Towards Accessible Metacognitive Measurement

by Jackson Souza

<u>Introduction</u>

- Can we reduce the theories of cognition? We cannot measure if we cannot reduce.

<u>Reducing Cognitive Psychology: A Reductionist View</u>

- We are warranted in attempting measurement, measurement *has* meaning. Do we actually do this? Or is it just philosophical conjecture?

<u>Toward Measuring Cognitive Processes: Cross-Discipline Examples</u>

- Cognitive measurement (specifically metacognitive) *actually* takes place in psychology, neurobiology and computer science. Although, this information concerning one's own cognition is not readily accessible to the layperson… Can we make it so?

<u>Accessible Methods of Measurement: Skillgenie</u>

- An exercise in metacognition, measuring and presenting data about one's own cognitive processes.

Introduction

Self-learning is a subject that extends into many different disciplines. The most accessible way to enter the arena of altering mental processes is through the promise of "rapid skill acquisition." Semi-scientific, non-academic writers such as Josh Kaufman and Tim Ferriss are accomplished investigators into this topic, championing simple, multi-step methods to "learn anything". Bordering on self-help, these authors present steps that inject confidence and heightened sensitivity to information into a reader's learning process. In the *4 Hour Chef* , Ferriss dramatically unveils his rigorously (actually) tested methods for acquiring skills which seem to elude most learners. These authors do much to demystify seemingly intuitive skills, such as cooking, language learning, and musicianship. Although their empirically verified methods actually do promote self-learning, the authors fail to discuss any deeper grounding in a parent discipline, and thus, the steps seem to lack continuity.

Despite this underlying "feeling", there are many direct parallels in to Kaufman and Ferriss in the scientific study of metacognition. For example, Kaufman says to "Define your target performance level"[1] as an endpoint for one's skill acquisition, which is an important piece of data in measuring metacognitive judgements; whether one actually is doing as well as they say. However, in Kaufman's system there is no mechanism by which to measure actual performance, so there is a very likely risk of repeating an erroneous process. A crucial point about self-learning is be able execute any mental process *correctly,* and rapid learning systems are unable to enforce this self-correction. There is little doubt whether a person can carry out the steps put forth by Kaufman and Ferriss, however, there is no way besides a *total* failure of

[1] Kaufman 35

the skill at the *end* of the process (ie: last place at the golf competition, unable to communicate with Japanese people) to motivate a correction of learning. Even if one competed in successively more difficult golf tournaments, as a "measuring stick" of progress, there would be no criteria by which to alter the learning process if one finds that they have a less than satisfactory grip on the skill. Although the processes detailed by Ferriss and Kaufman are explicit, they are of little use to a person who lacks the knowledge to self-regulate.

The Skillgenie app was born from this need, seeking to report individual metacognitive measurements to augment the lack of correction in rapid learning. Data is given by the user in the form of individual posts concerning learning goals/progress/landmarks on a timeline illustrating a skill being learned (Simple & actionable, Ex: "Playing Golf"). Data in/about their posts is aggregated, computed and presented to the user in the form of friendly, readable metrics concerning the learning process. The hope is that the user can use this data to accelerate their learning, by improving upon the process itself and thus being able to interact with the content at a more enjoyable speed, with less failure.

However, in the discipline that grounds rapid learning methods put forth by Ferriss and Kaufman, metacognition, there is doubt as to whether any measurements made have empirical *value*. So first, we must ask, if we are even warranted in attempting to measure metacognition in hopes of implementing a better "rapid learning" in the web application. If so, then the question becomes: are we able to make said measurements applicable and accessible for the layperson in the web app. The fact about whether any assertion made by metacognitive researchers has meaning rides on the issue of whether cognitive theories are *truly* empirically verifiable, and can be said to be reducible to more fundamental disciplines. We cannot give valuable measurement to users if we cannot reduce the theories that underly the measurement, because semantic autonomy destroys any transferrable meaning in the relationship between theory, measurement, and actionable skills.

