The Beauty of Simplicity?
(Simple) Heuristics and the Opportunities Yet to Be Realized

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THE BEAUTY OF SIMPLICITY? (SIMPLE) HEURISTICS AND THE OPPORTUNITIES YET TO BE REALIZED

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Introduction

Heuristics are all around us, both in the real world and the literature. There are many of them and there are many—too many—definitions of them. For example, in Ericson, White, Laibson, and Cohen (2015), the authors test a cleverly named Intertemporal Choice Heuristic (ITCH) model of choices between earlier or later payments by identifying the weight that individuals put on absolute and relative money value, as well as absolute and relative time difference. Controlling for various frames, and running subjects through a battery of parameterizations of intertemporal choices, they back out the importance of the additive component heuristics by estimating their weights from the cumulative distribution function of a logistic distribution with a mean of zero and a variance of 1. Essentially, they estimate the likelihood of larger and later outcomes through a nonlinear regression on realizations of determinants of intertemporal choice (absolute and relative money value, absolute and relative time difference), the component heuristics. Interestingly, the authors do not need to

[1] The authors are grateful for critical and helpful commentary on earlier versions from Nathan Berg, Gerd Gigerenzer, Ralph Hertwig, Konstantinos Katsikopoulos, Elizabeth Maitland, and Ben Newell. All errors in judgment and tone are ours. This manuscript is a draft of a chapter for a book edited by Morris Altman and forthcoming in 2016 with Elgar.

specify utility functions, making seemingly superfluous debates about functional forms, decision weights, risk attitudes, and their elicitations (e.g., Andersen, Harrison, Lau, & Rutström 2008). Using out-of-sample evaluation (about which more in a second), the authors demonstrate that their approach outperforms in terms of predictive accuracy the prominent traditional models of intertemporal choice (exponential, hyperbolic, and quasi-hyperbolic) by considerable margins. While an interesting as-if model of intertemporal decision making, ITCH is hardly a model of simple heuristics as used by real people (as the authors seem to suggest in the title of their article), i.e., of decision rules that are fast and frugal because they ignore information that might be available (Gigerenzer, Todd, & the ABC Research Group 1999; Gigerenzer & Gaissmaier 2011). In fact, it is not even clear to what extent it is a simple heuristic at all as it does not ignore any information and requires the calculation of both absolute and relative differences in variables (time and payoffs), thereby introducing redundancy rather than parsimony.

In this chapter we focus on the history of fast and frugal heuristics, as sketched out comprehensively in Gigerenzer, Todd, & the ABC Research Group (1999) and scores of follow-up books (e.g., Gigerenzer, Hertwig, & Pachur 2011; Todd, Gigerenzer, & the ABC Research Group 2012; Hertwig, Hoffrage, & the ABC Research Group 2013) and articles (see our list of must-reads). Specifically, we contextualize the emergence of the "Ecological-Rationality" (ER from here on) program as an explicit counterpoint to the "Heuristics-and-Biases" (H&B from here on) program initiated by Kahneman and Tversky (e.g., Tversky & Kahneman 1974; Kahneman & Tversky 1979; Kahneman 2003, Kahneman 2003a, Kahneman 2010) that informed and inspired scores of early behavioural economists. Simple heuristics are here understood to be fast and frugal rules of thumb because they ignore information that is available. Also, they ought to reflect cognitive processes (and hence be able to predict) rather than be as-if modelling exercises that explain ex post.

Our focus seems warranted by the fact that the H&B program has invaded economics, and other social sciences, to the extent that is now by many measures thoroughly mainstream (e.g., Camerer et al 2004, 2011; Heukelom 2015; Thaler 2015). While in the last few years increasingly critical questions have been asked about the H&B program (e.g., Ortmann 2015, 2015a and references therein), the predominance of it has largely overshadowed the ER program, in our view to the detriment of both economics and the ER program. It has not

helped that those in favor of an ER program have not done as much out-reach to economics as might have been desirable.

Sketching with a very broad brush indeed, we argue that the H&B program suggested that various bounds on rationality, and the make-up of human judgement- and decision-making facilities, induced humans to make rash decisions that produced systematic biases, or cognitive illusions. Cognitive illusions were rationalized with reference to optical illusions whose reality was well-established. The heuristics that people used—such as representativeness, availability, and anchoring and adjustment—were motivated by appeal to the principles also underlying optical illusions. An implicit—and increasingly explicit claim (e.g., Thaler 1980, p. 40)—was that cognitive illusions were as robust as optical illusions (see also Kahneman 2003, 2003a). Heuristics were considered to be problematic and decision makers as fallible, and even gullible, and in dire need of all the help that they could get to improve on their decision-making skills. As Cochrane (2015) has noted, not inappropriately, this view represents for the H&B program proponents a considerable moral-hazard problem.

It is worth noting that the assessment of people's performance as being severely wanting was quite a departure from the prevailing view in the 1950s, 1960s and early 1970's (e.g., Edwards 1956; Peterson & Beach 1967; see also Ortmann 2015). Even Tversky & Kahneman (1974), in the article that started it all, did not make the kind of sweeping claims that were made in the following decades.

