Robert Kurzban

University of Pennsylvania & Chapman University

Modularity & Decision Making

This paper is part of the Decision Making for a Social World webconference

Organized by the International Cognition and Culture Institute and
the Philosophy, Politics and Economics Program at the University of Pennsylvania

The paper is followed by a **discussion**

Unpublished manuscript prepared for the Strüngmann Forum:
Darwinian Decision Theory

Modularity & Decision Making

> *Adaptive specialization of mechanisms is so ubiquitous and so obvious in biology, at every level of analysis, and for every kind of function, that no one thinks it necessary to call attention to it as a general principle about biological mechanisms.*
>
> Randy Gallistel, 2000, p. 1179

> *Experimental psychologists often seem to feel that context effects are to be controlled and eliminated from an experiment if at all possible. This, we would argue, is a mistake. One can indeed suggest that some of the most serious conceptual errors in psychological history --- errors that misled researchers for decades --- began with naive attempts to remove phenomena from their natural contexts. We would argue that that context effects are impossible to eliminate, and that we should not wish to eliminate them totally, but only to study them. There is no zero point in the flow of contexts. They are not incidental phenomena that confound our careful experiments: they are* quintessential *in psychology. There is no experience without context.*
>
> Bernard J. Baars, 1988, p. 176

1. SPECIALIZATION YIELDS EFFICIENCY

When a tool is crafted with some goal in mind, it is designed and fashioned to have a particular shape that will efficiently allow its use to accomplish the goal. A hammer has a large, heavy part at one end and a long, graspable handle, a shape that allows the force of arm muscles to be focused on a small area, such as the head of a nail, which makes hammers efficient at driving nails into wood. The shape that a tool must have to turn a screw is quite different, embodying quite different principles, which is why hammer-shaped objects are not good at driving screws.

Because different shapes are required to solve different problems efficiently, as objects take on one form, they necessarily become worse at solving a host of other problems. This is why a carpenter owns a large number of shapes. Using an effective tool for a range of jobs requires having a large number of options to choose from so the right one can be found. Having a collection of hammer-shaped objects, from ball peen to sledge, allows jobs to be completed efficiently because of the advantages that accrue to using a shape specialized for the task at hand.

This is not to say that greater specialization is *always* better than less. Having multiple tools carries costs, which trades off against the efficiency gains of specialization. At some point, having an additional hammer to use for similar nails carries little marginal efficiency gain, and one is better off using the same hammer for slightly different nails.

In many cases, natural systems show tradeoffs in the direction of narrow specialization, proliferating functional units. White adipose cells' structure – round, expandable, with a small amount of cytoplasm and a vacuole containing fat – reflects its energy storage function. Per unit weight, twice as much energy is stored in fat compared to protein or carbohydrate. Similarly, the structure of neurons – small cell bodies with lengthy axons and dendrites capable of conducting electrical impulses which can influence other cells – reflects their function of transmitting information. One could imagine that the same cell might be able to both store energy and transmit energy, but in order for a single cell's structure to accommodate both functions, there would be substantial compromises regarding at least one, if not both, functions.

Specialization yields efficiency in economic production, as Adam Smith (1776) pointed out in *The Wealth of Nations*. Workers and firms, by focusing on one area or task, become better in those areas, gaining comparative advantage over competing workers or firms.

Computer scientists take advantage of the efficiency gains that specialization produces. The notion of "shape" in the context of tools has an analog in information processing. Different computational tasks can be solved efficiently with different computations. That is, the computations that a subroutine must perform depends on the desired input/output relationships in a way that mirrors the way that different tasks require different shapes. Different desired relationships require different computations.

This idea, referred to as "separation of concerns" – broadly, the idea that one should produce specialized subroutines to accomplish different information-processing goals – is seen as "a key guiding principle of software engineering" (Ossher & Tarr, 2001, p. 43). Subroutines that perform a narrow, well-specified task can be built to be efficient at performing just that task.

