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# Fast and frugal heuristics in sports

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**Abstract**

*Objectives:* This paper summarizes the fast-and-frugal-heuristics (FFH) approach to judgment and decision making, particularly as it applies to sports. The aim is to provide a framework through which current sports psychologists may apply this approach to better understand sports decision making.
*Methods:* FFH are studied using a variety of methods, including (1) computer simulations and mathematical analysis of heuristic performance as it depends on environmental structure (what we call the ecological rationality of heuristics); (2) empirical analysis of the heuristics, performance in naturally occurring environments; and (3) experimental research examining whether people actually use the identified heuristics.
*Results:* Simulations and analysis have shown that FFH can perform as well as complicated optimizing models while using less information and without integrating this information. Furthermore, in many cases FFH are more robust than optimizing models, outperforming these models when generalizing to new cases.
*Conclusion:* FFH depart from many models of human decision making in that they set a reasonable standard of rationality based on real-world constraints such as (a) limited time, information, and cognitive capacity, (b) decision tasks that may have no calculable optimal solution, and (c) the structured environments within which humans have learned and evolved. These simple heuristics are particularly

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appropriate in the sports domain, in which athletes often must make rapid decisions—that may ultimately make the difference between success and failure—with limited information and divided attention.


*Keywords:* Ecological rationality; Judgment and decision making; Recognition heuristic; Sport psychology and leisure; Take The Best; Take The First

## Introduction

How might a scientist build a robot that can catch baseballs as effectively as a professional outfielder?[1] To make the question simpler, imagine that the ball is already on its descent, that its trajectory is in line with the outfielder, and that the goal is simply to be sure that the robot is in the right location at the right time so that the ball collides with it. One way to try to solve this problem would be to program all the relevant information into the robot that would be necessary to calculate the trajectory of the ball and where it will land (as well as some program for getting to that location as quickly as possible), and have the robot power through the calculations. Such relevant information would include, among other things, the ball's distance, its angle, velocity, and acceleration of descent, the wind speed and direction, as well as the necessary formulas for using these variables to correctly calculate the trajectory. This will be called the optimizing approach to cognition in that it uses and integrates all relevant information to make the best possible prediction.

Of course, actual outfielders do not have the capacity to accurately assess any of these variables, much less all of them. Nor would most outfielders have the physics training or cognitive ability to combine these variables into usable answers, particularly in the fractions of a second outfielders take before beginning to run for the ball (McLeod & Dienes, 1996). Indeed, even the robot would need a team of scientists with sensitive equipment and some kind of transmitter to send it the appropriate measurements. Nonetheless, a similar approach to studying human behavior is not uncommon among a large subgroup of researchers who use such optimizing models to both predict and evaluate human decision making.

Another approach would be to try to determine what processes baseball outfielders actually can and do use to solve the task. As it turns out, human decision makers often use simple rules that neither require all available relevant information nor integrate the information that is used, but that nonetheless allow the decision makers to accomplish their aims quickly and effectively given the environments within which they are used. Such simple rules are called heuristics. In the case of the outfielder catching the ball, one possible heuristic has been called the gaze heuristic (Gigerenzer, 2004a).

The gaze heuristic involves three steps (or building blocks): (1) Fixating one's gaze on the ball, and (2) starting to run and adjusting one's speed so that, (3) the angle of gaze remains constant. The gaze heuristic does not require knowledge of any of the variables required by the optimizing approach, nor does it require the outfielder to integrate information, yet it allows the outfielder to

[1]This discussion is drawn from a chapter on fast and frugal heuristics (Gigerenzer, 2004a) in the *Handbook of Judgment and Decision Making* (Koehler & Harvey, 2004).

intercept the ball accurately. Although there is more involved in catching a fly ball than this, empirical evidence suggests that experienced ball catchers use something akin to the gaze heuristic (see McLeod & Dienes, 1996 for a detailed discussion). Not only does identifying such heuristics move us a long way towards being able to design machines that can behave like humans, it more importantly moves us towards understanding how actual people judge and choose. In the case of the gaze heuristic, we are able to predict not just *that* outfielders will catch the ball, but *how* they will catch it (e.g., while running rather than standing still), and the conditions under which such a heuristic will not work (e.g., when the ball is on it's way up) (Gigerenzer, 2004a; McLeod & Dienes, 1996).

The gaze heuristic is a good example of what Gigerenzer and Goldstein have called a ''fast and frugal heuristic'' (FFH) (Gigerenzer & Goldstein, 1996; Gigerenzer, Todd, & ABC Research Group, 1999). ''Frugal'' refers to the fact that these heuristics use less information, or require fewer cognitive steps, than would an optimizing process. ''Fast'' refers to the speed with which decisions can be made, in part as a result of these heuristics' frugality and in part because FFH tend not to require complicated cognitive processing, such as weighting and integrating multiple cues. The purpose of this paper is to describe the FFH approach to the study of judgment and decision making, and to discuss ways in which this approach has been and can be applied in the sports domain. The main body of work on FFH comes out of the Center for Adaptive Behavior and Cognition at the Max Planck Institute for Human Development, Berlin, and has been detailed in their book, *Simple Heuristics That Make Us Smart* (Gigerenzer et al., 1999).

The paper will be divided into three sections. The next section outlines key theoretical and methodological aspects of FFH. The penultimate section reviews some concrete examples of FFH with particular reference to research within the sports domain. Application of the FFH approach to the study of sports decision making is in its infancy and has primarily involved forecasting tasks (i.e., predicting which team or player will win in a competition). At the same time the FFH approach is well suited for understanding decisions made at the ground level, that is, decisions made by coaches, athletes, and referees that have direct bearing on the outcome of a competition. Given the paucity of research, the last section provides an exploratory consideration of potential areas for application of the FFH approach to these ground-level decisions.