Drawing on arguments by Herb Simon (1947, 1955, 1956) and his insight that rationality cannot be defined through cognitive and emotional processes alone, Gigerenzer and the ABC Research group, showed that many of the demonstrations of the H&B program were highly problematic. The main criticism was directed at the design and implementation of the experiments used to produce supporting evidence (e.g., prominently Gigerenzer 1991), and that indeed heuristics could have surprising performance properties, particularly so as environments became more uncertain (Gigerenzer & Gaissmaier 2011).

We first review in more details how this battle of programs unfolded and then a) lay out what we consider the considerable accomplishments of the ER program, b) point out some overlooked connections between the ER program and economics, and c) enumerate what we consider to be open questions and challenges. In the interest of full disclosure, let it be known that both authors spent time at the Max Planck Institute for Human Development, which

houses the ABC and ARC groups (both of which contribute to the ER program, more about this below); Ortmann in 1996-97 and 1999-2000 one year each with the ABC group and Spiliopoulos having visited the ABC group twice (for a couple of weeks each) and since mid-2014 being a Humboldt Experienced Research Fellow with the ARC group.

How the battle of H&B program (H&BP) and ER program (ERP) unfolded

First, H&BP. Calling Richard Cyert, James March, Herbert Simon the "old behavioral economists, who focused on bounded rationality, satisficing, and simulations" p. 740), historian of economics Esther-Mirjam Sent (2004) explained the transition from Old to New Behavioral Economics (pp. 742 – 747), thus: "The roots of new behavioral economics may be traced to the 1970s and the work of especially Amos Tversky and Daniel Kahneman, …" (p. 742). She identifies the "Behavioral Foundations of Economic Theory" conference held at the University of Chicago in October 1985 as a key event. In the preface to their book that drew on the conference, Hogarth & Reder (1987) argued that there was "a growing body of evidence – mainly of an experimental nature – that has documented systematic departures from the dictates of rational economic behaviour." In his review of the book, Smith (1991) dismissed such claim: "(experimental economics) documents a growing body of evidence that is consistent with the implications of rational models." (p. 878)

Acknowledging that Simon's work on bounded rationality had influenced them, too, Kahneman (2003) identified three separate lines of research.

> "The first explored the heuristics that people use and the biases to which they are prone in various tasks of judgment under uncertainty, including predictions and evaluations of evidence (…). The second was concerned with prospect theory, a model of choice under risk … and with loss aversion in riskless choice … . The third line of research dealt with framing effects and with their implications for rational-agent models … ." (p. 1449) and,
>
> "Our research attempted to obtain a map of bounded rationality, by exploring the systematic biases that separate the beliefs that people have and the choices they make from the optimal beliefs and choices assumed in rational-agent models. The rational-agent model was our starting point and the main source of our null hypotheses, but Tversky and I viewed our research primarily as a contribution to psychology, with a possible contribution to economics as a secondary benefit. We were drawn into the interdisciplinary conversation by economists who hoped that psychology could be a useful source of assumptions for economic theorizing, and indirectly a source of hypotheses for economic research (Richard H. Thaler, 1980, …)." (p. 1449)

Kahneman & Tversky's H&BP was based on the idea that thinking was typically fast and rarely slow, and very fundamentally about accessibility or intuition. The argument was that, since our thinking was typically fast, it had to rely on rules of thumb (heuristics) which led to systematic divergences (biases) from normative behavior as described by standard economic theories (Tversky 1974; Kahneman & Tversky 1996; Kahneman 2003, 2003a). People were increasingly conceptualized as bumbling fools and this theme was also the general drift taken up by those starting the movement that later became Behavioral Economics. Thaler (1980), for example, exclaimed that "Research on judgement and decision making under uncertainty, especially by Daniel Kahneman and Amos Tversky (1974, 1979) has shown that (...) mental illusions should be considered the rule rather than the exception. Systematic, predictable differences between normative models of behavior and actual behavior occur ..." (p. 40). Importantly, the cognitive illusions were explicitly constructed (e.g., Kahneman 2003, 2003a) in parallel to optical illusions whose reality and robustness had been reasonably well established. It is striking that the optical illusion analogy was not taken to its logical conclusion, namely that the documented illusions either *never* occur in the environment or in the few instances when they do, they rarely impose any real cost on the organism. How many times have you encountered, and been fooled, by the Müller-Lyer Illusion, a Necker cube or an Ames room in the *real* environment?—see http://www.michaelbach.de/ot/ for a discussion of these and other optical illusions. In fact, the properties of the visual system that produce these illusions are argued to be optimal given the characteristics of real-world visual environments and the constraints of the visual system, i.e., a finite number of neurons with a bounded response range. We have argued elsewhere (Spiliopoulos & Ortmann 2014) that specific diagnostic tasks, i.e., specific parameterizations of tasks where competing models make starkly different predictions, should not be used to infer the rationality of agents. Rationality can only be assessed on a wide range of parameterizations that must include those found in the real environment (see on this, Hogarth & Karelaia 2005; 2006; 2007; Erev et al. 2015).

There were some obvious problems with the H&B approach and two decades ago they were the subject of a highly-visible dispute between Kahneman & Tversky (1996) and Gigerenzer (1996) about the reality of cognitive illusions. From the critics', and also the present authors', view the H&BP was characterized by a lack of process models (key

concepts such representativeness, anchoring and adjustment, and availability being hardly more than labels); too much story-telling, un-incentivized scenario studies, polysemy, often deception, and experimenter demand effects, to name a few. There was, in Nobel Prize laureate Vernon L. Smith's sarcastic and brilliant observation too much fishing in the tail ends of human behaviour (Smith 2003, fn 8). No surprise then that many anomalies were found that were taken as proof of people's limited rationality. The interpretation of that evidence as being indicative of humans' typically underwhelming performance was subsequently contested.

