Center for Adaptive Behavior and Cognition

The Center for Adaptive Behavior and Cognition

The **Center for Adaptive Behavior and Cognition** (Director: Gerd Gigerenzer) investigates human rationality, in particular decision making and risk perception in an uncertain world. Current research focuses on (1) bounded rationality, that is, the simple heuristics—cognitive, emotional, and behavioral—that laypeople and experts use to make decisions under constraints of limited time and knowledge; (2) social intelligence in cooperation and competition; and (3) risk understanding and uncertainty management in everyday life, including applications in medicine, law, and education. Each of these research areas emphasizes the evolutionary foundations of behavior and cognition, in particular their domain specificity and functional adaptiveness.

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Introductory Overview

The Center for Adaptive Behavior and Cognition (ABC) investigates reasoning and decision making under uncertainty at the levels of both individuals and social groups. The research group consists of psychologists, mathematicians, computer scientists, evolutionary biologists, economists, and researchers from other fields. Using a range of methodologies, such as experimental methods, computer simulation, and mathematical analysis, we cooperate in solving the same problems. The ABC program combines a strong theoretical focus with practical applications, that is, the research group both develops specific models and explores their applications. Applications range from helping physicians and patients understand the statistical evidence arising from medical research; helping courts, administrators, and legislators understand the importance of heuristic thinking in the law; and improving teaching practices in statistical education by introducing transparent representation formats. The theoretical focus is on rationality and can be, albeit artificially, divided into three aspects: bounded, ecological, and social rationality.

Bounded Rationality

Models of bounded rationality attempt to answer the question of how people with limited time, knowledge, money, and other scarce resources make decisions. This program is an alternative to the dominant optimization paradigm in cognitive science, economics, and behavioral biology that poses the question of how Laplacean superintelligences or near omniscient beings would behave. We study the proximal mechanisms of bounded rationality, that is, the adaptive heuristics that enable quick and frugal decisions under uncertainty. This collection of heuristics and their building blocks is what we call the adaptive toolbox.

Ecological Rationality

Models of ecological rationality describe the structure and representation of information in actual environments and their match with mental strategies, such as boundedly rational heuristics. To the degree that such a match exists, heuristics need not trade accuracy for speed and frugality: Investing less effort can also improve accuracy. The simultaneous focus on the mind and its environment, past and present, puts research on decision making under uncertainty into an evolutionary and ecological framework, a framework that is missing in most theories of reasoning, both descriptive and normative. In short, we study the adaptation of mental and social strategies to real-world environments rather than compare human judgments to the laws of logic and probability theory.

Social Rationality

Social rationality is a variant of ecological rationality, one for which the environment is social rather than physical or technical. Models of social rationality describe the structure of social environments and their match with boundedly rational strategies that people might use. There is a variety of goals and heuristics unique to social environments. That is, in addition to the goals that define ecological rationality—to make fast, frugal, and fairly accurate decisions—social rationality is concerned with goals, such as choosing an option that one can defend with argument or moral justification or those that can create a consensus. To a much greater extent than the cognitive focus of most research on bounded rationality, socially adaptive heuristics include emotions and social norms that can act as heuristic principles for decision making.

Bounded Rationality

Humans and other animals must make inferences about unknown features of their world under constraints of limited time, knowledge, and computational capacities. We do not conceive bounded rationality as optimization under constraints nor do we think of bounded rationality as the study of how people fail to meet normative ideals. Rather, bounded rationality is the key to understanding how people make decisions without utilities and probabilities. Bounded rationality consists of simple step-by-step rules that function well under the constraints of limited search, knowledge, and time—whether an optimal procedure is available or not. Just as a mechanic will pull out specific wrenches, pliers, and gap gauges to maintain an engine rather than just hit everything with a hammer, different tasks require different specialized tools. The notion of a toolbox full of unique single-function devices lacks the beauty of Leibniz' dream of a single all-purpose inferential power tool. Instead, it evokes the abilities of a craftsman, who can provide serviceable solutions to almost any problem with just what is at hand.

