGNITIVE MONITORING

Learners often monitor features of learning. When asked “What is the tangent of an angle of 45°?” or “What caused the fall of Rome?” they almost always monitor if the answer they construct is right. This is perhaps the most basic example of metacognitive monitoring. Importantly, standards are not only “in” the subject matter. Standards for metacognitive monitoring are what learners deem appropriate.

Qualities likely to be metacognitively monitored regarding knowledge recalled when asked why the Roman empire declined include: whether an answer is complete (“Is this all I should say?”), the degree to which the answer is judged familiar (“Hmm, I think the Visigoths were major players...”), and the answer’s coherence (“Does it make sense to include the Germanic invasions?”). Qualities of procedural knowledge that might be standards for monitoring how a production executes include: effort required (or cognitive load) and the reliability with which the procedure yields expected products—is it algorithmic or heuristic? Qualities of cognitive experience also can be monitored. But learners probably cannot access cognition directly so they monitor experiential “side effects” plus results of cognitive operations, then make inferences about cognition on the basis those results (Koriat, 1997).

Consider Alan again. If Alan is metacognitive, he might follow a simple If–Then routine for answering a teacher’s question in class: If an answer is available (i.e., “I know the answer,” thinks Alan to himself), THEN check it for qualities of completeness and coherence before volunteering (“Avoid what happened last time!”). Monitoring can occur twice in this situation. First, Alan monitors properties of knowledge activated by spreading activation. Is anything activated? Does the activated knowledge match standards for a potential to answer the question. In the case of the tangent of angle \(\triangle ABC\), monitoring whether search returns an answer is straightforward. In other cases, such as questions about “What caused the fall of the Roman empire?”; it is more difficult to monitor an answer’s adequacy because such answers involve multiple and imprecise standards.

The second occasion for monitoring occurs if Alan metacognitively interrogates how he answered the teacher’s question. For example, to answer the question about the tangent of \(\triangle ABC\), Alan might have activated a mnemonic that provides first letters for terms that define trigonometric relations: “Some old horses can always hear their owner’s approach.” (Sine = opposite/hypotenuse, etc.) If that worked well this time, THEN use this approach again, ELSE try something else, maybe brute force rehearsal to increase formulas’ memorability.

WHERE DO STANDARDS ORIGINATE?

Teachers or authors who give learners objectives for learning supply standards learners can use in metacognitive monitoring. For example, consider: “Be able to develop an argument, pro or con, for the three issues examined in this chapter.” Learners who know about Toulmin’s schema for arguments set standards to monitor information in the chapter (and, likely, the Internet) for fit to six categories constituting a fully argued case: claims, data, warrants, backing, rebuttals, and qualifiers.

Scores of studies in various domains demonstrate that providing learners with objectives (standards) elevates achievement (Hamilton, 1985). Kiewra, Benton, Kim, Risch, and Christensen (1995) provided learners with various kinds of outlines and matrices that alerted undergraduates to topics of information they should identify and annotate while watching a videotaped lecture.
Having standards to guide selection of material for processing and how to process it improved notes they took and learning.

Learners' knowledge can serve as their own standards. These are memories of prior performances, and expectations about levels and qualities of future performance. For example, when monitoring whether an item of information can be recalled, two quite different kinds of standards are available: actual retrievability and experiences associated with retrieving knowledge. For example, a judgment about the familiarity of to-be-retrieved information may be the standard a learner uses to judge its retrievability (Begg, Anas, & Farinacci, 1992). Or, consider the self-handicapping student who deliberately chooses not to study for a test so he has a backstop explanation for poor performance that avoids attributions to low ability: "I could have aced that test if I studied but I had to practice piano instead." In both cases of metacognitive monitoring, standards are counterproductive.

Students' self-chosen standards for metacognitive monitoring don't always undermine learning. For example, a common problem is that learners are overconfident—they suffer an illusion of knowing what they don't really know (Glenberg, Wilkinson, & Epstein, 1982). The degree of overconfidence is often inversely proportional to actual competence. Thus, learners who know more tend to restudy more. While this can solidify knowledge, particularly skills that need extensive practice, it has the drawback of robbing time from learning new information.

MEASURING METACOGNITIVE MONITORING

Most research investigating metacognitive monitoring used simple materials, such as a list of paired associates—"cat—fork." The typical protocol unfolds like this: First, learners study a list of paired associates with the goal to be able to recall the 2nd item when provided the 1st as a cue. After studying, the experimenter provides the cues in random order and asks learners to judge whether they will recall the 2nd member on an upcoming test. This is a judgment of learning (JOL). After JOLs are generated, learners are again shown the cues in a new random order and asked to retrieve the 2nd item. With these data, the researcher can index the accuracy of metacognitive monitoring in predicting recall.