## The fast-and-frugal-heuristics (FFH) approach

### *Theoretical underpinnings*

#### *Bounded rationality*

As with much research in the study of judgment and decision making, the FFH approach draws significantly on work by the late Nobel laureate Herbert A. Simon and his concept of *bounded rationality*. Simon criticized expected utility theory and other optimizing normative models of rational choice (see, for example, Becker, 1978; Savage, 1954; von Neumann & Morgenstern, 1947) on the grounds that people generally do not have the time, available information, or cognitive ability to optimize (Simon, 1955, 1957). Indeed, judgment and decision tasks are often sufficiently complex that they would be intractable even if time and cognitive capacity were limitless (Gigerenzer, 2004a; Todd & Gigerenzer, 2003). Simon proposed the notion of bounded rationality as an alternative to optimizing normative models, suggesting that the quality of people's choices should be evaluated in a less black-and-white manner according to how reasonable the choices are given realistic constraints of the situation (Simon, 1955, 1957). He proposed simple rules of thumb (i.e., heuristics) as a normative alternative to optimizing models of rationality—in his case, *satisficing*, a heuristic that, simply put, involves choosing the first option that meets one's minimum criteria. The gaze heuristic demonstrates the idea of bounded rationality well: even though outfielders have no means by which to judge and integrate the ball's distance, acceleration, etc., by using a simple heuristic they can still get where they need to be.

*Ecological rationality*

Ecological rationality is a particular vision of bounded rationality. Simon wrote, "Human rational behavior… is shaped by a scissors whose two blades are the structure of task environments and the computational capabilities of the actor" (1990, p. 7). In the words of Gerd Gigerenzer (2004b, p. 336), "The basic tenet of ecological rationality is that the rationality or irrationality of a judgment can only be decided by an analysis of the structure of the environment or the experimental task". More specifically, the study of ecological rationality concerns the fit between a particular heuristic and the environment within which it is applied (Gigerenzer et al., 1999; Goldstein & Gigerenzer, 2002). While a major component of this is analytical and normative, modeling different potential heuristics in environments with different informational structures to evaluate how well they perform relative to other models (Gigerenzer & Goldstein, 1996; Goldstein & Gigerenzer, 2002), ecological rationality also has a strong descriptive and empirical component. This involves the study of which heuristics people actually use (Bröder, 2000), how this changes across different environments (Rieskamp & Otto, 2006), how the environments are structured that people are most likely to encounter given their particular decision task, and how well the heuristics people use work given the environments within which they are used (for examples see Gigerenzer et al., 1999). The ecological rationality of the gaze heuristic depends, for example, on whether or not the ball is on its descent. If the gaze heuristic were used when the ball were just leaving the bat, the receiver would lose time by running too far away from the ball's eventual landing point before moving back towards it (McLeod & Dienes, 1996).

*Adaptive thinking*

The FFH approach begins with the assumption that the processes people use to make decisions are matched to the environments within which they make these decisions (Boyd & Richerson, 2001; Gigerenzer, 2000; Payne, Bettman, & Johnson, 1993; Simon, 1990; Todd, 2001). This approach suggests certain hypotheses about the relationship between the heuristics people use and the environments within which they are used. One hypothesis, for example, is that if some fast and frugal heuristic performs well in a particular environment, people will tend to use that heuristic within that environment. Another hypothesis is that if a heuristic is in wide use, environments that favor that heuristic will tend to be similarly widespread. While the assumption that the heuristics that people use are adaptive may not always be correct, particularly within the context of novel or artificial environments, it serves as a useful starting point for hypothesizing heuristics that people will (or will not) use given particular environmental structures. It also provides a fundamental theoretical framework through which ecological rationality, as opposed to optimizing rationality, can be understood: heuristics have been adapted to the environments within which people find themselves, allowing people to make decisions quickly and effectively, even while there may be significant constraints on available information and cognitive capacity.

*Connections to other behavioral decision research*

The FFH approach has been influenced by, and shares connections with, a great deal of other research on the psychology of judgment and decision making. The strong concern with adaptation highlights its commitment to understanding human behavior within its (biological and cultural) evolutionary context, and echoes arguments made by Thorngate (1980) and Hogarth (1981). These authors have emphasized the idea that it is important to analyze heuristics with relation to the task environments within which they are used, and that, with this in mind, heuristics may provide adaptive solutions to difficult problems. Similarly, Payne et al. (1993), showed that people select the heuristics they use in a given environment in ways that balance the accuracy and the costs involved with the application of the heuristics.

Related to this, commitment to the idea that psychological processes depend irreducibly on the structure of the environment descends from the work of Egon Brunswik and his extension into decision science by Kenneth Hammond (for a nice review, see Goldstein, 2004), as does the emphasis on *naturally occurring* environments (i.e., those that occur outside the laboratory). In this same vein, the FFH approach has strong affinity with work by Gary Klein and his colleagues (Klein, 1998; Klein, Wolf, Militello, & Zsambok, 1995), whose program of research into what they term "Naturalistic Decision Making" consistently focuses on experienced decision-makers as they operate within their environments of expertise.