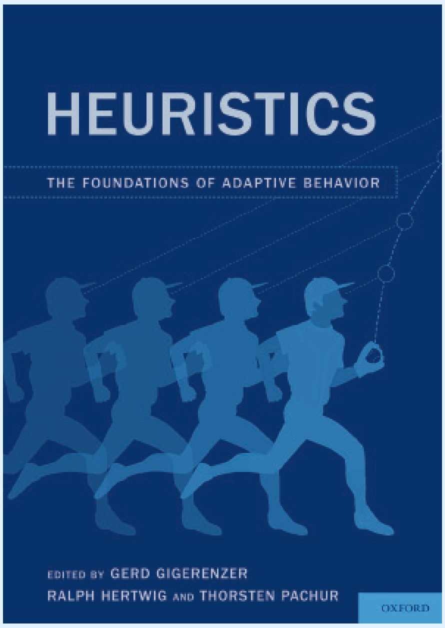
The Adaptive Toolbox

This repertoire of specialized cognitive mechanisms, which include fast and frugal heuristics, are shaped by evolution, learning, and culture for specific domains of inference and reasoning. We call this collection of mechanisms the "adaptive toolbox." We clarify the concept of an adaptive toolbox as follows:

- It refers to a specific group of rules or heuristics rather than to a general-purpose decision-making algorithm.
- These heuristics are fast, frugal, and computationally cheap rather than consistent, coherent, and general.
- These heuristics are adapted to particular environments, past or present, physical or social.
- The heuristics in the adaptive toolbox are orchestrated by some mechanism reflecting the importance of conflicting motivations and goals.

Fast and frugal heuristics generally consist of three building blocks: simple rules for guiding

New Book! *Heuristics: The Foundations of Adaptive Behavior*



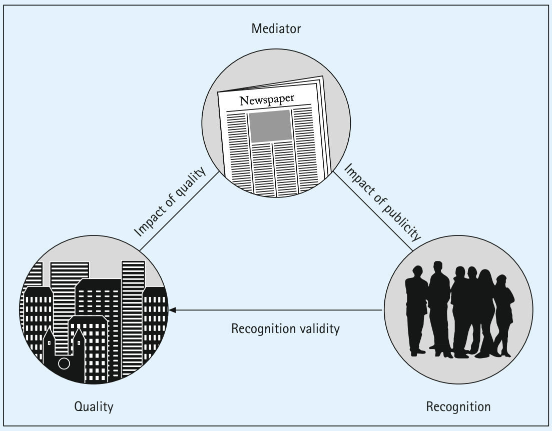
How do people make decisions when time is limited, information is unreliable, and the future is uncertain? In other words, how do people reason when optimization is out of reach? This is the central question that *Heuristics: The foundations of adaptive behavior* (2011) addresses. Nobel laureate Herbert A. Simon once said that his entire scientific career was driven by this single question. Based on Simon's work, and with the help of colleagues around the world, the Adaptive Behavior and Cognition (ABC) Research Group at the Max Planck Institute for Human Development in Berlin has developed a research program dedicated to the study of simple heuristics.

Providing a fresh look at how the mind works as well as the nature of rational behavior, this program has stimulated a large body of research; led to fascinating applications in fields as diverse as law, medicine, business, and sports; and instigated controversial debates in psychology, philosophy, and economics. In a single volume, this book brings together key articles that have been previously published in journals across many disciplines. These articles span theory, applications, and experimental studies, contributing, in the words of Simon (1999), "to this revolution in cognitive science, striking a great blow for sanity in the approach to human rationality."

Box 1.

A Flood of Research on the Recognition Heuristic

Marewski, Pohl, and Vitouch (2010) edited three special issues of the open source journal *Judgment and Decision Making* on recognition processes in inferential decision making. These special issues feature articles on a simple decision strategy that operates on recognition processes: Goldstein and Gigerenzer's (2002) recognition heuristic. The second issue provides an overview of past, present, and likely future debates on the recognition heuristic. A third issue is forthcoming in 2011.



The recognition heuristic predicts that people with less knowledge can make more accurate decisions than those with more. This prediction was tested by BBC Radio 4 in May 2009, when listeners in New York and London were asked which of Detroit or Milwaukee has a larger population. Initially skeptical about the BBC's ability to run a tightly controlled study, we were delighted that they reported only 65 % of listeners in New York correctly answered "Detroit," compared to 82 % of listeners in London.

Box 2.

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Goldstein, D. G., & **Gigerenzer, G.** (2002). Models of ecological rationality: The recognition heuristic. *Psychological Review, 109,* 75–90.