RELATIVE ACCURACY

In the relative accuracy approach to measuring metacognitive monitoring, a correlation is calculated. For each learner, the data are a pair of scores for each paired associate. The first score is the learner's prediction: Can the 2nd item be recalled given the cue? Score 1 if the prediction is positive and 0 if it is negative. The second score is whether the 2nd item was correctly recalled: score 1 if it was and 0 if not. Then, correlate the learner's predictions about recall with actual recall scores.

A learner who makes highly accurate judgments would generate a correlation near +1.0. A learner who made many errors in JOLs—predicting recall of the 2nd item when it could not be retrieved and judging the 2nd item would not be retrievable when it actually was recalled—would generate correlations near −1.0. A learner who was just guessing randomly would have a correlation near 0. This correlation measures relative accuracy because it gauges metacognitive accuracy for items relative to one another—items that are judged accurately contribute to a positive correlation relative to items that are misjudged that contribute to a negative correlation.
Calibration

Computing calibration involves four steps. After the learner has studied a list of paired associates, present the cue of each pair and ask for predictions on a scale form 0%—100% about the likelihood of recalling the 2nd items. Second, average the learner’s predictions over the list of pairs. Third, calculate a percent of correct recall by counting the number of 2nd members the learner actually recalls divided by the total number of items. Fourth, subtract the percentage actually correct from the average percent of the predictions. Perfect calibration is index of 0: predictions exactly match recall. Learners are indexed as overconfident to the extent their predictions exceed recall and underconfident if the opposite holds.

What Differentiates Relative Accuracy and Calibration? Relative accuracy and calibration reveal different qualities about metacognitive monitoring. Indexes of relative accuracy describe the extent to which a learner knows which items she knows. The relative accuracy of metacognitive monitoring would be useful when learners need to judge whether particular knowledge can be recalled or applied in a task.

Calibration describes a learner’s tendency to bias judgments of what he knows. Is he overconfident or underconfident? Calibration of metacognitive monitoring is useful for inferring a learner’s tendencies for similar tasks.

METACOMPREHENSION AND ITS ACCURACY?

Relative accuracy and calibration aren’t limited to describing metacognitive monitoring about learning paired associates. In other research, learners studied texts before taking a test of comprehension. Typically, the text is presented as a set of separate passages or paragraphs. Learners predict whether they understood each one. Achievement tests measured comprehension of information presented in each passage. Metacomprehension accuracy was mostly gauged using the relative accuracy approach, hence the label, metacomprehension accuracy.

When learners study simple material, such as definitions or translations of words between two languages, JOLs can be fairly accurate. What contributes most to high accuracy is that the learner actually experiences trying to retrieve the 2nd item of a pair. When this is enforced, relative accuracy can be as high as 0.93 (Nelson & Dunlosky, 1991).

When learners study texts and predict their comprehension, metacomprehension monitoring as indexed by relative accuracy is distressingly low. Maki (1998) reviewed 25 studies and reported a mean coefficient of 0.27. Dunlosky and Lipko (2007) reported the same result in their review of different studies. Other reviews concur (Lin & Zabrucky, 1998; Weaver, Bryant, & Burns, 1995). Various methodological factors have been implicated in this poor result, and these factors have implications for experimenter's alike.

First, consider a methodological note with broad implications. Coefficients of metacomprehension accuracy are intrinsically affected by the reliability of data used in their calculation. Tests of comprehension are often brief, and this typically lowers the reliability of the experimenter’s measurement. In turn, this limits the maximum possible coefficient of metacognitive accuracy.

Second, measures of comprehension in research and in classrooms rarely sample all the information that learners study. Tests are samples and samples may be biased. If so, inferences about what learners comprehend may be compromised if what was tested imperfectly aligns to what learners understood. A similar misalignment can occur between what learners studied
and calibration for that material. Together, these methodological properties may bias downward indexes of metacomprehension accuracy.

These issues also affect learners. If learners judge their comprehension based on a sample of information—say, comprehension of key terms listed at the end of a chapter, a parallel to researchers’ paired-associate tasks—the accuracy of those judgments can be reduced. Short “measures” of comprehension inherently downwardly bias correlations with broader tests of content. Choosing to use key terms as the targets of metacomprehension monitoring, even though these may quite well represent the scope of a textbook chapter, may nonetheless be biased samples relative to a teacher’s objectives (Rawson, Dunlosky, & Thiede, 2000; Wiley, Griffin, & Thiede, 2005). For example, key terms align poorly with analyzing a critical event or developing an argument (Metcalf, Schwartz, & Joaquin, 1993).