Emphasis on the idea that simple rules can and often will outperform more complicated ones extends from work by Dawes (1979)—who may have provided the first demonstration that a simple heuristic can outperform optimizing models (in this case multiple regression) when generalizing from one sample of data to another. Two other early models that are similar to FFH are Simon's previously mentioned "satisficing," and Tversky's (1972) "Elimination by Aspects". Elimination by Aspects applies when people must choose among options with several attributes, such as to whom to pass the ball in basketball, in which case how open the player is and the player's shooting percentage, distance from the basket, and number of fouls, are but a few among many potential attributes that might be relevant to making a good decision. An optimizing model of rational choice might have the passer weight each attribute according to its importance to pass success (whatever the standard of success might be), and sum across all attributes for each potential pass recipient, so that each recipient could be compared across all attributes. Tversky hypothesized and presented evidence that decision makers often compare one attribute at a time, eliminating options (potential pass recipients) who fail to meet some particular standard on the most important attribute before moving on to consider the next attribute among the now reduced set of options.

*Characteristics of FFH*

In the following we describe four of the central characteristics of FFH: (1) they exploit evolved capacities, (2) they exploit structures of the environment, (3) they comprise a set of process rules, and (4) they are simple. For sports psychologists wishing to develop a model of a fast and frugal heuristic, these characteristics can be used as a guideline for doing so.

*FFH exploit evolved capacities*

One of the key features of FFH is that they depend on evolved capacities. The gaze heuristic depends on the evolved capacity to fixate one's gaze on an object. The recognition heuristic (Goldstein & Gigerenzer, 2002), to be discussed later, depends on the specialized capacity for recognition memory, which allows people to discriminate between novel and previously encountered objects. Exploiting evolved capacities allows FFH to work quickly and efficiently, while at the same time remaining relatively simple.

Although these capacities will often be biologically evolved, they need not be; they may also be products of cultural evolution (Boyd & Richerson, 2001; Henrich et al., 2001) or individual learning (Rieskamp & Otto, 2006). With respect to cultural evolution, FFH that depend on such cultural artifacts as Google™ could be used today though they would have been impossible just a decade ago. Similarly, FFH that depend on accurate maps and a compass could be used in orienteering, though they would have been impossible prior to the development of accurate topographical maps and the invention of the compass. With respect to individual learning, quick pattern recognition that depends on expertise within the domain may be necessary for the use of such heuristics as Take the First (TTF) (Johnson & Raab, 2003) or Take the Best (TTB) (Gigerenzer & Goldstein, 1996), both of which will be discussed later.

*FFH exploit structures of the environment*

As mentioned previously, FFH exploit the structure of the environment. FFH, by themselves, are neither adaptive nor maladaptive, effective nor ineffective, rational nor irrational. Instead, their performance depends on the structure of the environment. Models of heuristics strive to specify the structures of the environment within which heuristics either perform well or perform badly. A complete description of how a heuristic can be expected to perform in the range of possible environments is no minor task, however. Indeed, there may be no limit to the range of environments to which a heuristic might be applied and its performance affected, and so this will be an ongoing process.

*FFH are composed of a set of process rules*

Subjective expected utility theory (Savage, 1954) is an "as-if" model of rational choice. It does not make any claims as to the processes people are going through when they make decisions. Rather, it suggests people should make decisions "as if" they were going through a certain set of processes. That is, the choices they make should be the same choices *as if* they were considering the different available options and the possible outcomes given each option, assigning a subjectively determined probability and a utility to each possible outcome, and choosing in such a way as to maximize their subjective expected utility. If an investor buys whatever stock Warren Buffet buys, and this leads to the same outcome *as if* the investor were doing the calculations herself, she is still maximizing subjective expected utility (assuming that's what Buffet is doing).

The FFH approach, however, *is* concerned with psychological processes, and models of heuristics aim to be models of the processes involved in actual human decision making (for a critique of heuristics that fail to specify detailed process models see, Gigerenzer, 1996, 1998;

Gigerenzer & Regier, 1996; Hogarth, 1981). FFH spell out the set of simple rules (or ‘‘building blocks’’) that comprise a heuristic in a clear enough fashion that they can be represented and modeled as a computer algorithm. The building blocks of heuristics tend to include (1) search rules (what information or cues are considered and in what order), (2) stopping rules (when will additional information stop being considered), and (3) decision rules (how is the choice made based on the acquired information).

Whether or not search, stopping, and decision rules are necessary, however, depends on the nature of the task. The gaze heuristic does not involve a choice among options and so there is no place for a decision rule, and the object of concern is so narrowly circumscribed (the ball which always departs from an opponent's bat) that a search rule hardly needs to be specified. Deciding who to pass the ball to in basketball, however, does require a choice among options, and in this case search and decision rules would be necessary. The point is that the judgment or decision process should be sufficiently well defined that it can be computationally modeled.

Such precise process models allow researchers to determine how a heuristic performs given a defined environment. Just as importantly, such models give clear predictions about how decision makers can be expected to behave, useful for testing hypotheses regarding whether a particular heuristic is being used, for predicting behavior once the use of a particular heuristic has been established, and for giving prescriptive advice as to whether or not a heuristic will lead to beneficial results given a particular environment.

### *FFH are simple*

One of the underlying assumptions of the FFH approach is that, since heuristics have been adapted to conditions under which they must be applied rapidly and with limited information, and since they can take advantage of evolved capacities and regularities in the environment, they will be relatively simple. One key contribution to this simplicity is that FFH tend not to integrate cues, for example by weighting or adding them; instead, they consider them one at a time (or even consider just one cue, as in the recognition heuristic). In many cases this leads to decisions based on just one reason (e.g., ‘‘Do I recognize one option and not the other?’’ or ‘‘Does the cue being considered discriminate between the possible options?’’ Gigerenzer et al., in press).