Part 1 - Reducing Cognitive Psychology: A Reductionist View

We often hear the contention between hard scientific disciplines and social sciences, the former accusing the latter as lacking explanatory power. The social sciences concern themselves with explaining abstract features of our minds, which often acts as double edged sword, condemning them to scrutiny for an inadequate empirical foundation. This lack of causal explanation for the social sciences has lead philosophers of science to section them off from easily *reducible* science, where bridge laws are few and logically straightforward. Granting this metaphysical and semantic separation, or “autonomy”, to psychology and other social sciences can be looked at as the consequence of a larger issue, namely a discussion of the “unity of science”. This issue asks if, “we are able to affirm [by reduction] that scientific laws apply on *all* levels of organization” and thus, extending Putnam’s multiple realizability thesis, “if we can indeed reduce ‘special sciences’ to physical sciences.”

Naturally, much of the debate has happened where these scientific connections seem to grow weak. Psychology is the chief “special science” that has served as the battleground for the debate and the one that we will be examining, especially cognitive psychology concerning mental states (esp. pain). We will view the issue through two prominent philosophers of science: Jerry Fodor, an anti-reductionist who extends Hilary Putnam’s “multiple realizability” thesis, advocating the disunity of science *because* of the “special sciences”, and Jaegwon Kim who refutes Fodor and affirms that reduction of the so-called “special sciences” is possible.

The implications for the issue at hand, whether or not cognition can be accurately measured in neighboring disciplines, are fundamentally destructive if we affirm an anti-reductionist view. If Fodor is correct, then any measurement made in neurobiology or computer science, concerning theories in cognitive psychology are meaningless. Long story short, we are certainly not warranted in attempting to measure metacognition if we cannot reduce it to other sciences. Kim's reductionist position rightly allows the special sciences to be semantically connected to physical sciences by asserting that Fodor's extension of multiple realizability is fundamentally misguided. Fodor's extension does not validly represent the kinds (that are responsible for mental states) utilized in psychophysical reduction, and as Kim challenges, some neural kinds are multiply realizable *and* have a basis in the physical sciences.

Context & Definitions

Reductionism spawned as a response to logical positivism, asserting that all complex things are reducible to a set of parts. In the philosophy of science, this manifests as the issue of all scientific theories being reducible to some more basic theory or set of laws. Biology is said to be reducible to chemistry, which is then reducible to physics. Another commonly used example is that Kepler's theories about the motion of the planets are reducible to Newtonian physics. These instances beg the question: is this type of "domino-effect" causality true for all fields of scientific inquiry? Emerging sciences concerning the mind have prompted a reconsideration of what reduction means. The above question about causality is certainly not true if we treat reduction as translation, which continues the thoughts of strict logical positivism. Reduction as translation as expressed by Rudolf Carnap means that, "An object (or concept) is said to be reducible to one or more objects if all statements about it can be transformed into statements about these other objects… science is a unity, that all empirical statements can be expressed in a single language, all states of affairs are of one kind and are known by the same method."[2] So, scientific disciplines must be equal in terms of method (like a language's syntax) and explanation or meaning (semantics). This is the classic reductionist view, that all disciplines can be reduced to physics.

This needed reconsideration about reduction has spawned two redefinitions: reduction as derivation and reduction as explanation. The latter employs heavy emphasis on equal semantics and a loose version of equality in method, stating that if the theory is just as well "systematized" in its respective discipline, then it can qualify as reducible. Reduction as derivation is the view debated by Kim and Fodor, that emphasizes semantics and takes a more articulate view of method than espoused by old-school positivists, giving philosophers an entire vocabulary to assess the equality of a theory's terms.