METACOGNITION IS CONTEXTUAL

Learners monitor a wide variety of features in almost every learning task (Winne & Marx, 1982) and different learners monitor different features (Winne, 1996). Because the products of metacognitive monitoring guide learners’ choices about how to study, a learner’s perception of context is critical. If learners misperceive conditions of tasks, phase 1 of SRL, they may proceed to exercise metacognitive control based on invalid premises. This suggests three requirements for productive SRL. First, learners need to accurately perceive features of tasks and knowledge they can bring to tasks. Second, they need to have at least one effective option for engaging in the task—without options, regulation is precluded. Third, standards learners apply in metacognitive monitoring need to be validly diagnostic.

Koriat (1997) introduced a valuable conjecture about how learners may base metacognitive control on invalid results of metacognitive monitoring. The cue utilization hypothesis describes that, when learners’ monitor cognition, they attend to various properties of cognitive experience, such as the familiarity of information in new materials they study, fluency in reading texts, effort required to retrieve knowledge and time (latency) for retrieval. Common sense suggests that if information is familiar, reading is fluent and knowledge is easily and quickly retrieved, learning is proceeding well. Unfortunately, these can be invalid signals of good comprehension (Begg, Duft, Lalonde, Melnick, & Sanvito, 1989; Koriat, 2008). In general, learners often mistake “easy” cognition for good comprehension and learning. Sometimes, difficult cognition is beneficial particularly if standards for metacomprehension monitoring concern what actually can be retrieved rather than experiential qualities of retrieving that mislead learners about what they know (Bjork, 1994).

METACOGNITIVE CONTROL

Having monitored how well a target matches standards, learners are poised to act: If monitoring reveals differences, THEN choose tactics and strategies that reduce those differences. Consider an example of reading a textbook filled with new terms. If metacognitive monitoring supports a judgment that the meaning of “antibiotic” is below a threshold for studying productively, a learner well-equipped with multiple study tactics can choose among remedies: THEN look up “antibiotic” in the glossary, ELSE ask a peer, ELSE keep reading to develop meaning based on subsequent material, ELSE examine word parts (prefixes, suffixes, roots) for meaning ... and so
on. Managing “larger” and more complex tasks, such as outlining an argument for or against using standardized achievement tests to gauge the quality of schooling, can be described using chains of If–Then–Else components.

A learner has three basic choices for exercising metacognitive control to manage challenges to cognition. One is to change environmental conditions in which a task is embedded. For example, a learner can control external conditions such as the time allocated to studying and the schedule for restudying. Internal conditions are also controllable, such as choosing to interpret errors as opportunities to improve vs. negative feedback about ability.

The second form of metacognitive control is choosing content for study and for restudy. For example, a learner may choose to study only an author’s summary of a chapter rather than the entire chapter, or to self-test knowledge by attempting to recall descriptions for a list of “key concepts.”

The third arena of choices for metacognitive control is selecting cognitive operations for processing information and knowledge. For example, a learner may elect to summarize a chapter by generating several key words rather than rehearse material that was highlighted when the chapter was studied initially.

TO RESTUDY OR NOT

A basic and often researched issue in metacognitive control is whether learners choose to restudy. First, consider the simplest decision, whether to reread everything previously studied. Callender and McDaniel (2009) researched this issue in a context where undergraduates studied and then immediately restudied textbook chapters and articles like those used in their classes. They reported no benefits to rereading immediately. Why?

First, in experiments and in classrooms, learners are often directed to “understand” what they study. Learners process this goal (phase 1 of SRL) and set standards (phase 2) for metacognitively monitoring whether and how well they understand during study (phase 3) and during restudy (phase 3, again) where they have opportunity to adapt how they study (phase 4) based on their experience of studying the first time. Assume learners are skilled readers, are motivated to understand, have requisite knowledge to understand what they study, and are provided enough time to study as productively; and, that they choose to restudy to boost understanding even further. It would seem they should fare well. But, they don’t. The culprit appears to be standards for metacognitively monitoring understanding that they set in phase 2, use in phase 3, and don’t alter because they omit phase 4. Specifically, learners mostly set standards for understanding surface features of text—the set of propositions called the textbase. They too often do not address the underlying architecture of information—the text’s situation model—that represents schemas and interrelationships among propositions (Kintsch, 1988).