Non-human animal minds are collections of specialized information-processing devices. Specialization is evident in the very different computational capacities required to meet the adaptive challenges that animals face in their particular ecological niche. Web-spinning mechanisms require different computations from those required by navigational systems for migration or memory systems for storing and recalling the location of cached seeds. In the same way that the non-human animal (and plant) world consists of species with different specialized physical parts to solve their specific problems, non-humans similarly have specialized computational mechanisms to guide their behavior (Alcock, 2001).

Certain aspects of the human nervous system show exquisite specialization. Photoreceptors in the retina have the narrow function of transforming electromagnetic radiation of particular wavelengths into information to be used to recover information about the external world. These cells are divided more finely still, with the structure of the cells reflecting their slightly different functions (responding to different parts of the spectrum, high vs. low light levels, etc.).

Further, large collections of cells in the central nervous system are organized around particular functions. The visual system efficiently builds a representation of the external world. Specialized memory systems store semantic information or episodic information (Sherry & Schachter, 1997). The observed specialization of these systems reflects the ideas above, the gains from specialization and functional incompatibilities, such that the computational desiderata of one function are inconsistent with the desiderata of another, leading to multiple systems.

One possibility is that the efficiency gains for problem solving are reflected in cells, organ systems, economies, computer programs, animal minds, and aspects of evolved human cognition ranging from perception to memory systems, but that this principle of specialization systems ends there, and does not apply to “central systems,” the computational procedures responsible for human decision making and social behavior (Fodor, 1983).

Alternatively, it could be that these systems, the mechanisms that underpin human decision making, are also functionally specialized, or, to use the more common term in cognitive science, “modular”(Fodor, 1983; Barrett & Kurzban, 2006).

2. THE PROBLEM OF DEPLOYMENT

Drawing on the above logic, some have argued that the advantages to specialization gave rise to a collection of evolved decision-making systems tailored to the array of adaptive problems, including social problems, faced by our ancestors (Tooby & Cosmides, 1992). Exhaustive accounts of this idea are available elsewhere (Pinker, 1997; Sperber, 2005).

Systems that consist of large numbers of subsystems gain the advantages that specialization of the subsystems afford, but give rise to another problem, that of deployment. With a large collection of computational devices, the use of which will generate very different input/output relationships, selecting the appropriate device is a problem of obvious importance (Gigerenzer, 2008).

In human-made devices with a large number of specialized functional devices – such as a smart phone loaded with applications (Kurzban, 2010) – the choice of application is done by the user. Natural computational devices such as the human mind must make this decision by itself. One way this problem is solved is by virtue of the input structures. For instance, in the context of the human sensory apparatus, eyes and ears are struck by both electromagnetic radiation and by changes in air pressure but they act on only the appropriate form of energy because of the design of photoreceptors and hair cells (Barrett, 2006). In the context of other tasks, this option is not available, so, to determine which systems to deploy, the mind must use information in the sensory array to determine which adaptive challenge or opportunity is currently at issue, and recruit the mechanisms designed around this problem.

One area in which the mechanism-selection process has been discussed at some length is emotions. Tooby and Cosmides (2008) have argued that the emotions can be thought of as one way of solving the problem of selecting among candidate computational mechanisms.

This view suggests that there are particular cues in the environment that will reliably activate certain suites of systems, deactivating others. The selection of the cue/system mapping is possible because of the reliable value of deploying particular systems contingent on the presence of particular environmental cues. (No specific commitment is made about the ontogenesis of these cues or the level of abstraction of the cues. The presence of a sexual rival might reliably give rise to jealousy, but which set of people count as rival must be acquired ontogenetically.)

Emotions can be thought of, then, as being activated by a specific set of cues in the environment, which activate some (and deactivates other) computational systems whose function is to solve the adaptive problem associated with the cues. The activation of these systems leads to the characteristic phenomenology associated with emotions, as well as the physiological correlates that prepare the organism for appropriate action.