This deepening of assessing the equality of method begins with two types of reduction, heterogenous and homogenous. Strict translation of terms was no longer a prerequisite for reduction, and with the former being the new term introduced, the non-fundamental science in question could have additional terms not included in the base science. Heterogenous reduction allows much more freedom in reduction, creating an ever more hotly contested rule for reduction: "As a matter of logic, all that is required for a successful derivation are bridge laws that take the form of conditionals."[3] To put this in a better perspective, here is an the same statement repeated in "logicese"[4] from IEP:

> The occurrence of a B1 causes the occurrence of a B2 (a law in the base science).
>
> Something's being a B1 = its being a T1. (bridge law)
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> Something's being a B2 = its being a T2. (bridge law)

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[2] IEP, Reductionism, Reduction as Translation http://www.iep.utm.edu/red-ism/#SH1a

[3] IEP, Reductionism, Reduction as Derivation

[4] Ibid

∴ The occurrence of a T1 causes the occurrence of a T2 (a law in the target science).

On an underlying logical level, the contention is, if can we be warranted in creating bridge laws that are identity statements, biconditionals or even disjunctions, as Kim proposes. Clearly, this form of reductionism is absolutely dependent on these bridge laws, which Nagel says can be "be (1) logical or analytic connections between terms, (2) conventional assumptions created by fiat, or (3) empirical hypotheses."[5] It is only possible that the special sciences be connected with harder disciplines through this method of reduction. What then seems to alienate the "special sciences" from being included in the reducible, physical sciences, is that the abstract terminology, say, mental states described by cognitive psychology, must have a bridge law that "gives a physical correlate." So, when one seeks to reduce special to physical, the gap from the abstract to a concrete correlate is what looms large. Putnam and Fodor use this to their advantage, while Kim rebukes the special/physical separation by using heterogenous reduction using disjunctive statements as bridge laws.

Putnam extended by Fodor: Disunity of Science by Multiple Realization

Hilary Putnam and later, Jerry Fodor, slowly alienated the social sciences, namely psychology and economics, from other tried and true, reducible sciences via "multiple realization" (MR). This was not the aim of MR, although it was a consequence of this thesis put forth by Putnam that states, "a given psychological [or second-order] kind (like pain) can be realized by many distinct physical [or first-order] kinds: brain states in the case of earthly mammals, electronic states in the case of properly programmed digital computers, green slime states in the case of extraterrestrials, and so on."[6] On Putnam's view, we can see that states

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[5] Ibid

[6] SEP, Multiple Realizability

described by psychology do not have any *single* causal origin and may arise from any one of the "many levels" set forth by Putnam. Each of these levels are used to separate certain disciplines from those that underlie them.

He gives six levels: social groups, living things, cells, molecules, atoms and particles.[7] In order to give some structure to reductionism as derivation, Putnam devised these levels as conducive to the recently introduced emphasis on bridge laws. The most crucial features of the levels are that they naturally exist in such a way observable by empirical science while reduction must only take place from higher to lower levels. For example, this simply means that concepts in physics cannot reduce to laws in biology, necessitating an impossible *reduction* from level 1 to 5. He bolsters his many levels by saying that they are practical, giving a "good synopsis of scientific activity" and that they are compatible with the tendency towards reduction inherent in science, "to explain apparently dissimilar phenomena in terms of qualitatively identical parts…"[8]

Putnam reaches multiple realization in a separate discussion of mental states, but Fodor shines a light on the implications of the thesis for Putnam's overall view on the unity of science. The unity of science is absolutely dependent on the fact that all scientific disciplines are reducible, and Fodor asserts that if second-order properties such as brain states are not reducible, then the disciplines that house them surely are not. Fodor does not have any disagreement about their scientific status, rather, he seeks to "give" the special sciences an out from the constraint given to physical sciences, that they *must* be reducible to the last of Putnam's many levels.[9] So, it becomes clear that in order to mitigate the problem of

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[7] Putnam 9

[8] Putnam 16

[9] Fodor, 1

uncomfortably wedging these special sciences into the many levels, he grants the semantic "autonomy" of psychology.

