MacDougal, K. & Ritter, F. E. (2018). Generative models as a third paradigm for decision making: A response to Markman. Journal of Applied Research in Memory and Cognition. 7. 26–28

A response to "Combining the strengths of naturalistic and laboratory decision making research to create integrative theories of choice" by Arthur B. Markman

Korey MacDougall (korey.macdougall@psu.edu)

Frank E. Ritter (frank.ritter@psu.edu)

College of IST, Penn State University, University Park, PA

v3, 28 December 2017

For submission to: *Journal of Applied Research in Memory and Cognition*

Abstract

In this response to Markman's target article, after concurring with many of the conclusions, we note some effects of generative cognitive models built within cognitive architectures. A major effect is how these effects allow models to built and used earlier to make predictions, and that the role of a cognitive model might not only be used as a summing up, but also as an expression of what mechanisms are sufficient to generate behavior, sometimes a priori. This generative behavior also makes them difficult to test in the traditional sense because of the enormous number of predictions they make.

In "Combining the strengths of naturalistic and laboratory decision making research to create integrative theories of choice" (Markman, present issue), Markman examines the relative strengths and weaknesses of two paradigms for studying decision making: naturalistic decision making (NDM) research and traditional laboratory (TL) research. He argues that NDM offers greater extrinsic validity of results, because of its focus on real-life task scenarios, while TL offers greater intrinsic validity, because of its capacity to control and repeat environmental conditions across trials and participants. He argues for a integrative approach to the study of decision making that combines the complimentary strengths of the two paradigms.

We largely agree with the thrust of Markman's article, and commend the author on a cogent and compelling work. We wish to offer commentary on a couple of issues addressed by the article. Specifically, we wish to respond to the characterization of cognitive architectures as a paradigm for the study of human decision making, and to offer a perspective on the relationship of these architectures to a community of practice (i.e., an element in the sociology of cognitive science). We believe the suggestions offered here would strengthen the research program proposed in the article.

First, we would like to offer an alternative characterization of the research conducted using cognitive architectures. Markman argues that cognitive architectures like ACT-R and Soar are promising avenues for integrating naturalistic decision making research and traditional laboratory research in decision making (along with two other strategies suggested: the construction of microworlds, and increased cross-talk between researchers in the NDM and TL communities). The suggestion is "to use computational cognitive architectures like the ACT and SOAR [footnote 1] families of models to specify the processes underlying performance", (p. 23). Architectures can thereby serve as a bridge between laboratory work, which can study individual mechanisms or systems, and naturalistic decision making work, which can then examine how these various mechanisms fit together in complex scenarios. While this is a reasonable view of the cognitive architectural enterprise, we would argue that implicit within it is a mischaracterization of the theory-building-and-refining function of cognitive architectures. Cognitive models serve a different theoretical function than do laboratory experiments: while experiments require a priori specification of a hypothesis, and the subsequent application of statistical tests to determine whether that hypothesis was supported or not, cognitive architectures represent a collection of (hopefully) evidence-based beliefs of the scientific community about the various components of the system being modeled and how they generate behavior. In other words, architectures evolve and improve as a function of their use, and their state of development at a given time represents the community's best guess about the functional components of the object under scrutiny, i.e., the human mind.

This difference in the characterization of development patterns of scientific frameworks was identified by Imre Lakatos (1976), who argued that Popperian falsification is not as prevalent in scientific work as we might believe, and more importantly, is not an accurate or realistic description of how scientific fields evolve. He agreed with Thomas Kuhn's (1970) statement that "No process yet disclosed by the historical study of scientific development at all resembles the methodological stereotype of falsification by direct comparison with nature" (p. 77), but disagreed with Kuhn as to the typical degree of hegemony of an individual scientific paradigm and of the mechanisms of paradigmatic change (Lakatos, 1976). Lakatos argued that basic unit of scientific appraisal was the "research programme", where a programme comprises a number of competing theories united by a common "hard core" of assumptions, which are axiomatic, and supported by a "protective belt" of peripheral commitments, which require logical or empirical support. In other words, the appropriate unit of analysis is not the individual testable hypothesis or theory. When an experiment produces evidence challenging the operative theory, the community's first response is typically to rearrange the commitments in the protective belt; only after the protective belt has reached its tolerance for refutation are the core assumptions of the paradigm discarded or modified. If this were not the case, and strong falsificationism were in fact operative, we would expect a theoretical framework to be jettisoned immediately upon receipt of disputive evidence; this is clearly not the case in practice. And for a model generating behavior would happen almost immediately (Grant, 1962).