To illustrate, consider fear. This emotion might be activated in a situation in which there is immediate threat of attack, such as when one is walking in an unfamiliar environment with the possibility that predators or enemies are about. This recruits a suite of mechanisms, including those relating to vigilance to increase the chance of detecting threats, while at the same time suppressing less urgent priorities, such as the need to sleep or eat. At the same time, there is the phenomenological experience of fear, as well as physiological changes – increases in heart rate, production of adrenaline, etc. – that prepare for the action that might be required in response to the current priority, the possibility of physical attack.

If, as in the case of emotions, decision making systems for different domains exist side by side in the human mind, including systems for choosing and attracting mates, finding food and foraging efficiently for it, building a network of allies, and so on, then several empirical issues immediately come to the fore. First, what are the systems, and what computations do they perform? Second, how is the selection among candidate systems made?

3. EMPIRICAL INVESTIGATIONS

If there are specialized, distinct computational devices with evolved functions, then it should be possible to specify the functions of these devices. In turn, these functions should make commitments in terms of their computational properties, including the circumstances that recruit their operation, the inputs that these systems take, the specific computations that the systems perform, and the outputs of these systems, which are potentially visible through decision making. There is substantial research driven by these sets of ideas. This section discusses a very small number of them as examples of the overall approach.

3.1 Detecting Cheaters

Probably the best known example of work along these lines is Cosmides and collaborators' work on the putative cheater detection module. Reviews of this work are available elsewhere (Cosmides & Tooby, 2008), which serves as an important illustrative example of the approach, particularly in terms of the empirical strategy to test entailments of the central claims.

As Cosmides et al. (2010) recently put it, modular systems "succeed by deploying procedures that produce adaptive inferences in a specific domain, even if these operations are invalid, useless, or harmful if activated outside that domain...by exploiting regularities—content-specific relationships—that hold true within the problem domain, but not outside of it" (pp. 9007-9008).

It follows that for the putative computational mechanism they posit – the cheater detection algorithm – to implement its function, the cognitive system must be able to delineate the conditions under which the algorithm is to be deployed. Their "social contract theory" points to the cues to such situations, namely cases in which there is an allocation of costs and benefits, along with costs that must be paid or obligations that must be met. (See Cosmides and Tooby, 1992, for a more detailed specification of the computational model they have in mind.) The cheater detection algorithm is recruited when an individual could have intentionally taken a benefit without having paid the cost or met the requirement.

Cosmides et al. (2010) used a standard method in this area, the Wason Selection Task (Wason, 1983), in which subjects are given a conditional rule (if P then Q), and asked to see if the rule has been violated. This is typically done with cards, or pictures of cards, with writing on both sides. So, if the rule is (*if you drink beer, then you are over 21*), then a card with (*P: drinking beer*) on one side and (*~Q: 17 years old*) on the other would be a violation of the rule.

Cosmides et al. (2010) varied the content of the narrative surrounding the task, adding or removing elements that, by hypothesis, would be differentially likely to evoke the cheater-detection algorithm, but which other models (e.g., permission schema) predicted would have no effect. Because of the adaptive logic surrounding social exchange theory, this model commits to the view that particular contents will affect performance, allowing the hypothesis to be put at risk by varying the relevant contents.

Specifically, holding the rest of the content of a conditional rule constant, they varied whether the person in the conditional rule was taking a benefit, paying a cost, or neither. Under social contract theory, the presence of someone taking a benefit should recruit the cheater-detection algorithm. As predicted, when the content of the rule involved someone taking a benefit, performance was very good (82%), significantly better than a nearly identical rule, in which all was constant except the benefit was transformed to a cost or to something neutral. Similar manipulations, varying other aspects of the rule contents relevant to recruiting the cheater detection algorithm showed similar results, suggesting that the algorithm is differentially likely to be activated depending on the details of the contents of the conditional rule.