Second, ERP. The ABC research (see also Lopes 1991) was constructed in contrast to the H&BP. Gigerenzer (1991), for example, successfully deconstructed some key findings of Kahneman and Tversky who eventually found themselves prompted to respond to Gigerenzer's critique (Kahneman & Tversky 1996; Gigerenzer 1996). ABC also developed a fundamentally different view of heuristics and did so by formulating cognitive process models that could be tested. It is interesting to note that many of the process models were also based on a frequentist view of the world, with ABC researchers taking broadly an evolutionary-psychology perspective, which conceptualized humans as intuitive statisticians that were almost naturally good at navigating environs that were familiar to them. It has also been demonstrated persuasively that an important moderator of these findings is the way statistical information is presented (Sedlmeier & Gigerenzer 2001; see Hertwig & Ortmann 2005 for a summary).

To the extent that the H&BP was gobbled up hook, line, and sinker by the initial waves of Behavioral Economics/Finance, ABC remained an outsider of sorts although its influence has grown, as recently evidenced by a 20-year celebration that was attended by more than 100 participants. Part of the problem is that ABC rarely engaged with modern economics and focused its critiques on normative economic models of deductive reasoning. We will argue later on that there exists important work assuming inductive reasoning in economics that can serve as a bridge with the ERP, although important differences remain, and offer considerable opportunities yet to be realized.

Our LIST OF TWENTY MUST-READS, in alphabetical order:

Brighton & Gigerenzer (2015, The Bias Bias)

Brandstätter, Gigerenzer, & Hertwig (2006, The Priority Heuristic: Making Choices Without Trade-Offs)

Dhami, Hertwig, & Hoffrage (2004, The Role of Representative Design in an Ecological Approach to Cognition)

Gigerenzer & Brighton (2009, Homo Heuristicus)

Gigerenzer & Gaissmaier (2011, Heuristic Decision Making)

Goldberg & Podell (1999, Adaptive Versus Veridical Decision Making and the Frontal Lobes)

Goldstein & Gigerenzer (2011, The Beauty of Simple Models: Themes in Recognition Heuristics Research)

Grüne -Yaniff & Hertwig (2015, Nudge Vs Boost: How Coherent Are Policy and Theory?)

Grüne -Yaniff, Marchionni, & Moscati (2015, Introduction: Methodologies of Bounded Rationality)

Hertwig & Erev (2009, The Description-Experience Gap in Risky Choice)

Hogarth & Karelaia (2007, Heuristic and Linear Models of Judgment: Matching Rules and Environments)

Katsikopoulos & Gigerenzer (2008, One-Reason Decision-Making: Modeling Violations of Expected Utility Theory)

Katsikopoulos, Schooler, & Hertwig (2010, The Robust Beauty of Ordinary Information)

Luan, Schooler, & Gigerenzer (2014, From Perception to Preference and on to Inference: An Approach-Avoidance Analysis of Thresholds)

Mandler, Manzini, & Mariotti (2012, A Million Answers to Twenty Questions: Choosing by Checklist)

Manzini & Mariotti (2014, Stochastic Choice and Consideration Sets)

Marewski & Schooler (2011, Cognitive Niches: An Ecological Model of Strategy Selection)

Pleskac & Hertwig (2014, Ecologically Rational Choice and the Structure of the Environment)

Schooler & Hertwig (2005, How Forgetting Aids Heuristic Inference)

Volz & Gigerenzer (2012, Cognitive Processes in Decisions Under Risk are not the Same as Decisions Under Uncertainty)

The accomplishments of the Ecological Rationality Program

The ERP is characterised by a heavy reliance on cognitive process models (which require some serious theorizing), empirical and experimental testing of these models, and an important methodological innovation in that the preferred mode of testing relies on "out-of-sample" prediction, or "cross-validation" (Gigerenzer & Gaissmaier 2011). That is, performance is not measured by the best fit on an existing dataset but by the performance of a model on not yet known datasets, as also done in Ericson et al. (2015) and Erev et al. (2015). There is, in other words, no data-fitting after the fact. Cross-validation addresses the important bias-variance tradeoff (Gigerenzer & Brighton 2009). Simple models exhibit higher bias but typically less variance than complex models—it is the relative strength that determines which type of model outperforms the other in prediction. The key finding is that heuristics often exhibit little or no bias vis-à-vis more complex models, therefore the variance effect tends to dominate—we return to this below.

Among ERP's key successful demonstrations is that, when cross-validation is used, the performance of simple heuristics such as the recognition heuristic or the "take-the-best" is better than that of complicated, computationally slow and greedy models such as multiple regression favoured by economists (e.g., Gigerenzer, Todd & the ABC Research Group 1999; Todd, Gigerenzer & the ABC Research Group 2012; Gigerenzer & Brighton 2009; Gigerenzer & Gaissmaier 2013). The simple, and rather intuitive, reason is that multiple regression essentially overfits, looking backwards, without taking into account the noisiness that is inherent in datasets yet to result from the same data-generating process. An important implication is that the widely believed effort-accuracy trade-off (Payne, Bettman, & Johnson 1993) is often not something one needs to worry about. Those using simple heuristics can have their cake and eat it, too. Less can be more.