## Existing research on FFH in sports

This section will review some existing research on FFH that have been identified and applied to the sports domain. These include (A) Take The First (TTF), a heuristic that can be used by players to generate and choose from among practical options, (B) the recognition heuristic, which relies on partial ignorance to make powerful inferences, and (C) Take The Best (TTB), which allows for inferences about known options using very few cues. The latter two of these three heuristics have been primarily tested with sports forecasting (i.e., predicting which teams or athletes will win) rather than with decisions by athletes or coaches. This should not, however, be taken as a sign that the FFH approach does not apply to athlete or coach decisions. Rather, the application of the FFH approach to sports is simply in its early stages. We will discuss some possible ways to use this approach to model athlete and coach decisions in the final section.

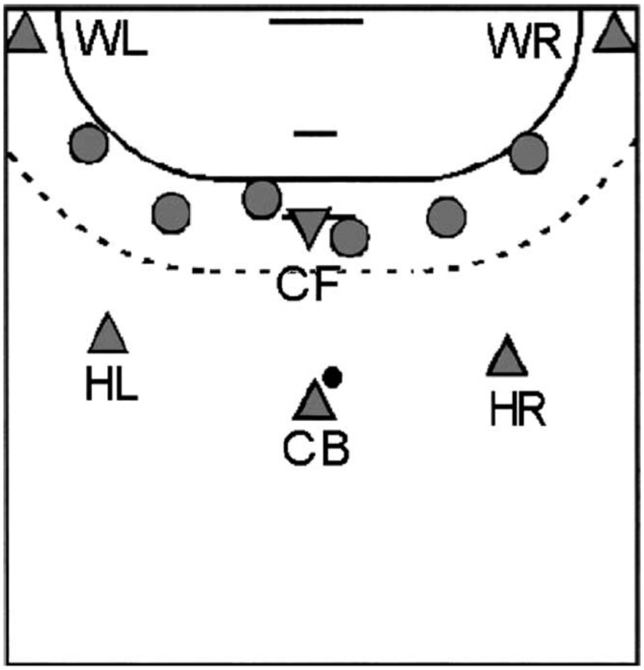


Fig. 1. "Typical position of the offensive players in the handball scene, at the point where it was 'frozen' to begin each trial. Triangles represent offensive (attack) players, circles represent defensive players. CB, center back; WR, wing player on the right; WL, wing player on the left; HL, half-back player on the left; HR, half-back player on the right; CF, center-front (pivot) player at the 6-m line; long solid line, goal; short solid line, 6-m line (defense zone); dotted line, 9-meter line." From Johnson and Raab (2003, p. 221).

*Take the First (TTF)*

Johnson and Raab (2003) applied the FFH framework to study how athletes generate different options and subsequently choose among them. Consider the constellation of players in a handball match depicted in Fig. 1. What options does *Player CB* have?[2] He could attempt a shot on the goal. Alternatively, he might prefer to pass the ball to one of his teammates, WL, HL, CF, HR or WR. But to whom and how? What are the processes (or strategies) underlying the generation of possible options?

According to their *Take-The-First* (TTF) heuristic, "rather than exhaustively generating all possible options and subsequently processing them deliberately" (Johnson & Raab, 2003, p. 218), one simply picks one of the initial options generated. In other words, the heuristic relies on the quality of options that spring to mind spontaneously (for more extensive evidence of this claim, see Klein, 1998; Klein et al., 1995). Johnson and Raab assume that the generation of options is governed by strategies that determine the overall "flavor" of the required solution; for instance, whether the spatial result of ball movement (pass to the left vs. right) or the functional result (shoot vs. pass) is the dominating goal. Further options are then generated sequentially according to their similarity to the initially generated option.

[2]Player CB is depicted by the triangle with a small circle, representing the ball, next to it.

Why should options generated early on be more useful than those generated later? Taking an associative network perspective, Johnson and Raab argue that "better" options are more likely to be activated first due to their stronger connections in the network. This, however, requires that the player has experience with the task and the possible options. In other words, once a player has some familiarity with the task, he can rely on the quality of spontaneously generated options and "take the first".

TTF resembles other fast and frugal heuristics, such as Take The Best (to be discussed later), in that it takes into account the sequential nature of the option generation process and in its use of search and stopping rules. It also "bets" on a particular pattern in the task environment, that is, that there is a correlation between the position of the option in the generation process and the quality of the generated options. Finally, TTF undertakes no attempt to optimize since the strategy governing the option generation process takes into account only a small set of the characteristics that determine suitable options, and it takes the first generated option. Finally, TTF relies on evolved characteristics which allow it to accomplish a computationally difficult task. In this case, the evolved characteristic is the associative neural network combined with extensive learning in the domain, allowing for immediate recognition of similarities between previously experienced situations and the current one.

Investigating handball players in an empirical study, Johnson and Raab indeed found support for some of the assumptions underlying TTF. They presented the players with situations of a handball match on a video screen, froze the picture at a particular point and asked the players which option first came to mind for that specific situation. Next, participants generated further options and finally picked from the generated options (including the first) the one they considered best overall. The quality of the generated options was subsequently rated by experts.

Supporting the assumption that options most likely to be activated are successful ones, the number of options judged by the experts as "appropriate" decreased markedly the lower the serial position in which the option was generated. Did participants also "take the first"? They chose the first option generated in around 60% of the cases, in line with TTF. Still, if they had not generated any further options after their first, their choices would have been even better than the options they finally picked. Less (information considered) would have been more.