3.2 Predicting Events

While cheater detection is among the best known applications of the ideas surrounding modularity to decision making, it is not the only one. Recently, Wilke and Barrett (2009) suggested a novel explanation for the “hot hand” phenomenon that draws in large part on the “ecological rationality” approach (Todd, Gigerenzer,

& the ABC Research Group, 2010) as well as the sorts of ideas sketched here. The hot hand phenomenon refers to the observation that people's predictions about events suggest that they expect these events to come in "streaks," with the probability of an event occurring being higher after one has just occurred. The classic finding in this literature is in the domain of basketball; Gilovich et al., 1985 found that observers thought a player was more likely to make a shot after having just made one.

While this is often referred to as a "fallacy" – and indeed, people do make systematic errors – Wilke and Barrett (2009) argue that this phenomenon is the manifestation of a well designed modular system built around foraging. Specifically, because items in the world for which people search – prey items, sources of water, people – are generally clumped spatially and temporally, a well designed prediction mechanism should take this into account. This produces an implicit assumption that the world is autocorrelated.

Most centrally to the point here, they delineated the context in which the hot hand phenomenon should be observed. They predicted that it should be observed in the context of the structure of the environment, and seen in cases of sequential search – in space or in time – in which there is a binary result of each search, a "hit" or a "miss." (This does not characterize all searches; sampling from a fixed pool, for instance, they would predict, should not elicit this pattern.) As an ancillary prediction, they suggest a content effect, such that the phenomenon should be evoked to a greater degree for some types of objects – naturally occurring resources – than for others (evolutionarily novel ones).

Investigating these ideas in both American undergraduates and Shuar hunter-horticulturalists in Ecuador, Wilke and Barrett (2009) presented subjects a large number of observations in sequence of the presence or absence of an array of items (fruits, nests, bus stops, etc.). The task in each case was for the subject to predict whether or not the next event in the sequence would be a hit or a miss.

As predicted, the hot hand phenomenon was observed in both cultures, suggesting that the implicit assumption that items for which one is sequentially searching in the world is autocorrelated is a default. Further, the Shuar showed a greater effect for coins than the American undergrads, raising the possibility that the default assumption can be “unlearned” over time with cultural experience with certain types of objects. Together, the pattern of data suggest that the implicit assumption that the world is clumpy is a component of an aspect of the foraging system, applied to new contents during certain types of sequential search. (See also Scheibehenne, Wilke, & Todd, in press).

3.3 Choosing Levels of Altruism

Research in behavioral economics has shown systematic deviations from predictions of standard economic models (Camerer, 2003). Nonetheless, in some settings, people’s decisions conform to the predictions from these models with surprising precision. More specifically, in some cases, people look as though they are motivated purely by self-interest, maximizing their earnings from the experimental context, while in others people seem to be generous, delivering benefits to others, showing so-called social preferences. What explains these patterns?

The modular view here suggests that one source of difference derives from the bringing to bear of different computations depending on the cues of the decision environment. According to this view, properties of the task recruit different algorithms, which in turn guide choice.

Consider the canonical double auction, in which subjects are given the role of either buyers or sellers for some abstract commodity. Values for items are assigned to buyers and sellers and trades are allowed; subjects earn money by selling above their value or buying above their value.

In these environments, behavior of subjects as a group are well predicted by standard models, and subjects look, more or less, as though they are perfectly selfish, or money maximizing. One possibility for explaining this is Smith's (1998) notion of "impersonal exchange." There are no cues in these settings that one is part of a group; rather, the framing is competitive, with people assuming roles as in stock exchanges, where gains are made at the expense of other agents.

Compare this to public good games, in which subjects must make decisions about allocating resources (selfishly) to themselves, or (generously) to an account that will grow the pie that members of their group share. In these settings, people contribute to the group – though rates of cooperation declines over rounds of play – suggesting social preferences of some sort.