Fodor explains that the point of reduction is not to reduce a concrete correlate in a lower discipline for every theory but to "explicate the physical mechanisms by which events conform to the laws of the special sciences."[10] In effect, Fodor discerns that psychology and economics cannot be inserted in one of Putnam's levels, rather that they are concerned with the unpacking, or realizing, the meaning of physical events on all of the many levels. This essentially validates Putnam's assertion that second-order properties are multiply realizable, releasing psychology of the "physical reduction" constraint, and imbuing it with the freedom to be applicable in any physical discipline. However, this puts the special sciences out of the running to qualify as reducible, or even in league with physical sciences.

Kim: Refutation of Multiple Realization

To summarize the viewpoint that Jaegwon Kim takes issue with, he quotes LePore and Loewer, "It is practically received wisdom among philosophers of mind that psychological properties (including content properties) are not identical to neurophysiological or other physical properties. The relationship between psychological and neurophysiological properties is that the latter *realize* the former."[11] Since we have already sketched out a rudimentary understanding of what realization is, we can see that the view Kim holds is one that rejects the autonomy of special science, putting it back into the running to be reducible. The gist of Kim's view is this, that properties of non-physical science are *not* of a different explanatory type, so that the explanations cannot reconcile, but are *coextensive* with first order physical properties,

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[10] Fodor 107

[11] Kim 2

making them second-order. He argues that bridge laws can be disjucntive, which implies the following: "there is no single neural kind *N* that "realizes" pain, across all types of organisms or physical systems; rather, there is a multiplicity of neural-physical kinds such that N_h realizes pain in humans, N_t realizes pain in reptiles…"[12] Alternatively, Fodor would have us believe that bridge laws cannot be disjunctive, which implies that there would indeed have to be some *single, causal* neural kind *N,* that has a physical correlate in all organisms. As Kim posits, the *multiplicity* of laws bridging special to physical must be disjunctive.

The issue with disjunctive bridge laws is that they are not a simple, finite set of conditional statements. Rather, they may be a seemingly infinite succession of statements as seen in the above example with pain. Challenging Fodor, it is not that we cannot reduce psychological theories, but when they expand into such a multiplicity that it is difficult to ascertain any, single, "across-the-board" truth. Clearly, this is a result of pain being multiply realizable. What we can say with certainty is that, considering mental states, that neural kind, $N_{h,}$ realizes pain in humans. We know what realizes pain in humans, namely perception, and that this kind is a feature physical science. Echoing Kim, to bridge the psychophysical gap, we need to recognize that reduction does not operate in the same way as it does *within* the physical sciences, and that we may need to enjoy the few "micro"-reductions that are possible. Kim does not deny Fodor's explanation by denying the existence of the psychophysical gap, rather, this is what defines reductions made from the special sciences to the physical. What Kim does reject is that these reductions cannot be made, as more specific, narrow reductions are possible.

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[12] Kim 5

One such micro-reduction is that of the neural kind, perception, prompting a mental state in humans. In an analysis of Kim's argument, Ned Block gives an example that illustrates just how powerful the human faculties of perception are. "[I]f a hand is amputated, the amputee later feels the sensation of the hand being touched when his cheek is touched…The reason that the hand sensation "migrates" to the cheek is that the hand receptors and the cheek receptors in the sensory cortex happen to be adjacent."[13] Block calls this the hand/cheek phenomenon, an effect of phantom limb, which is clearly tied to a psychological cause. In the most simple psychological terms, the habitual behavior of touching the cheek still persists in the mind even after the hand ceases to exist physically. As Block explains, it is as though the hand is still very much alive within the *brain also*, which sends the appropriate neural response through the arm which now terminates before the hand. For many dealing with phantom limb, this also manifests in pain in the amputated area.

It is clear through this example that there are *actual* physical correlates for pain, at the very least, that can be empirically verified. This definitely constitutes a relationship between the special and physical sciences, which is a far cry from Fodor's assertion, but as Block moves through his argument, he asks: does this relationship constitute a valid reduction? After nearly affirming Kim's view, Block takes a skeptical turn, "The fact that kinds are relative and graded shows that there is something wrong with the analytic apparatus common to Fodor and Kim. If talk of reduction presupposes a non-relative non-graded notion of a kind, then there is no matter of fact about reduction."[14] This means to say, not every phantom limb hurts and not every touch of the cheek gives a conditioned response from the brain.