The second hypothesis for why immediate restudying may not elevate achievement points to standards learners use to monitor their experience of restudying rather than monitoring comprehension itself. When a learner immediately restudies, the material almost surely seems more familiar than the first time it was studied. For example, when re-reading an explanation of Rome’s downfall, recognizing content can be mistaken for actual understanding. As well, if learners puzzled out difficult vocabulary and complex sentence structures during the first study period, reading is more fluent during restudy. Learners may mistake that perception of fluency for understanding (Levy, 1993). Due to these errors, they are overconfident about comprehension which leads them to short change cognitive processing.
WHAT SHOULD BE RESTUDIED?

Learners rarely reread entire texts when they restudy. Instead, they select particular content to restudy. Productive choices depend on metacognitive monitoring being well calibrated and relatively accurate. As noted earlier, a learner who is overconfident about knowledge of a topic probably will not restudy when it would be beneficial. A learner whose relative accuracy is low may restudy the wrong information.

What learners choose to restudy has been widely researched. In a typical experiment, technical terms and their definitions or small blocks of text are studied. Then, learners rate the probability they can retrieve each term’s definition or their understanding of each block of text. Next, they can choose terms or blocks of text to restudy, sometimes under a condition that not everything can be restudied. Finally, they are tested.

In this scenario, two models have been proposed to account for what learners choose to restudy. Dunlosky and Hertzog’s (1998) discrepancy-reduction model posits that items learners judge they know the least are judged the first and most important to restudy. Metcalfe and Kornell (2005) offer a contrasting model, the region of proximal learning model. They propose learners restudy by first eliminating material they judge they know well enough (items whose features match standards used to judge knowledge). Then, learners select items judged easiest to learn are first and most important to be restudied.

Research somewhat favors the region of proximal learning model. External conditions, such as time pressure, affect choices about what to restudy. In such situations, learners restudy material they judge they “almost” know, i.e., for which a strong judgment of learning reflects minimal discrepancy between targets and standards that describe when knowledge is retrievable (e.g., Thiede & Dunlosky, 1999). By choosing easier material, learners can transform more information into knowledge given limited opportunity to restudy versus puzzling over “difficult” items that would take longer to learn.

Also, metacognitive control of restudying is affected if the standard used in metacognitive monitoring is change in the rate of progress, a judgment about the rate of learning. Metcalfe and Kornell (2005) showed that, if perceptions about the rate of learning decline below a learner’s idiosyncratic threshold, the learner will stop studying those items. It’s as if improvements to knowledge accumulate too slowly, so attention is directed where there’s more effort. Son (2004) observed an important pattern about this rule for stopping restudying. When learners judged knowledge was weak and the change in rate of learning that material was large—i.e., items were difficult but restudying helped a lot—learners “crammed.” They studied each item over and over in a pattern called massed practice. But, when learners judged they knew items rather well and the change in rate of learning was minimal, they put off restudying it. This creates a pattern called spaced studying. Ironically, cramming and other massed practice routines are largely ineffective.

WHAT SHOULD LEARNERS DO WHEN THEY APPLY METACOGNITIVE CONTROL?

Having metacognitively monitored and judged that material should be restudied, what should learners do to restudy? Which study tactics should they use? What changes should they make to conditions surrounding their task?

When metacognitive control involves choosing study tactics that improve knowledge, there is a long list of options because research has identified a wide variety of effective study tactics...
and learning strategies. Although, to my knowledge, it has not been researched, these same benefits likely accrue when learners apply these tactics and strategies to re-study material or to redirect effort when information they are currently studying is not transforming into knowledge.

For example, when studying with software, copying and pasting information into notes is a very popular tactic among high school students (Igo, Bruning, McCudden, & Kaufman, 2003). Igo, Bruning, and McCudden (2005) researched how this tactic affected learning. One group of learners in their experiment was restricted to notes using only 7 words. Compared to learners who could copy and paste with no restriction, learners restricted to 7-word annotations recalled more facts, demonstrated better conceptual understanding, and excelled at recalling relationships in the information they studied. In interviews, participants forced to condense information into 7-word notes significantly increased metacognitive monitoring using standards that addressed coherence and meaning over superficial, unrelated “facts.”