The significance of Lakatos' model of scientific advancement for work involving cognitive architectures has been expounded by several authors, most notably Newell (1990) and Cooper (2007). Newell (1973) argued, in his now famous "You can't play 20 questions with nature and win" paper that Popperian falsification is an inappropriate scientific stance when the goal is the construction of unified theories of cognition; piecemeal refutation does not allow for progress or unification. Cooper argues that the Lakatosian framework is particularly apt in the case of cognitive architectures (though not perfect; he also explores alternatives that may better contend with issues of falsification), and that it offers a way to assess the health and future viability of the architectural enterprise, namely, the "positive heuristic". This heuristic asks whether a scientific framework continues to generate new, testable hypotheses and theoretical positions, and if so, it remains useful. Generativity is the true test of a framework's viability.

We think these considerations bear upon the conclusions of Markman's article regarding how cognitive architectures may be used to aid in the integration of disparate strands of decision making research. Architectures represent a different mode of theoretical advancement than that embodied in either laboratory testing or naturalistic decision making research. Cognitive models do not simply offer support for empirical results, but offer a third way to advance our collective state of knowledge. We disagree with Markman's assessment of the role of architectures, specifically the statement that

> When a process is reasonably well-understood, it can be implemented in a cognitive architecture, but it may be difficult to specify a model completely in the absence of a significant amount of data. In addition, there are many alternative formulations of the same process, and so it can be difficult to generate a priori predictions for a study." (p. 24)

This suggests that the function of a model is to offer a different form of support for lab or NDM work. We would argue instead that cognitive architectures represents a shared platform (in the best cases) to standardize theorizing about the cognitive system and its elements, and embodies a model of scientific advancement resembling iterative design in engineering. For example, a recent project used default ACT-R parameters to perform a 20-minute non-iterative task while learning over four trials with good response time predictions (Paik, Kim, Ritter, & Reitter, 2015).

Second, and closely related to the above concern, we disagree with the statement that "the architecture itself does not place a lot of constraints on the predictions of models", (p. 24). The architecture, whether it be ACT-R, Soar, EPIC, or another, tends to be highly specified in some areas, and underspecified in others, with substantial variation across architectures. These differences in specification reflect different commitments and positions taken by the communities of use surrounding and building the architectures. As an example, ACT-R specifies exactly the speed at which memory chunks decay in models (or permits such specification), but is agnostic regarding the effects of fatigue and external state on memory. The architecture specifies exactly the degree of noise or interference in the declarative memory system (or allows such specification), but is flexible concerning the modules that make up a cognitive agent. Finally, ACT-R specifies exactly the speed of a memory retrieval (or allows such specification), but is agnostic regarding the emotional content of chunks.

Cognitive architectures allow multiple realizations of the same task model; this is consistent with both the Lakatosian framework of scientific advancement described above and Marr's three levels of analysis of cognitive systems that Markman describes in the article: different models of a task might be consistent at the computational level but differ at the algorithmic level. It is also consistent with what knowledge and strategies people use to solve problems (e.g., Siegler, 1987). The flexibility that architectures offer is perhaps problematic if the goal is to generate and test (i.e., attempt to falsify) a priori predictions, but that, we argue, is not the most useful way to conceptualize the role of cognitive models. Previous work in this area has proposed modeling faster and slower users (Card, Moran, & Newell, 1983) and bracketing (Kieras, 1988), which includes more and less efficient strategies.

In sum, we support the views advocated by Markman in this issue. We recognize the fragmentation of the various scientific communities studying decision making, and are sensitive to the potential (probable) waste and duplication of effort that this can entail. We agree that greater integration between communities of researchers offers possibilities for more insightful work and improves our odds at building accurate, unified models of how individuals and groups make decisions. We wish to contribute to this effort, and to that end have offered some alternative perspectives on how cognitive architectures might factor into progress in the direction of greater theoretical and methodological integration.

References

Card, S. K., Moran, T., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, NJ: Erlbaum.

Grant, D. A. (1962). Testing the null hypothesis and the strategy and tactics of investigating theoretical models. *Psychological Review, 69*(1), 54-61.

Kieras, D. E. (1988). Towards a practical GOMS model methodology for user interface design. In M. Helander (Ed.), *Handbook of Human-Computer Interaction* (pp. 135–158). Amsterdam: North–Holland Elsevier.

Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.

Lakatos, I. (1976). Falsification and the methodology of scientific research programmes. In S. Harding (Ed.), *Can theories be refuted?* (pp. 205-259). Springer: Dordrecht.

Newell, A. (1973). You can't play 20 questions with nature and win. In W. G. Chase (Ed.), *Visual information processing* (pp. 283-308). New York, NY: Academic Press.

Newell, A. (1990). *Unified Theories of Cognition*. Cambridge, MA: Harvard University Press.

Paik, J., Kim, J. W., Ritter, F. E., & Reitter, D. (2015). Predicting user performance and learning in human-computer interaction with the Herbal compiler. *ACM Transactions on Computer-Human Interaction*. *22*(5). Article No. 25.

Siegler, R. S. (1987). The perils of averaging data over strategies: An example from children's addition. *Journal of Experimental Psychology, 115*, 250-264.

Footnotes

[1]. Note that SOAR used to be an acronym, but as a name, it is noted as ‘Soar’ by the community of folks who use it.