Much work has been done to understand these remarkable results; what drives the success of heuristics such as recognition and take-the-best is now much better understood (Baucells et al 2008; Luan, Schooler, & Gigerenzer 2011, 2014; Katsikopoulos 2013; Drechsler et al. 2014). There are three important environmental characteristics that are sufficient, but not necessarily necessary, that induce these striking results: non-compensatoriness of cues, dominance, and cumulative dominance. If at least one of these three is true, then a lexicographic heuristic exhibits no bias vis-à-vis a linear rule, *and* is computationally less

demanding. However, these theoretical results are not important if these conditions are not found regularly in the real environment. Şimşek (2013) found that these conditions are extremely common in 51 real-world datasets; consequently, a lexicographic heuristic performed as well as multiple linear regression in the median dataset for approximately 90% of cases. Recent work has analyzed fast-and frugal trees and successfully connected them to signal-detection theory (Luan, Schooler, & Gigerenzer 2011; 2014), new heuristics such as the fluency and priority heuristics have been proposed (Hertwig et al 2008; Brandstätter et al. 2006, 2008; Drechsler et al. 2014; but see also Johnson et al 2008 on the priority heuristics), and a persuasive rationalization has been provided for the tendency of many economists and psychologists to overlook the benefits of simplicity (Brighton & Gigerenzer 2015).

Another important contribution of the ERP is the distinction between "decisions-from-description" (DfD) and "decisions-from-experience" (DfE) and the empirical validation of a robust gap between the two (e.g., Barron & Erev 2003; Hertwig & Erev 2009). It is indeed intuitive that risk maps into, or maybe better, invokes DfD, and that uncertainty maps into, DfE. We note parenthetically that DfD and DfE also map into eductive and evolutive (deductive and inductive) game theory (Binmore 1990; Friedman 1991). This is also the appropriate place to note that decisions under risk roughly map into decisions in the small and those under uncertainty map roughly into decisions in the large (see Gigerenzer & Gaissmaier 2011 for a discussion). Hopefully, researchers both at ABC and ARC continue recent attempts at theory integration (e.g., Schooler & Hertwig 2005, Luan, Schooler, & Gigerenzer 2011, 2014) and related attempts to break down disciplinary boundaries (e.g., Hutchinson & Gigerenzer 2005), something that was to some extent also reflected in the make-up of the ABC Research Group but maybe not as much as would have been desirable ex post in particular regarding the group's engagement with economists.

An increasing number of economists and researchers from management and organization (no wonder here, given where it all started: Simon 1955, 1956) have been attracted by the ER paradigm. For example, Åstebro & Elhedli (2006) have empirically demonstrated the usefulness of simple heuristics in forecasting commercial success for early-stage ventures. Eisenhardt and some of her colleagues (see for a self-centered primer, Bingham & Eisenhardt 2014) have argued that successful repeated product innovation is best implemented through "simple rules", or "semi-structures" which define a path between too much and too little

structure. Maitland & Sammartino (2014) have empirically demonstrated the use of simple decision rules for location choice by multinational companies when environments are politically hazardous. Indeed, Artinger, Petersen, Gigerenzer, and Weibler (2014) have provided a useful primer of heuristics as adaptive decision strategies in management but it seems clear that the use of heuristics in management and organization is under-studied and remains a fruitful area of research. To see how understudied the topic is academically, google strings like "rules of thumbs to determine when projects pay off" to find more than 14 million hits and scores of list of simple decision rules for everything from cash flow, real-estate investments, to other financial investments.

The can be no doubt that progress towards a science of heuristics has been tremendous and that the ABC group's influence is increasing; there remain important blind spots though in our view.

ERP and economics – a missed opportunity (so far)

The incompatibility of the ERP with economics has been emphasized by a number of ERP researchers. To a large extent, the ERP is positioned as an antithesis both to the B&HP and the neoclassical-economics program, including behavioural economics which is viewed as a disguised extension of the neoclassical program (Berg & Gigerenzer 2010). We are sympathetic to the claims made (as far as they pertain to the overwhelming mass of those working in that neoclassical paradigm), for example, we ourselves have argued about the advantages of process models compared to as-if models (Spiliopoulos & Ortmann 2015). However, we fear that a purely antagonistic approach of emphasizing the divide has the unfortunate consequence of deepening the schism rather than fostering an exchange between these programs. The differences in opinions are well known; here we will attempt to highlight (perhaps surprising) similarities between these research programs, indeed in some cases we will find parallel, independent emergence of similar ideas. This suggests that there is significant scope for future exchange of ideas and productive collaboration between researchers from the two fields.