Although a number of proposals have been made to explain the results of the large number of public goods experiments (Camerer, 2003), one possibility is that the structure and terminology of the game activates mechanisms designed around reciprocity (Nowak & Sigmund, 2005), alliance-building (DeScioli & Kurzban, 2009), or other social systems. Indeed, manipulations of "identity," for instance, lead to increased contributions, for instance (Brewer & Kramer, 1986)

More generally, there is evidence that players in these games search for and use a framing with which they are familiar. Henrich et al. (2001) conducted a series of studies among 15 small scale societies, using a number of tasks from behavioral economics, including the public goods game. Members of one society, the Orma, dubbed the public goods game the "harambee" game, mapping it onto a local means of producing things such as roads and schools (Gintis et al., 2003). Gintis et al. (2003) argue that many local social norms are reflected in game play across cultures, suggesting that subjects in these studies search for mappings between the game and some aspect of social life.

The self-interested play in auction games set against the prosociality in public goods games suggest that people can, often, compute where their economic self-interest lies and pursue it, but they certainly do not always do so, choosing instead to deliver benefits to others. This is consistent with the idea that the game framing recruits different modular structures, though the details of the mapping might depend on the details of local institutional norm clustering.

3.4 Summary

These examples are obviously not intended to be exhaustive, but rather a very small sampling of the types of areas to which a modular perspective can be applied.

Indeed, while research informed by these ideas is continuing, a particularly interesting line of work places subjects into relatively unstructured decision environments. Consider the recent work of DeScioli and Wilson (in press), who placed people into a foraging environment in which subjects' avatars could move around a virtual world, exploiting patchy resources. Given considerable freedom of action, subjects spontaneously developed property right norms in some ecologies, in particular, those with patchy rather than uniform resources. This suggests that properties of the ecology are recruiting different systems, but in similar fashion across subjects in the experimental setting. Such work holds considerable promise for illuminating how different psychological systems are recruited as a function of parameters of the decision environment.

4. CONTROVERSIES

The modular approach sketched here is not free from controversy, though the details of the controversy depend on what one takes "modularity" to mean. In contrast to Fodor's (1983) initial formulation, modern views take modularity to turn on functional specialization (Barrett & Kurzban, 2006; Pinker, 1997). Consequently, a system that is modular in the sense of functionally specialized can simultaneously fail to fulfill, as an empirical matter, criteria that Fodor (1983) assigned to modules (e.g., localized, shallow outputs, etc.).

This section addresses two of the most prominent issues raised in the context of this more recent construal of modularity. This is not intended as an exhaustive treatment of critiques of modularity, but only to provide a sense of the larger issues and entry points into this literature.

4.1 Information Integration

Chiappe (2000) and, more recently, Chiappe and Gardner (in press) have suggested that the human ability to integrate information across different domains, along with the human capacity to reason analogically and use metaphor, undermine the view that the mind's architecture is modular.

Defenders of the modularity thesis, however, would reply that these abilities, and the associated empirical findings, while they support the notion that particular systems are capable of taking informational inputs from other systems does not, however, carry as a logical entailment that the systems doing this integration don't have a (narrowly, or, at least, specifiable) function. That is, to show that a given input influences a particular process demonstrates that the process in question is not encapsulated with respect to that particular computational input, not that the system doesn't have an evolved function (Barrett & Kurzban, 2006, in press).

To return to the reasoning task discussed above, consider Gigerenzer and Hug's (1992) demonstration that performance on the task depends on whether the subject is given the perspective of an employer or employee. For precisely the same problem content, one's role interacts such that those primed with the employer perspective identify cases in which someone received an underserved pension; those primed with the employee perspective identified cases in which a deserved pension wasn't received. The content of the problem was integrated with one's knowledge about one's role to produce the solution, but in both cases a solution predicted by the hypothesized function, detecting instances of cheating.

Information integration is relevant to arbitrating claims that a given mechanism is (or is not) encapsulated from another, which in turn can be relevant to distinguishing among hypotheses regarding function.

4.2. Novelty & Flexibility

A second frequent critique of modularity revolves around novelty. Chiappe and Gardner (in press) write that modularity "has limited usefulness in explaining the existence of mechanisms designed to deal with novel challenges and with the development of novel solutions to longstanding adaptive problems" (p. 2).