## *Recognition*

Less is not only more among athletes. The FFH program demonstrates how people attempting to forecast the outcome of sports events can benefit from limited knowledge as well. In general, the *recognition heuristic* (Gigerenzer et al., 1999; Goldstein & Gigerenzer, 2002) is a strategy to predict which of two objects has a higher value on some criterion (e.g., which of two teams or athletes will win a competition). The heuristic applies when one out of two opponents (players, teams) is recognized and, irrespective of any further knowledge, the recognized actor is predicted to win.

Note that in order to apply the recognition heuristic, partial ignorance is required. When both actors are recognized the recognition heuristic is not applicable. Note also that as with TTF, the recognition heuristic relies on a particular pattern in the information available: it "bets" that successful sports actors are also more frequently mentioned in the media, and thus are more likely to be recognized (an association found by Pachur & Biele, in press). This reliance on the structure of the environment makes the heuristic a prime example of *ecological rationality*.

Goldstein and Gigerenzer (2002) demonstrated that the recognition heuristic can lead to a counterintuitive *less-is-more effect* that concerns the relationship between the number of objects recognized (from among a set of objects)—e.g., the number of teams or athletes—and the overall accuracy achieved when all objects are compared. This can happen when the recognition validity is higher than the validity of further knowledge about the items. In less technical language, it can happen when the fact of (a) *one object being recognized and a second object not*, (i.e., when *less* is known) tells a decision maker more about a desired prediction (e.g., which athlete will win in a competition) than (b) *differences in knowledge about two objects when they are both recognized* (i.e., when *more* is known). That is, full knowledge can be associated with fewer successful predictions than when fewer objects are recognized.

Note that the ecological rationality of the recognition heuristic depends on two characteristics of the environment. First, it requires that lack of recognition of one object (when the other object is recognized) is a better cue for predicting outcome success than simply guessing. Second, it depends on how many objects are recognized. If too many or too few objects are recognized, the heuristic cannot be used as often. The recognition heuristic can be used most often when half of the possible objects to be compared (e.g., half of the teams in a sports league) are recognized.

Various studies have examined the recognition heuristic in the context of sports. Three aspects have been of primary interest. Can the recognition heuristic predict people's forecasts? How well does recognition predict outcomes in sports compared to other predictors? And, finally, is there evidence for the less-is-more effect?

Concerning its descriptive accuracy (i.e., whether or not it predicts people's forecasts), the recognition heuristic appears to work well (Ayton & Önkal, 2004; Pachur & Biele, in press; Serwe & Frings, in press). For instance, Serwe and Frings (in press) asked tennis amateurs to make forecasts of matches at the 2003 Wimbledon tennis tournament and used the recognition heuristic to model the forecasts. It was found that more than 90% of the time when a recognized player played against an unrecognized player, the recognized player was predicted to win (similar results were found for soccer matches by Ayton & Önkal, 2004, and Pachur & Biele, in press, and for NHL players by Snook & Cullen, 2006).

But can recognition help to make correct forecasts? In other words, is the reliance on recognition an ecologically rational strategy in the sports domain? Recognition was a highly valid cue in a study by Snook and Cullen (2006): When a recognized NHL player was judged to have achieved more career points than an unrecognized one, this inference was correct more than 86% of the time. Serwe and Frings (in press) examined how well recognition was able to predict the actual winner of tennis matches at Wimbledon. To evaluate the performance of recognition, they compared it to predictions based on two types of ATP rankings, which both rely on the integration of detailed information concerning the players' past performance. The rankings were able to correctly predict the winner 68–69% of the time. Recognition, surprisingly, outperformed both, leading to 73% correct predictions, demonstrating the ecological rationality of the recognition heuristic. However, although recognition might often be helpful in forecasting sporting events, Pachur and Biele (in press) pointed out the limits of the usefulness of recognition. In their study on the EURO 2004, recognition was not able to reach the predictive accuracy of "expert" indicators such as rankings, previous performance, or betting odds, although it was still considerably better than chance.

Finally, what of the "less is more" effect? When Ayton and Önkal (2004) studied forecasts of FA cup matches by both British and Turkish participants, it was observed that in spite of their greater knowledge about English soccer teams, the British participants were not able to outperform their Turkish counterparts. A similar result was reported by Snook and Cullen (2006) in their study where participants had to judge which of two NHL players had achieved more career points. Comparing participants with different levels of knowledge (in terms of the number of teams that were recognized), they found that judgmental accuracy increased as the number of recognized players increased until about half of the players were recognized. Beyond this point accuracy leveled off, akin to the less is more effect. Pachur and Biele (in press), however, did not find this patter in their study on lay forecasts of soccer matches at the EURO 2004. This result was surprising as the average recognition validity was higher than the validity of knowledge beyond recognition, and thus the conditions for a less-is-more effect specified by Goldstein and Gigerenzer were fulfilled (see Pachur & Biele for a discussion of why the less-is-more effect might sometimes be hard to find).