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[13] Ned Block

[14] Ibid

Conversely, every object in the cosmos reacts with a reasonably predictable response to gravity. This would be the type of reduction sought by Fodor, Putnam and Block. Kim remains sure that psychology should remain semantically connected, because of the fundamental disagreement with the three others about the implications that MR has for reduction.

Kim revels in micro-reductions, asking, "Do our considerations show that psychology is a pseudo-science like astrology and alchemy? Of course not. The crucial difference, from the metaphysical point of view, is that psychology has physical realizations, but alchemy does not." [15]Fodor and company would claim that because neural kinds are multiply realizable, it is unclear whether they can be reduced. Kim would retort with the fact that reduction, especially psychophysical reduction, is about "physically grounded and explainable [kinds] in terms of the processes at an underlying level."[16] It is not necessary to make sweeping claims about truth when asserting the reduction of a multiply realizable thing, because the truth of the matter lies at a more local, narrow level.

Block's claim that validity of psychological reductions is dubious because of the relativity of mental states, undermines the whole of psychology. It seems that Block falls victim to the slippery slope, because if his claim were true, how could we make any truthful assertions about behavior, when it differs from being to being. Kim accounts for this in a similar fashion by saying that psychological laws are often seen as statistical and non-deterministic, as are laws in physiology and anatomy. In psychophysical reduction, it is clearly

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[15] Kim 36

[16] Ibid

important that we privilege the discipline “bridged from” (the one higher in Putnam’s many levels) because of this fact.

Harkening back to pain, if it is realized by perception, despite the multiplicity of bridge laws, then we have made a psychophysical reduction. Kim asserts the validity of reduction on a more local level, showing that it can be just as powerful as the large, objective truths set forth by inter-physical reductions. Psychology does not need to be granted autonomy by Fodor, because its semantic connection is readily apparent on a smaller scale. Reduction may not work the same from “special” to physical, but it is still valid.

Part 2 - Towards Metacognitive Measurement: Cross-Discipline Examples

We have asserted how special sciences can be accurately reduced to lower, physical sciences, so the value of psychophysical measurements remains intact. What affirms the reality of the reductionist view are metacognitive measurements and concepts that also serve to ground rapid skill acquisition. Much of the debate about autonomy since Putnam and Fodor has been mitigated through the boom in cognitive science in the last decade. We can empirically verify the once dubious existence of metacognitive phenomena, such as the "tip of the tongue" judgement, and say with increasing certainty that mental processes are not a figment of our imaginations.

There are three perspectives from which metacognitive measurements have been researched: computational, neurobiological and psychological. Until the late 20th century, the psychological perspective has been responsible for maturing the discipline of metacognition from its roots in the philosophy of mind. Concerning the computational perspective, the analysis of mental structures and processes is becoming increasingly crucial for the development of artificial intelligence and machine learning. The computational "human in the loop" simulation method of assessing aptitude in a specific activity (think flight simulation), is heavily dependent on the analysis of judgements, confidence and memory. The reality of psychophysical reductionism is confirmed in the neurobiological perspective on metacognition, as "our understanding of psychological constructs… have been enriched by the knowledge of their neural underpinnings."[17] In "Studying Metacognitive Processes at the Single Neuron Level", Middlebrows et al express a similar sentiment, "neuronal correlates

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[17] Fleming 1

such of functions such as attention, executive control, working memory, decision-making and reward processing, all have been elucidated, to an impressive level of detail, at the single cell and circuit levels."[18] All of these perspectives serve to play an important role in the development of the Skillgenie metrics, however, we must begin by making clear *what* we are measuring before we discuss any nuances of implementation.