There is, however, a sense in which modules *only* deal with novel challenges. Any particular given object is one that was never seen during evolutionary history, yet our visual systems build representations of them. This is because modules are designed to process inputs in a systematic, useful way, even if the inputs are novel *tokens* of the *types* they operate over (Barrett & Kurzban, 2006).

Further, an advantage of modular systems is that they potentially allow vast new combinations. The adaptive immune system, for instance, is modular, allowing surface immunoglobulins to take a vast array of new shapes, which in turn contributes to the system's function. Modularity allows novelty through combinations, just as in generative natural language grammar.

Broadly, novelty is a problem for any evolved system, since the system at an given moment is the result of the interaction between the organism's developmental environment and the genes that have been brought through the process of selection to that point, tested against previous, historical adaptive challenges. Successful architectures are ones that led to adaptive behavior given tokens never previously encountered. Modular architectures, such as the adaptive immune system, allow the combination of many different types of parts, allowing for flexibility and dealing with novelty. (On this point, see Sperber, 2005).

Two final points surrounding novelty are worth brief mention. First, while humans are surpassingly good at navigating certain types of novel contexts, as cultural adaptation illustrates, some sorts of novelty, such as the availability of inexpensive high energy foods has presented significant challenges (Burnham & Phelan, 2000). Second, some human evolved systems seem specifically designed around novel tokens, as in the case of social learning systems, which, some have suggested, are designed to use features of other individuals to pick out which (novel) ideas to attend to and differentially acquire (Henrich & Gil-White, 2001).

5. SUMMARY & CONCLUSION

Specialization is common across the biological world. In the domain of human cognition, the idea that the computational mechanism of the mind might be specialized, including those mechanisms designed to solve adaptive problems associated with navigating the social world, has fallen under the rubric of "modularity." While some empirical evidence has been gathered to distinguish between claims that the systems that underlie behavior are more or less specialized, considerable debate remains about the details.

References

Alcock, J. 2001. *Animal behavior: An evolutionary approach* (7th Ed.). Sunderland, MA: Sinauer.

Baars, B. J. 1988. A cognitive theory of consciousness. New York: Cambridge University Press.

Barrett, H. C. 2005. Enzymatic computation and cognitive modularity. *Mind and Language, 20,* 259–287.

Barrett, H. C., & Kurzban, R. 2006. Modularity in cognition: Framing the debate. *Psychological Review*, *113*, 628-647.

Barrett, H. C., & Kurzban, R. in press. What are the functions of system 2 modules? A reply to Chiappe and Gardner. *Theory & Psychology*.

Brewer, M. & Kramer, R. 1986. Choice behavior in social dilemma: Effects of social identity, group size, and decision framing. *Journal of Personality and Social Psychology*, 71, 83-93.

Burnham, T., & Phelan. J. 2000. *Mean genes.* Cambridge, MA: Perseus.

Camerer, C. F. 2003. *Behavioral game theory*. New York: Princeton University Press.

Chiappe, D. 2000. Metaphor, modularity, and the evolution of conceptual integration. *Metaphor and Symbol, 15,* 137–158.

Chiappe, R. & Gardner, R. in press. The modularity debate in evolutionary psychology. *Theory & Psychology*.

Cosmides, L. & Tooby, J. 1992. Cognitive adaptations for social exchange. In J. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture*. New York: Oxford University Press.

Cosmides, L. & Tooby, J. 2008 Can a general deontic logic capture the facts of human moral reasoning? How the mind interprets social exchange rules and detects cheaters. In W. Sinnott-Armstrong (Ed.), *Moral psychology*. (pp. 53-119) Cambridge, MA: MIT Press.

Cosmides, L., Barrett, H.C., & Tooby, J. 2010. Adaptive specializations, social exchange, and the evolution of human intelligence *Proceedings of the National Academy of Sciences, 107,* 9007-9014.

DeScioli, P., & Kurzban, R. 2009. The alliance hypothesis for human friendship. *PLoS ONE, 4,* e5802.