## *Take the Best (TTB)*

Often both objects that a decision maker wants to make an inference about are recognized, particularly if the decision maker is experienced within the domain. For example, a sports forecaster might recognize both teams in a competition whose outcome she wishes to predict. In that case, recognition cannot serve as an inferential cue and other available cues must be used to make an inference. The "Take-The-Best" (TTB) heuristic (Gigerenzer & Goldstein, 1996; Gigerenzer et al., 1999) searches cues in order of their validity (essentially the order of their correlation with the outcome to be predicted), beginning with the cue with the highest validity. If this cue discriminates between the two objects being compared (e.g., between two athletes or two teams), the information search is ended and TTB decides in favor of the object with the higher value on this cue, without considering further cues. If the cue does not discriminate between the objects (i.e., if two objects both have the same value for that cue), TTB moves on to the next most valid cue, continuing down the line of cues in order of validity until it comes upon a cue that discriminates between the two objects.

Just as environmental structure is critical to how well the recognition heuristic performs, it is also critical to the performance of TTB. For example, the performance of TTB concerns whether or not the environment is *non-compensatory*. A non-compensatory environment is one in which the weight for each cue based on linear regression is greater than the sum of all subsequent cues, assuming the cues are ordered by weight. Within such environments, TTB matches the performance of optimizing models (in this case, multiple regression; Martignon & Hoffrage, 2002).

An important and counter-intuitive finding that was demonstrated for TTB is that—although it does not integrate information and makes a decision based on only one cue—it can outperform optimizing models. Optimizing models often have many free parameters that allow them to fit a given data set very well. This fitting power, however, makes them prone to *overfit*; that is, they are calibrated to noise in the sample. As a consequence, when generalizing to new data, they loose much of their predictive power. TTB, by contrast, does not overfit (since it is not fit to the data at all) and can thus outperform optimizing models (see Table 1) (Gigerenzer et al., 1999).

Table 1
Performance of TTB vs. multiple regression (derived from Todd & Gigerenzer, 2000).

| Strategy | Frugality | Accuracy (% correct) Fitting | Accuracy (% correct) Generalization |
|---|---|---|---|
| Take The Best | 2.4 | 75 | 71 |
| Multiple regression | 7.7 | 77 | 68 |

Performance of TTB vs. multiple regression across 20 data sets. "Frugality" indicates the mean number of cues used by each strategy. "Fitting accuracy" indicates the percentage of correct answers when fitting data (test set = training set). "Generalization accuracy" indicates the percentage of correct answers achieved when generalizing to new data (using cross-validation; test set $\neq$ training set).

Determining just which environments favor TTB (or other heuristics), and to what degree, depends on careful mathematical analysis and computer simulation (for an example of an analysis of TTB with respect to its ecological rationality, see Hogarth & Karelaia, 2005, in press; Martignon & Hoffrage, 2002).

Mathematical and computer analysis of the performance of TTB with respect to environmental structure is one aspect of ecological rationality. Whether or not people use TTB and how well it performs in existing decision-making environments is another. For example, do sports forecasters use TTB? And how well does TTB perform in sports forecasting environments?

These questions have rarely been examined in the sports domain. Todorov (2001) predicted the results of 1187 games in one season of the NBA with the help of two different models of TTB and one model based on Bayes' Theorem. Bayes' Theorem is an example of an optimizing model of rational choice that begins with some initial estimation of outcome probability (in cases of complete ignorance, this would be equal to chance), and updates those probabilities based on subsequent outcome values and frequencies. In Todorov's study TTB performed as well as Bayes' Theorem (for similar results see Gröschner & Raab, in press). In a second study, this time examining whether or not people actually use TTB when predicting sports outcomes, Todorov found that participants ordered cues based on their validity, just as TTB would predict. Moreover, TTB described their forecasting behavior very well.

## Identifying and modeling new FFH in the sports domain

Application of the FFH approach to the study of sports is relatively new and there is a great deal of progress still to be made. While the three heuristics discussed above have all been applied to the sports domain, two of the three (the recognition heuristic and TTB) refer specifically to forecasting. Only Johnson and Raab's (2003) TTF influences the outcome of sports competitions (forecasting heuristics *predict* outcomes but do not *influence* them). This might be surprising, since the FFH approach is well suited to better understanding athlete, coach, and referee strategies, since these strategies depend on limited information, must be applied quickly (for athletes often in fractions of a second), and must be effective relative to other possible strategies.

The current section will describe other research where the FFH approach could be applied, and will briefly sketch some ideas for identifying other FFH in the sports domain. Finally it will suggest some features of the sporting environment that should be taken into account with respect to modeling heuristics. It should be stressed, however, that these suggestions are necessarily preliminary, reflecting the paucity of existing research in the area.

*Could "belief in the hot-hand" contribute to an effective heuristic?*

Gilovich, Vallone, and Tversky (1985), and Tversky and Gilovich (1989a) found that while many people (including players and coaches) believe that basketball players become temporarily hot or cold in their shooting in a way that can be used to predict their performance in the immediate future, there was no empirical evidence for it (in fact there was a slight negative correlation between recent past and immediate future shooting percentages). Because of concerns with both how it ought to be measured (Bar-Eli, Avugos, & Raab, in press; Crust & Nesti, 2006; Frame, Hughson, & Leach, 2006) and whether it might be domain specific (Ayton & Fischer, 2004; Bar-Eli et al., in press; Dorsey-Palmateer & Smith, 2004; Frame et al., 2006; Smith, 2003), the question of whether or not a hot hand exists in sports is controversial (Gula & Raab, 2004; Koehler & Conley, 2003; Larkey, Smith, & Kadane, 1989; Tversky & Gilovich, 1989a, b). Remaining agnostic on this question, however, how might a researcher using the FFH approach explore belief in the hot hand?