The key element that makes learners less error prone is a higher level of metacognitive efficiency. Although I will explain this more in depth, a working definition for efficiency is the measure of "objective memory ability" in a person. There are a series of measurements that comprise efficiency, namely: cognitive monitoring, metacognitive sensitivity & bias via "feeling of knowing" (FOK) judgements and metacognitive sensitivity & bias via "judgements of learning" (JOL). We are able to reach the efficiency measure by first assessing one's executive control of memory, then calculating the disparity between one's judgements about their knowledge vs. the reality of the situation.

Straddling the line between psychological and neurobiological, we have memory, which Pina Tarricone in "The Taxonomy of Metacognition" says is the foundational, primarily measurable construct of metacognition. A study of metacognition in neuroscience concerns the "monitoring and control of information processing". Arthur Shimamura in "Toward a Cognitive Neuroscience of Metacognition" gives parallel concepts for executive processes studied in neuroscience, one of which is cognitive monitoring. Monitoring (whose parallel process is called 'updating') "refers to the ability to modulate and rearrange activity in working memory."[19] This measure of executive control is crucial to mitigating errors in

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[18] Fleming 225

[19] Shimamura 316

comprehension. Consider the following situation: a Skillgenie user watches a video by Tiger Woods on golf, saying that a good swing is dependent upon pivoting the foot exactly 45 degrees, and then overwrites the good information with false information given by his caddy, *on the course*. Because their working memory is deficient, they will continue to commit this same error.

Monitoring is usually measured with an *n*-back test. From Shimamura, "For each presentation, subjects respond whether or not the letter presented on the current trial is the same letter that was presented *n* trials ago. For example, in a 2- back task, subjects respond "yes" if the current stimulus is the same one presented two trials earlier (*n* -2 trial)."[20] Data is aggregated by examining the number of correctly guessed tasks vs. the amount of incorrectly guessed tasks. N-back facilitates deliberate remembering of important details which is characteristic of "planful, intentional, goal-directed, future oriented behavior."[21] Although this may seem trivial and *too* low-level, memory monitoring is the executive process which underlies metacognitive efficiency, and its implications for psychophysical measurement at large are critically important.

Metacognitive bias is a measure of cognitive mis-confidence, whether one is either more or less confident than they should be given a constant level of task performance. As it pertains to sensitivity, it is the difference between actual performance and confidence. Two separate ways of assessing confidence are by taking in a "feeling of knowing" or "judgements of learning" as input from the user. FOK indicates the likelihood of memory recall, where JOL indicates the likeliness of information acquisition/comprehension. These are both valid

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[20] Shimamura 317

[21] Tarricone 64, quoting Flavell

measures of subjective confidence but have extremely different implications for the sensitivity measurement. With this in mind, the measurements of bias with FOK as input need to be distinct from the JOL based data. Measuring both is similar to the *n*-back test, where data about confidence is collected either before or after the knowledge is obtained, then compared in the sensitivity and efficiency calculations. In either case, minimizing bias is crucial to mitigating error even if a user has high cognitive monitoring skills. Future oriented behavior, as Tarricone might say, is only useful if it is correct.

Metacognitive sensitivity, whether predictive or recollective, measures how well one can differentiate between their correct and incorrect judgments. This is the total calculation of the bias data based on FOKs or JOLs. Currently, there is no set way to "set aside" sensitivity as distinct from efficiency, but for the purposes of the Skillgenie measurements, it would be beneficial to the user to calculate and display various intricacies of the FOK and JOL bias data. Sensitivity as described in Tarricone's taxonomy is an "attunement to" or "awareness of" the requirements of a memory situation.[22] It would be informative to take the mean value or range of values of FOK or JOL judgements and display them. Displaying the difference between the reality of a situation and a user's judgement could help the user gain a sense of *how* to improve, for example, by concentrating on being either less or more predictive/recollective.