Heuristics

Extremely interesting work that seems to have developed in parallel to the work of the ABC Research Group has been done in economics by people like Manzini and Mariotti (e.g., 2007, 2012, 2012a, 2014; see also Mandler, Manzini, & Mariotti 2012). This parallel development seems scientifically counterproductive for a number of reasons (e.g., see Arkes & Ayton 1999 on the Concorde Fallacy and related work in economics on sunk cost effects such as Friedman et al. 2007 and McAffee et al. 2010). The well-cited Manzini & Mariotti (2007) was broadly inspired by the work of Gigerenzer and associates and formalized and axiomatized a type of sequential eliminative heuristic demonstrating that boundedly rational choice procedures could be tested with observable choice ("revealed preference") data favoured by more traditional economists. The more recent Manzini & Mariotti (2012, 2014) builds on this earlier two-stage deterministic model of choice by providing models of stochastic choice when consideration sets are present (i.e., agents fail to consider all feasible alternatives), a popular approach but typically less formalized approach in management science and marketing science that is related to Random Utility Models that have been around for decades in economics. Mandler et al. (2012) provides procedural foundations for utility maximization, with the checklists in the title of their paper being the equivalent of the—preferably non-compensatory—cues central to the fast & frugal heuristics extensively analysed by the ABC Research Group. The authors show that under specific conditions procedural utility maximization matches that of substantial utility. In Manzini & Mariotti (2012a), the authors extend and formalize a choice procedure introduced by Tversky (1969) that has recently also prominently featured in the work of Luan and Colleagues (Luan 2011, 2014).

How to choose heuristics from the adaptive toolbox?

Initial criticisms that the ERP had not adequately specified the heuristic selection method of the adaptive toolbox has prompted work directed at strategic selection. The most prominent response to this critique was to postulate a reinforcement learning mechanism over heuristics (Rieskamp & Otto 2006) – see also the RELACS model by Erev & Baron (2005). This is essentially the same solution proposed for strategic decision making by economists. For example, Aumann (p. 7-8, 1997) writes "Ordinary people do not behave in a consciously rational way in their day-to-day activities. Rather, they evolve 'rules of thumb' that work in

general, by an evolutionary process like that discussed above (Section 1*a*), or a learning process with similar properties." In the El Farol bar problem (Arthur 1994), agents hold a heterogeneous set of simple predictive models and learn to use the more effective rules (given their individual experience) over time; interestingly, such a learning process converges to the Nash equilibrium solution. Empirical work in repeated games by Stahl (1996, 1999, 2000); Haruvy & Stahl (2012) finds evidence that subjects learn to use relatively simple rules based on their prior performance – they refer to their model as rule-learning. These are striking similar concepts to those proposed by the ERP; however, the ERP studies were in the domain individual decision making, whereas the economic studies in strategic decision making. Clearly there is potential here for both disciplines to interact and advance our knowledge of the strategy selection problem.

What is the appropriate performance metric for model comparisons?

The ERP has, rightly so in our view, promoted the use of cross-validation to compare the performance of heuristics to other more complex models, hence shifting the focus from explanation to prediction. This is a consequence of the effects of the bias-variance dilemma. More complex models will tend to fit better in-sample than simpler models (such as heuristics), but may perform worse on out-of-sample predictions. Friedman (1953) was an early proponent of the notion that theories should be evaluated on the basis of their predictive power; of course, ERP researchers would take aim with his contention that the processes (and underlying assumptions) are irrelevant – see for example the billiard player example in Friedman & Savage (1948). Studies published in prominent economics journals as far back as Camerer & Ho (1999), including more recent work such as Wilcox (2011); Spiliopoulos (2012, 2013) have also argued for, and used, cross-validation. See also Erev et al. (2015) and literature therein. Interestingly, much of the work in economics has originated in the experimental game theory literature, specifically involving learning models, i.e., inductive learning.

What is the appropriate space for the calculation of deviations from rationality?

A further issue concerns how we measure deviations from rationality, if they exist at all? The ERP focuses on deviations in the *consequence* space, i.e., comparing the actual loss in

terms of the consequences of a behavior. Consequences can be actual payoffs, if they are well defined for a problem, or a metric based on the percentage of correct/wrong responses often used in binary tasks. Using deviations in the *consequence* space instead of the *choice* space is important, as seemingly large differences in choice may not translate into large deviations in the consequence space, particularly when computational costs are included. In the early history of Behavioral Economics, deviations from rationality where typically measured in the choice space, and admittedly this still occurs. However, experimental economists have taken issue with experiments that have a flat payoff function around the normative solution, culminating in the *payoff-dominance critique* (Harrison 1989) that prompted a large debate in the field (see the comments and replies to this paper in the American Economic Review Vol. 82, No. 5, 1992).

This debate has influenced future work in the field, see for example the extensions of the literature on the evidence of mixed strategy equilibrium behavior from the laboratory where incentives and the curvature of the payoff function may indeed be weak, to high incentives in the field, e.g., professional sport players. While originally intended as a critique of the design of many experiments in economics, implicit in the payoff-dominance critique is the notion that non-optimal behavior can only be concluded when it is accompanied by large costs in the consequence space.

The interaction between simple decision rules and the environment

The ERP is based on the premise that rationality should be assessed in the context of the environment, i.e., Simon's 'scissors' metaphor. In strategic settings, the definition of the environment must be extended to include institutions, market characteristics and the interactions between agents. Perhaps surprisingly—to ERP researchers—an early example of such interactions was given by Becker (1962) (oh, the irony!) who analysed a model of markets in which participants behaved irrationally or randomly. He found that seemingly rational behavior at the macro level could arise even from random behavior at the micro level. In this spirit, more recent developments in economics include the zero-intelligence program initiated by Gode and Sunder (1993) who examined the effects of the structure of continuous double-auctions on market outcomes. They found that simple agents, who made

random bids with the only constraint that they do not make offers that would lead to a loss, converged and achieved near perfect allocative efficiency.