DeScioli, P., & Wilson, B. in press. The territorial foundations of human property. *Evolution and Human Behavior*.

Fodor, J. 1983. *The modularity of mind*. Cambridge, MA: MIT Press.

Gallistel, C. R. 2000. The replacement of general-purpose learning models with adaptively specialized learning modules. In M.S. Gazzaniga, (ed.). *The Cognitive Neurosciences. 2d ed*. (1179-1191) Cambridge , MA . MIT Press

Gigerenzer, G. 2008. Why heuristics work. *Perspectives on Psychological Science*, *3*, 20-29.

Gigerenzer, G., & Hug, K. 1992. Domain-specific reasoning: Social contracts, cheating, and perspective change. *Cognition, 43,* 127–171.

Gilovich, T., Vallone, R., & Tversky, A. 1985. The hot hand in basketball: On the misperception of random sequences. *Cognitive Psychology, 17*, 295−314.

Gintis, H., Bowles, S., Boyd, R., & Fehr, E. 2003. Explaining altruistic behavior in humans. *Evolution and Human Behavior, 24(3),* 153 – 172.

Henrich, J., Boyd, R., Bowles, S., Camerer, C., Fehr, E., Gintis, H., & McElrcath, R. 2001. Cooperation, reciprocity and punishment in fifteen small-scale societies. *American Economic Review, 91,* 73–78.

Henrich, J., & Gil-White, F. J. 2001. The evolution of prestige: Freely conferred status as a mechanism for enhancing the benefits of cultural transmission. *Evolution and human behavior, 22,* 165-196.

Kurzban, R. 2010. *Why everyone (else) is a hypocrite: Evolution and the modular mind*. Princeton, NJ: Princeton University Press.

Nowak, M., & Sigmund, K. 2005. Evolution of indirect reciprocity. *Nature, 437,* 1291–1298.

Ossher, H. & Tarr, P. 2001. Using multidimensional separation of concerns to (re)shape evolving software. *Communications of the ACM, 44,* 43-50.

Pinker, S. 1997. *How the mind works*. New York: Norton.

Scheibehenne, B., Wilke, A., & Todd, P. M. in press. Expectations of clumpy resources influence predictions of sequential events. *Evolution and Human Behavior*.

Sherry, D.F. & Schacter, D.L. 1987. The evolution of multiple memory systems. *Psychological Review*, 94, 439-454.

Smith, A. 1776, *An inquiry into the nature and causes of the wealth of nations*. 2 volumes, London: W. Strahan & T. Cadell.

Smith, V. L. 1998. The two faces of Adam Smith." *Southern Economic Journal, 65*, 2-19.

Sperber, D. 2005. Modularity and relevance: How can a massively modular mind be flexible and context-sensitive? In P. Carruthers, S. Laurence & S. Stich (Eds.), *The innate mind: Structure and content* (pp. 53-68). New York: Oxford.

Tooby, J., & Cosmides, L. 1992. The psychological foundations of culture. In J. H. Barkow, L. Cosmides & J. Tooby (Eds.), *The adapted mind* (pp. 19-136). New York: Oxford University Press.

Todd, P.M., Gigerenzer, G., & the ABC Research Group 2010. *Ecological rationality: Intelligence in the world*. New York: Oxford University Press.

Tooby, J. & Cosmides, L. 2008. The evolutionary psychology of the emotions and their relationship to internal regulatory variables. In M. Lewis, J. M. Haviland-Jones & L. F. Barrett (Eds.), Handbook of Emotions, 3rd Ed. (pp. 114-137.) NY: Guilford.

Wason, P.C. 1983. Realism and rationality in the selection task. In J.StB.T. Evans (Ed.), *Thinking and reasoning: Psychological approaches*. London: Routledge & Kegan Paul.

Wilke, A., and Barrett, H. C. 2009. The hot hand phenomenon as a cognitive adaptation to clumped resources. *Evolution and Human Behavior, 30,* 161-169