Metacognitive efficiency is the total calculation that takes into account the previous three measures, a main feature of which is attempting to remove the specific task performance from sensitivity, creating a more objective and final measurement of overall metacognitive ability. In "How to measure metacognition", Fleming and Lau discuss generating a sensitivity

[22] Tarricone 87

measurement and then deriving the final efficiency measurement from it. They discuss the recent "meta-*∂'* " measure as being the best possible way to derive sensitivity from the bias data without corruption. Maniscalco and Lau discuss meta-d' in their 2012 article "A signal detection theoretic approach for estimating metacognitive sensitivity from confidence ratings," as "characterizing an observer's sensitivity in tracking overall metacognitive accuracy."[23] The overall sensitivity calculations done by Maniscalco and Lau still agree with the above definition of sensitivity, "to evaluate observed sensitivity with reference to the sensitivity that would be expected to occur."[24] Meta-d' acts as the ideal value for d', which is " the normalized distance between the distributions", or in other words, one's ability to discriminate the correctness of their decisions. Maniscalco and Lau provide many justifications for the measure which are outside the scope of this paper, but in many instances, they set it equal to 1 so that it becomes apparent how far d' is from meta-d'. Fleming and Lau state that, "metacognitive *efficiency* [can be defined as] as the value of meta-∂' relative to ∂' , or meta-∂'/∂' . A meta-∂'/∂' value of 1 indicates a theoretically ideal value of metacognitive efficiency. A value of 0.7 would indicate 70% metacognitive efficiency (30% of the sensory evidence available for the decision is lost when making metacognitive judgments), and so on. "[25]

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[23] Maniscalco and Lau in Fleming 25
Provided free Matlab calculations at http://www.columbia.edu/~bsm2105/type2sdt/

[24] Maniscalco and Lau 2012, 424

[25] Flemming & Lau 4

Conclusions - Accessible Methods of Measurement: Skillgenie

In order to implement a self-learning system that facilitates and promotes self-correction, it was necessary to harness the above metacognitive measurements. I chose to develop a “full-stack” Javascript web app named Skillgenie that, in essence, creates a feedback loop for learning in one system. If we take the traditional academic system, in which a student is presented with information, applies the information, then receives feedback on their application; the entire process spans a large amount of time. Skillgenie is designed to record one’s applications of their self-learning, so presentation of the information is a non-issue. However, Skillgenie (in its current state) becomes useful for tracking the progression of applications, from landmark “Goals” and steps to achieve those goals (“Practices”). The last two steps of the traditional educative feedback loop, application and feedback are dynamic in Skillgenie. To receive feedback on general aspects of learning, it becomes as easy as flipping over to the “Metrics” view. For example, Skillgenie is able to calculate cognitive confidence via the user’s practice and goal “difficulty” data to present accessible visualizations and actionable suggestions such as “decreasing (or increasing) the difficulty of goals” Skillgenie is designed to present the connections between applications of learning and especially between projected tasks and actual tasks. In both Ferriss and Kaufman’s accounts of learning a skill, deconstruction is necessary. The “timeline” view of Skillgenie functions like a todo list, where the user can project goals into the future and then track each step to achieving the goal.

For measurement purposes, Skillgenie cements and hides some of the initial data entered about practices and goals, to present the user with data about their own notions of progress versus what is actually taking place. Each practice and goal shares a relationship to one another, either by parent goal or ramping difficulty (deviation of difficulty), so that the user can gain a holistic view of their learning process. In traditional methods of metacognitive measurement, the subject is usually presented with a questionnaire. Especially when asked about their "feeling of knowing", students are blatantly asked, "how do you think you did on the test?" To avoid this removal from the immersion of self-reflection, Skillgenie tracks and computes confidence based on data given by the user. In other words, it is not blatantly obvious that measurement is taking place.The goal of many measuring efforts in metacognition focus on accuracy apart from the specific level of performance or, "objective memory ability". These efforts, however fail to give the *subject* any concrete or actionable data about themselves. In addition, measurements like meta-d`, while extremely useful, have little to do with any specific context and have no correlate information for the layperson. Skillgenie attempts to make these scientific metrics available and accessible for all learners. [26]

[26] For full bibliography, see "Reading List"