Four ways to approach this question would include (1) asking whether belief in the hot hand might itself be an adaptive fast and frugal heuristic that players use to decide to whom to pass the ball, (2) trying to specify a model of the heuristic that describes how basketball players, coaches, and fans use the heuristic to infer to whom to pass the ball, (3) examining the ecological rationality of such a heuristic; that is, examining how the heuristic performs both in actual basketball games and in the range of environments to which the heuristic might be applied, and (4) trying to specify what evolved capacities a hot-hand heuristic might exploit.

Research by Bruce Burns (2004) goes some way toward addressing the first three points. By specifying the exact nature of a possible hot-hand heuristic in algorithmic form and modeling its performance given players with different shooting percentages, he finds that belief in the hot hand can indeed be adaptive, since streaks occur more often and over longer duration among players with higher overall shooting percentages. In essence, while it may be true that players do not get hot in a way that can be used to predict future performance *beyond the player's base rate of success* (i.e., beyond the player's long—term shooting percentage), if one does not know which players have better or worse shooting percentages, the hot hand heuristic is useful for making the right inference.

Of course, professional players and coaches, as well as their fans, tend to know which players have better and worse shooting percentages, and so it is questionable whether a hot-hand heuristic would improve upon this knowledge. In any event, without base-rate knowledge, such a heuristic would be adaptive, and it may be the case that belief in the hot hand compensates for a tendency not to give sufficient weight to player's shooting percentages when making passing decisions. Indeed, in pickup games, if players do not know the base-rate shooting percentage of their team members, hot hand information may provide the best available cue as to where to pass the ball.

How exactly a hot-hand heuristic could plausibly be implemented needs further specification (e.g., how many successes in a row constitute a hot hand, and how do players keep track of streakiness for each of their teammates?), as do the environmental structures under which a hot hand under-performs or outperforms base-rate knowledge. There may be sports, for example, in which players are more likely to have teammates or face opponents who are still on a strong learning curve, in which case a hot hand heuristic would potentially be more effective than long-term base-rate information (indeed, this might be the case in college basketball, where most NBA players developed their skills and may have developed a commitment to belief in the hot hand). Similarly, there may be games in which psychological confidence has greater impact on player performance (perhaps poker, for example, which does not depend on physical learning), in which case hot hand information might again be a more useful cue than knowledge of base-rate success. In general, in games for which past shooting success is correlated to future success likelihood, using hot hand information will be better than choosing randomly.

A final step in modeling a hot-hand heuristic would be to try to specify the adaptive capacities on which the heuristic depends. With respect to the use of a hot-hand heuristic, there is evidence that certain regions of the brain are particularly sensitive to patterns in sequences of events, even if these patterns occur randomly (Huettel, Mack, & McCarthy, 2002; Skinner, 1947). Without this sensitivity to patterns, it is reasonable to assume that basketball players might not be so sensitive to the streaky shooting of other players, belief in the hot hand might not occur, and a hot-hand heuristic could not be applied so readily or effectively.

## *Fast and frugal navigation and orienteering heuristics*

Another area where a FFH approach might readily be applied concerns races involving navigation or orienteering. Research by Eccles, Walsh, and Ingledew (Eccles, Walsh, & Ingledew, 2002a, b) suggests that orienteers use heuristics to make their way, and that more experienced orienteers use different (and more effective) heuristics than their less experienced counterparts. A fast and frugal approach would seek to further specify orienteering heuristics so that the ecological rationality of various heuristics could be modeled and empirically tested. Orienteering is an ideal domain for applying the FFH approach because it involves limited environmental information which must be used as cues to make inferential judgments (i.e., where to go next). Most research using the FFH approach involves similar inferential heuristics that depend on cue order and validity.

An example outside the sports domain yet closely related and thus with likely application, concerns expert navigation among certain Micronesian islanders (for a detailed review, see Hutchins, 1983). These navigators are able to get from one island to another without modern navigational tools across long expanses of water during which no land is visible, a skill that is beyond that of trained Western navigators who depend on contemporary technological innovations. To do so, the navigators use simple heuristics, some of which rely on false beliefs as with belief in the hot hand. In this case, they imagine that neighboring islands rather than their own canoe is moving, which helps them to overcome certain difficulties in reasoning that would occur if they imagined their canoe to be moving rather than the islands (Hutchins & Hinton, 1984).

The heuristics also depend on (culturally) evolved capacities. In addition to specialized knowledge about what heuristics to use that is known only among the expert navigators who pass this information on to subsequent generations of specialists, there is a recorded "star compass". This compass depends on knowledge of a set of "star paths". Each star path describes a set of stars that travel in the same line from one point in the horizon to another across the course of the night. Navigators of the Caroline Islands use knowledge of fourteen unique star paths to make the star compass, which is a circular map representing the 360° range of directions visible across the horizon, and which relates the relative position of each star path to the others, thus allowing the islanders to figure their general location. This culturally evolved tool is necessary for the navigators to be able to use their navigation heuristics effectively.

A fruitful way to apply the FFH approach to sports, therefore, might be to consider the heuristics that skilled competitive navigators use when racing from one point to another point. As with orienteering, one aspect of this analysis should concern modeling the various environments in which a heuristic might be used so as to be able to determine the heuristics' ecological rationality. A first step, however, is simply to study skilled navigators (or orienteers) to begin to determine the heuristics they use (as did Eccles et al., 2002a, b).

*Suggestions for where to look for other FFH*

There are few limits to the variety of heuristics that may be employed by sports participants depending on the decision-maker's goals and the structure of the environment. Research on refereeing has suggested certain heuristics (Nevill, Balmerb, & Williams, 2002), yet no attempt to our knowledge has been made to specify when these heuristics will and will not be implemented or their ecological rationality. For example, it has been found that cheering leads referees to favor the home team (Nevill et al., 2002). A fast-and-frugal heuristics approach would immediately suggest modeling the heuristic and examining its ecological rationality.