Cognitive bounds and behavior

The premise that less is more with respect to the amount of information that decision makers use can be linked to bounds on cognition such as limitations in the amount of information that can be held in working memory (Cowan 2000) or the long-term memory retrieval system (Schooler & Anderson 1997). Economists have similarly been concerned with simple strategies that do not use all available historical information, starting back to the Axelrod (1984) tournament. Tit-for-tat and the win-stay/lose-shift strategies are examples of relatively simple heuristics that perform well in repeated games and are robust to the exact composition of types in the population and to noise. Explicit modelling of forgetting has been common in economic studies of learning in repeated games since Roth and Erev (1995); Cheung and Friedman (1997). Finite-state automata are another methodological tool explicitly aimed at examining the effects of limiting the prior (in a temporal sense) information that a player conditions his/her strategies on (e.g., Rubinstein 1996). Furthermore, it is well known in game theory that more information does not necessarily lead to better outcomes.

Procedural modeling

An important characteristic of most ERP studies is the insistence that models should be procedural (or process-based) in contrast to the majority of models in economics that are as-if models. The advantage of procedural models is that they make more specific predictions (choices *and* processes) than as-if models and are more falsifiable in the Popperian sense. For example, see Johnson et al (2008) who argue that the process data is incompatible with that implied by the Priority heuristic; this of course, would not have been possible for an as-if model. It is perhaps here that cognitive psychologists have already exerted a unidirectional influence on economists. Early work in psychology employing process-tracing techniques such as Mouselab (Johnson et al 1989) and eyetracking have spilled over to economics; see Crawford (2008) for an excellent overview. Providing process-level foundations to existing as-if models in economics, and highlighting the value-added of this, is another way of

engaging economists with the ERP. For example, Fischbacher et at (2013) modify economic theories of social preferences by imposing a decision tree structure to the order in which these variables are examined. Similarly, Spiliopoulos (2013) transforms a process-free model of pattern recognition in games (Spiliopoulos 2012) into a process-model encompassing both exemplar- and prototype-based categorization grounded in the ACT-R architecture.

Reasoning by similarity and cases

Reasoning by similarity can be a useful tool when confronted with uncertainty of a new situation from which an agent has not had experience. Important theoretical contributions have been made by economists to case-based and analogy-based reasoning, see for example early work by Rubinstein (1988) and Leland (1994) on decision under risk and the extensive work of Gilboa & Schmeidler (1995, 2001). Other work by economists exploiting similarity in inductive inference involves the question of how agents play a new game (that they have not seen before); specifically, how prior experience with other games may spill over to new (unseen) games on the basis of similarity between games (e.g., Mengel & Sciubba 2014). Also, Spiliopoulos (2013) shows that subjects learn from the similarity, not between games, but between patterns in the history of play during a single repeated game.

Open questions and challenges

While the success of the ERP cannot be disputed, there remain many open questions that are in need of answers. We enumerate and discuss them next.

First, what is the complete set of heuristics out there? This question may be unanswerable for the simple reason that, as illustrated by Ericson et al. (2015), there are probably as many definitions out there as there are researchers. And, it has to be added, researchers have often very vested interests to differentiate their product (e.g., Bingham & Eisenhardt, 2014, or the already mentioned Ericson et al., 2015, who do not reference Gigerenzer et al 1999). In other words, there will not be agreement on what is in the adaptive tool box of heuristics any time soon. An answer to this question will become even harder as heuristics – which so far have predominantly been studied in non-strategic decision settings – will be addressed in strategic decision settings; see Vuori & Vuori (2014) for an excellent primer. Constraining the infinite

number of available heuristics to those that are part of the adaptive toolbox can be accomplished by various means. One approach (e.g., Schooler & Hertwig 2005), is to constrain heuristics by using well-known cognitive limits such as the number of items that can be held in working-memory, the relationship between memory retrieval, and frequency/timing of events. Another approach is to first constrain heuristics (e.g., by modelling them as fixed-memory finite-automata), expose the remaining heuristics to evolutionary or competitive pressure, and assume that a small subset of the fittest heuristics are those that have made it into the adaptive toolbox. An alternative approach is to instead first ask what the set of building blocks that make up heuristics is? A broad, but by no means complete, characterization is that these are comprised of search rules, stopping rules and decision rules.

Second, how to choose the appropriate tool from that adaptive tool box remains a prominent question in search of better answers – see Marewski & Link (2013) for a review. ERP researchers have made considerable progress on this issue and interesting results about strategy selection have been provided (e.g., Marewski & Schooler 2011). A predictable argument has it that strategic selection is the result of evolutionary pressure or strategy selection using a reinforcement learning mechanism over heuristics (Rieskamp & Otto 2006). We find that argument only partially persuasive. Our skepticism harks back to old debates about to what extent people take into account structural changes in the environment. There is some evidence that people, possibly moderated by market institutions, have in many circumstances surprisingly rational expectations but, of course, it is dependent on many things even without market institutions moderating. We do know that the use of heuristics changes when environmental conditions change (e.g., the work of Hogarth and Karelaia, see also Rieskamp & Otto 2006, Spiliopoulos et al. 2015, Spiliopoulos & Ortmann 2015) but we are far away from understanding the issue of matching in their totality in a satisfactory manner. A problem related to the selection problem, is the associated costs; if we accept that heuristics evolve to match an environment, then we would expect the environment to remain somewhat stable. If an environment is not stable and in fact might become turbulent then heuristics' match to a specific environment will, by construction, overstay their welcome. For that reason, the claim that selection is driven by reinforcement learning defies belief in such environments. However, the issue of non-stationary environments can be addressed nicely by

the degree of forgetting without having to choose a different heuristic from the toolbox, i.e., adaptation is built into the heuristic. Ultimately, the complexity of the environment will determine the tools in the box.