Igo et al.’s (2005) research shows that metacognitive control for managing annotations can feed back to change standards used in metacognitive judgments of learning. Several other methods for expressing metacognitive control have similar effects. One is clearing working memory before judging whether studied material has been transformed to retrievable knowledge. This can be accomplished by delaying judgments of learning (Thiede & Dunlosky, 1994), generating keywords to reflect the gist of the material (Thiede, Dunlosky, & Griffin, 2005), or summarizing material (Thiede & Anderson, 2003).

JUDGMENTS OF AGENCY

Editors of the Handbook of Metacognition in Education (Hacker, Dunlosky, & Graesser, 2009) observed a common theme throughout the volume: agency. “Agency refers to a person’s ability to control their actions and, through them, events in the external world” (Haggard & Tsakiris, 2009, p. 242).

According to Haggard and Tsakiris (2009), people sense agency when they link a feeling of agency to a judgment about agency. A feeling of agency (FoA) is the implicit experience of controlling one’s actions as they are carried out. A judgment of agency (JoA) is an explicit determination of the extent to which one’s actions caused an observed change. For example, a learner who retreats to an earlier part of a chapter to re-examine a diagram may implicitly experience a feeling of agency as she turns pages to locate the diagram and, on locating it, re-inspects it. Without deliberating about it, she expresses and experiences control over her search. On inspecting the diagram, the student may think, “Ah ha! Now I see how supply affects demand. Good thing I checked!” She expresses a judgment of agency in attributing comprehension to her choice to review the diagram.

Haggard and Tsakiris’ review indicates that, “under normal circumstances, the FoA is a necessary condition for JoA … [but] FoA is not normally sufficient for JoA” (2009, p. 243). The former claim is made because the learner must have an experience of carrying out particular cognitive activities—without changes (or the absence of change) cannot be attributed to those cognitive events. However, having carried out particular cognitive activities, the learner is not obligated to make a JoA—making a JoA requires the learner to monitor the effect(s) of a cognitive event.

What does this research imply? First, a sense of agency is required for productive self-regulation. Without it, there is no basis to expect learners to deliberate about regulating engagement because they don’t expect that it matters what they do. Second, learners may need help to link the consequence(s) of cognition to their experiences of cognition. For example, if
learners aren’t aware of their cognitive operations, they can’t match a particular product to the cognition that created it, then monitor whether particular cognitive operations generated products that were positively evaluated relative to standards. To my knowledge, the field lacks research on this issue. How do learners pursuing authentic classroom work pinpoint a tactic or strategy as the operation responsible for a particular product?

SUMMARY AND FUTURE DIRECTIONS

Cognition and metacognition are governed, in part, by two psychologies. One is a psychology of ‘the way things are … psychological phenomena that, in principle, are universal among learners and across subject areas and are not likely under learners’ control (Winne & Nesbit, 2010, p. 654). The other is a psychology of the way learners make things because they are agents. The arena of SRL must accommodate both psychologies and interactions between them. For example, knowledge shapes cognition in a context of limited capacity for carrying out cognition. This is a proposition from the psychology of the way things are. Which knowledge—a belief, a tactic, or a fact—a learner chooses to apply when working on a task represents the psychology of the way learners make things. What the learner does (except for reflex-governed behavior) reflects an interaction grounded in both psychologies. Plumbing these features is a major task for future research.

As for practical implications of research on SRL, it must be acknowledged that a great deal of research bearing on this topic could not be examined due to limits of space. Given my selective review, I offer these main recommendations. First, the field very much needs thorough analyses of diverse findings. Interpretative and meta-analytic reviews should be given priority.

Second, it appears learners often regulate learning on the basis of unstable, unreliable, and sometimes irrelevant data. I suggest a metaphor for SRL is to consider learners as engaged in personal programs of research to describe, predict, and better control learning. Like scientists, a key factor in success is having high-quality data (Kornell & Bjork, 2007; Winne, 2006). Thus, an important task is inventing methods for tracing cognitive and metacognitive events as data learners, as well as researchers, need for researching the effects of SRL (Winne, Jamieson-Noel, & Muis, 2002; Winne & Perry, 2000). What research has yet to explore is how to format reports of traces about cognition and metacognition so learners can understand them, and what effects will follow when learners are provided process feedback about cognition and metacognition (Butler & Winne, 1995). A bright future will realize a productive collaboration among learners and researchers jointly pursuing research on the nature and benefits of productively regulated learning.

ACKNOWLEDGMENT

Work on this chapter was supported by the Canada Research Chairs Program and a grant from the Social Sciences and Humanities Research Council of Canada, #410-2007-1159.

NOTES

1. A researcher can choose from a variety of indexes of accuracy. See Schraw (2009) for a description and critical analysis.

REFERENCES