For example, might crowd noise also provide an ecologically valid cue for determining whether or not a foul has been committed in cases where the referees do not have an ideal perspective? Some fans in a sporting arena will often be able to see the action from a more-telling perspective than can a referee, and fan outrage (as expressed by the noise level) may correlate with knowledge of a bad call. Thus, fan noise might provide useful information to help referees decide whether or not a foul has been committed or even for over-ruling fouls. This is not meant to deny an advantage for the home team, since the protest and support from home fans will still be systematically louder than from visiting fans, but the heuristic might, nonetheless, lead to more fair calls overall by taking advantage of the systematic difference in fan noise between fair and unfair calls. In actual games referees might further improve their judgment by distinguishing between home team noise and away noise (such as by whether the noise is in response to a call against the home team or against the away team), and by factoring in their own perception of the ambiguity of the call. Of course, referees might be better off if they could ignore fans completely, but the FFH approach would seek to describe the processes through which this happens so as to be able to predict both when and how much fan noise will hurt—or perhaps help—referees' judgments.

Another example: What heuristics might lead to the apparent "reputation bias" among figure-skating judges (Findlay & Ste-Marie, 2004), and how might the ecological rationality of these heuristics depend on the nature of the competitive-figure-skating environment? If judgment of quality during an individual competition is highly prone to error, then using reputation might help to counterbalance the inherent error in judges' assessments. While a heuristic that used skater reputation might increase the number of false positives with regard to known skaters (i.e., might increase the frequency with which known skaters were judged victorious when they did not deserve it), a reputation-based heuristic might more than compensate for this by the degree it reduced false negatives (i.e., cases when these known skaters deserved to win but did not). Whether this were true or not, however, would depend on both the degree to which reputation predicted competition performance and the degree to which judges could accurately assess skater performance within a given competition, questions that remain to be considered.

Lest these examples create an artificially narrow range towards which sports psychologists' imagine applying the FFH approach, it is worth pointing out that the approach is quite general. How does and how should a football (soccer) player decide where to kick the ball when making a corner kick, when to shoot for a goal, or to whom to pass the ball? How do basketball coaches decide whether and which players to substitute for one another, when it is best to foul members of the opposing team, or whether to try for a three-point basket? How does a snooker player decide between playing offensively or defensively, a tennis player decide when to go to the net, or a Nascar racer decide whether to try to pass another driver. In all of these cases, how does the choice and performance of a heuristic depend on the structure of the environment? The FFH approach provides powerful tools for addressing these questions.

### *Identifying common structures of sporting environments*

One area for future research concerns identifying the structural characteristics of sports environments, allowing for an analysis of known and yet to be discovered heuristics from the perspective of ecological rationality. This can be accomplished within the sports domain both by considering how sports decision making tends to differ from other decisions and by considering ways in which environments tend to differ from one another across sports.

One characteristic of sporting environments that is shared across a wide range of sports is the requirement for fast decisions that draw upon considerable experience within the domain. This makes heuristics like TTF and TTB particularly useful, since they depend on the integration of previously acquired information about the domain, while allowing for quick application of this acquired knowledge to new judgments.

The relatively well circumscribed rules within which heuristics can be applied provide another common characteristic of sports environments. This should facilitate the identification of heuristics in the sports domain, as it greatly reduces the range of possible heuristics that might be used as well as the range of environments that one might confront. Finally, unlike the building and breaking down of alliances that commonly occur outside the sports domain, alliances in sports tend to be stable and dependable, at least within a game or tournament. This excludes the need to consider many game-theoretical relevant heuristics, such as tit-for-tat.

Environmental differences across sporting domains may also be worth considering. Team sports (which will involve many heuristics that regard when and how to cooperate with teammates) will differ broadly from one-on-one competitions (in which athlete heuristics will systematically concern how to mislead or outdo one's opponent), which in turn will differ broadly from individual sports (in which one is competing against one's own best time or score, and heuristics concerning mental toughness, consistency, and form may take priority). Some sports depend on more strategic heuristics (e.g., snooker) and others more on physical, implicit learning (e.g., pole vault), and again this will influence the kinds of heuristics that are most appropriate.

These differences are important to single out as they have bearing on the heuristics that are more or less likely to work

Finally, environments vary widely depending on the perspective of the decision-maker (e.g., coach, athlete, referee, judge, or forecaster). Athletes have to make decisions within fractions of a second, with limited and low-quality information, with well-defined individual roles, and using learned physical skills; coaches' decisions concern the functioning of the team as a whole, are based on more analytical than physical knowledge, and include time to confer with assistant coaches who may have access to a team of analysts and historical records with integrated statistical data; and referees, decisions (at least ideally) aim toward fair and correct. Each domain will likely have its own set of heuristics relevant to the tasks common to it.

## Conclusion

Rather than beginning with an omniscient and omnipotent model of human rationality, the study of FFH grounds decision processes in empirical reality, and sets a normative standard based on feasible processes given this reality. The FFH approach may be particularly relevant to the study of decision making in the sports domain, where speed is of the essence, the decision makers (e.g., athletes) have limited access to information but can rely on highly automatized processes, and multiple tasks and goals limit cognitive capacity and attention. We hope this summary of the FFH approach has provided food for thought and inspired new research ideas that will fruitfully be applied to the sports domain.

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