Third, while it is an interesting question to understand how changing environments can affect choice of heuristics, to what extent the use of heuristics can shape the environment is a question that brings about important issues of causality (e.g., Hertwig et al. 2002 on parental investment) that strike us as under-researched.

Fourth, ERP researchers have recently argued that the two programs of rationality have not only very different assessments of human rationality but have also very different policy implications identified as nudging and boosting (Gruene-Yanoff & Hertwig 2015; Katsikopoulos 2014). These issues strike us also as understudied. We are also not certain that the real issue is that of nudging versus boosting. We do appreciate the fact that nudging might have some undesirable intertemporal consequences (e.g., Carroll et al. 2009 and the literature that followed it) but submit that boosting is often an unavailable option. Despite the difficulties, this opens up important avenues for the ERP program to have a significant impact at the policy level.

Fifth, the ERP, it seems fair to say, has not managed to have much *practical* impact on management science and organization science. This is somewhat surprising given the intellectual origin of the key parts of the ABC agenda (Simon, anyone?). Despite the fact that many publications on the theoretical properties of heuristics have made their way into prominent management/organization science journals (e.g., Hogarth & Karelaia 2005; Katsikopoulos 2013), we are unaware of any significant impact on this literature on organizations directly, or applied/empirical work on heuristics in organizations. This is particularly surprising given that bounded rationality has become an influential concept in management science and organization science and economics. An exception is the *hiatus heuristic* that predicts whether a customer is active or not, i.e., will make future purchases. Wübben & Wangenheim (2013) not only find evidence of its use by executives, but also show using real-world data that this simple heuristics can out-predict more complex models.

Sixth, as (simple) heuristics are being discovered by management and organization sciences (e.g., Loock & Hinner 2015), the movement away from non-strategic decision making (the core of early ERP research) to strategic settings brings in new complexities

arising from strategic interactions. It is not that ABC has not started to struggle with these issues but the work in this area seems pedestrian compared to the rather more sophisticated work on non-strategic decision making. Promising examples include the collaboration between economists and psychologists in Fischbacher et al (2013) mentioned earlier, which we hope to see more of in the future. Another example is Stevens et al (2014), who examine the effects of forgetting on the emergence of cooperative strategies in repeated interactions. Further bridging the different concepts of bounded rationality that psychologists and economists would be a fruitful endeavour. There are, of course, important differences across disciplines that we cannot fully discuss here—Katsikopoulos (2014) and Grüne-Yanoff et al (2014) are excellent primers. Here, we choose to focus on aspects that can more easily be bridged between the disciplines. While economists tend to ignore the ecological rationality of bounded rational strategies (such as Level-k and cognitive hierarchy theory) it is but a small step to extend analyses in this direction. For example, in the lab many subjects' behaviour is explained particularly well by the L1 heuristic that assumes that an opponent chooses each of his available actions with equal probability. Consequently, the L1 heuristic simplifies a strategic problem to a non-strategic one (e.g., Spiliopoulos et al. 2015). The million-dollar question—that economists have not systematically asked—is what is the impact of this on subjects' payoffs? Recall, however, our discussion of the closely-related payoff-dominance critique. This is at the heart of the main contention of the ERP that less may be more. A simple, yet illustrative, example of how the redundancy of cues (or information) can be imagined in strategic environments is to consider strictly competitive games between agents, i.e., constant-sum games. In constant-sum games, a player's payoff for each possible outcome is perfectly negatively correlated with the opponent's outcome. Therefore, a player need only sample information about the payoffs for one of the players. The correlation between players' payoffs depends on the type of games that exist in an environment. At the extreme, perfectly competitive and perfectly cooperative environments both exhibit informational redundancies that could be exploited by heuristics matching the environment. Furthermore, a map of bounded rationality specifying which heuristics are effective in different classes of games is a difficult, but important, goal, i.e., something akin to the systematic exploration of the environment and decision rules in Hogarth & Karelaia (2006), but applied to games. An example of work by economists in the spirit of the ERP work of comparing the performance

of simple heuristics to other more sophisticated models, but applied instead to games is Duersch et al (2014). They characterize the set of symmetric two-player games where tit-for-tat (and a wider array of imitation strategies) cannot be beaten by any other strategy of unbounded sophistication.

Seventh, the topic of learning has not been broached successfully by the ERP program; however, the potential exists for important work on simple heuristics of learning. A starting point is Selten's Learning Direction Theory, which is ultimately a simple story of ex post rather than ex ante rationality using minimal information—note again that this is an inductive model of reasoning. For example, LDT requires information only about the *direction* that would have led to an improvement in the outcome; reinforcement learning would also require the *magnitude* and regret-based learning would require information about counterfactual outcomes. As an aside we draw the reader's attention to the edited volume by Gigerenzer & Selten (2002). An excellent example of work along these lines is Bonawitz et al (2014) who show that a simple heuristic (Win-stay, lose-sample) can approximate computationally demanding Bayesian inference in non-strategic settings. Strategic interactions entail additional uncertainty- how often is the assumption of perfect information fulfilled in the real world? Do we know what the action space is, what the payoffs are, and the type/motives of our opponent? With so much uncertainty is strategic ignorance or bounded sophistication necessarily a detrimental approach? ERP researchers should note that economists have not ignored these important questions, such as uncertainty, as the literature is literally full of extensions and concepts specifically addressing them. On the other hand, ERP researchers can and should critique the characteristics of the solutions proposed by economists. For example, in many cases the extensions or refinements to equilibrium solution concepts that deal with these types of uncertainty may be orders of magnitude more complicated than those under perfect information. Again, however, we note that these solutions belong to the deductive strand of game theory, not the inductive strand; the latter should be far more palatable to psychologists. An example of inductive learning under uncertainty, where the payoffs of a game are unknown is Oechssler & Schipper (2003); despite finding that subjects did not efficiently learn the true game, they often converged on the Nash equilibrium.

Eighth, and relatedly, some celebrated heuristics can easily be exploited (e.g., default settings in situation where the choice architect has vested interests: credit card companies,

etc.). In general, it is necessary to assert to what extent the interests of the default-setter and the people that defaults are meant to nudge coincide. It would be a mistake to assume that it always the case.

Ninth, Goldberg (2005; see also Goldberg & Podell 1999) have argued that studying lotteries does not capture decision making in the wild in reasonable ways. The real issue is what to do with other problems that cannot be represented by lotteries with two or three outcomes? Like most problems we face. The important difference between DfD (decisions from description) and DfE (decisions from experience) is all but lost on economists, in fact we are unaware of any explicit acknowledgment of this distinction. However, note that inductive game-theoretic models are in some sense decisions from experience, i.e., the observed history of play in repeated games; however, admittedly, the game structure and payoffs are commonly not deduced from experience as they are often described. The economics discipline has become enamoured with models of DfD, in particular Prospect Theory. The speed and impact of Prospect Theory in behavioural finance has been surprising and has displaced the dominant existing paradigm (the Mean-Variance framework). However, finance is a large-world environment, where returns and volatility are not learned by description but rather from experience; the major Prospect theory assumption—an inverted S-shaped probability weighting function—would then be questionable. In fact, the underweighting of rare events found in DfE seems particularly relevant to miscalculation of the likelihood of Black Swan events. Engagement with behavioural finance is an important challenge for the ERP program.

Tenth, the fast and frugal heuristics literature, in its insistence on avoiding the calibration of heuristics to empirical data has glossed over the issue of behavioral heterogeneity.

Concluding discussion

We set out to sketch established facts and open questions about simple heuristics, whilst also pointing out some areas of similar thinking with the economics discipline that could serve as a bridge for future work. As it turns out there is an increasing number of authors that lay claim to the term “simple heuristics” which seems to originate with Gigerenzer, Todd, and the ABC Research Group (1999). While sketching the history and different premises of the two big programs in the heuristics space, the H&BP and the ERP, we have focused on the

latter and discussed its undoubtable accomplishments and prospects. Among its considerable accomplishments are the successful demonstration that, when cross-validation is used, the performance of simple heuristics such as the recognition heuristic or the "take-the-best" is better than that of complicated, computationally slow and greedy models such as multiple regression favoured by economists (e.g., Gigerenzer, Todd, & the ABC Research Group 1999, Todd, Gigerenzer & the ABC Research Group 2012; Brighton & Gigerenzer 2009; Gigerenzer & Gaissmaier 2013). The simple, and rather intuitive, reason is that multiple regression is prone to over-fitting to the noise in the data-generating process by only looking backwards. Another important implication is that the widely believed effort-accuracy trade-off is often not something to worry about. It has also been demonstrated persuasively that an important moderator of these findings is the way statistical information is presented. There remain many open questions and interesting research topics which we have tried to enumerate.

We have tried hard to draw attention to work in the ERP and economics that seems closely related, and highlight where common ground exists for the two disciplines to initiate a dialogue and collaborate despite their differences. The reader will notice that the majority of research that we have cited in economics is firmly grounded in inductive (learning from experience) rather than deductive models. We believe that much of the criticism of economics by ERP researchers has been directed at normative solutions involving deductive reasoning. This however is a straw man of sorts, and does not acknowledge the richness of contemporary economics. We further draw attention to the fact that many of the studies in economics that we have cited are published in mainstream, highly ranked journals such as the *American Economic Review*, *Quarterly Journal of Economics*, *Econometrica,* and *Games and Economic Behavior*. Therefore, we believe that sufficient interest exists for work that can be related to the ERP, and for the ERP to make significant headway into the economics discipline. This attempt will be most successful by connecting new research to prior work in economics and *simultaneously* pointing out the similarities and differences. Economists would also be well advised to seek out common ground with psychologists beyond the (now) orthodox Heuristics-and-Biases program.

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