Cook, L. (2001). The world trade center attack: The paramedic response; An insider's view. *Critical Care, 5,* 301–303.

search for information (in memory or in the environment), for stopping search, and for decision making. They are effective when they exploit the structure of the information in the environment. That is, their rationality is a form of "ecological rationality" rather than one of consistency and coherence. We continue to explore fast and frugal heuristics and their importance in diverse disciplines, such as biology, economics, and cognitive psychology. In addition, we have applied our basic research in the areas of consumer behavior, election forecasting, and medical decision making. A collection of 40 landmark articles spanning theoretical foundations and real-world applications now appear in revised form and in a single volume, *Heuristics: The foundations of adaptive behavior* (Oxford University Press, 2011, see Box 1). In addition, in 2010, the journal *Judgment and Decision Making* devoted two special issues to the analysis and use of a single heuristic, the recognition heuristic, and a third issue is forthcoming (see Box 2). In what follows, we describe some of the major developments in the understanding of the adaptive toolbox in the past 2 years.

Fast and Frugal Trees

In recollecting September 11, 2001, Louis Cook of the Emergency Medical Services Division of the New York City Fire Department noted how the triage system *Simple Triage and Rapid Treatment* (START) helped his team prioritize victims and identify the ones who needed help the most (Cook, 2001). START classifies the injured into two major categories: those who need medical treatment immediately and those whose treatment can be delayed. When employing START, which is illustrated in Figure 1, a paramedic sequentially checks up to five diagnostic cues to decide which category a person falls into; a decision can be made after each cue is checked. In essence, START is a decision tree with a very simple structure. Using this type of tree, a person does not need to search for, and integrate all, the relevant information to reach a decision; thus, a decision can be quickly made with little effort. Such fast and frugal trees are designed to help people make decisions in real settings, potentially achieving a high level of decision accuracy under the constraints of limited information, time, and resources.

In contrast to fast and frugal trees, many other decision strategies, such as signal de-

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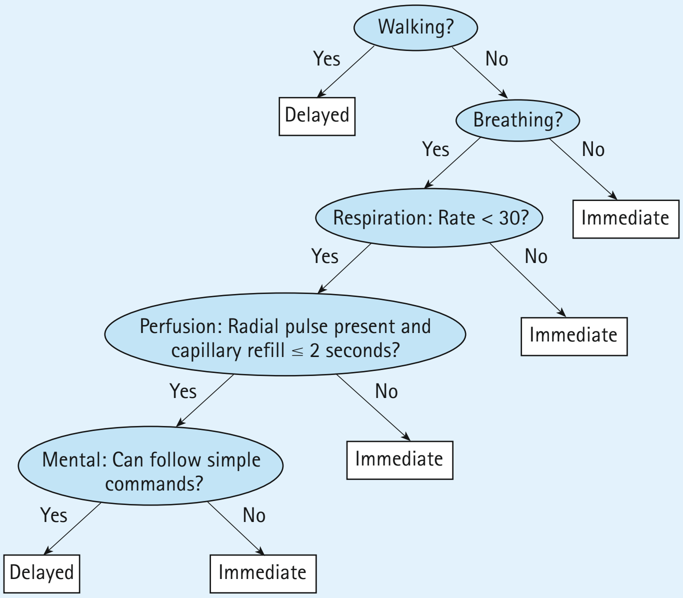

Figure 1. A fast and frugal tree used in the Simple Triage and Rapid Treatment (START) procedure, which categorizes patients into those who need immediate medical treatment and those whose treatment can be delayed (Super, 1984).

tection theory, ignore such constraints. Originating from the statistical theory of Neyman-Pearson hypothesis testing, signal detection theory has been applied widely in psychology, starting with the study of perception and sensation. Arguably, signal detection theory's most important contribution is to characterize performance in terms of sensitivity and decision bias. For instance, the sensitivity of a smoke detector is how well the device measures smoke, and its decision bias is how much smoke must be in the air before the alarm is set to sound. A liberal alarm would be set to trigger at the slightest hint of smoke, so it would likely detect a fire when there is one (a hit), but, at the same time, it might be set off by burnt toast (a false alarm).

By attempting an integration of signal detection theory with simple heuristics, Luan, Schooler, and Gigerenzer (in press) showed how the concepts of sensitivity and decision bias can be used to understand the workings of fast and frugal trees. For example, a tree's sensitivity is, in general, positively related to the sensitivities of the individual cues that compose the tree and affected little by the decision biases of these cues. The principle of *lexicographic decision bias* can be used to determine which of two trees is more liberal: If two trees share cues that are ordered by the relative sensitivity of the individual cues, then the relative bias of the two trees can be compared simply by considering the bias of the top most cues that distinguish them. That is, cues lower down in the tree cannot override the bias of the cues considered earlier.

In comparison to other models—including a sequential sampling model that tries to strike an optimal balance between the gains associated with having access to additional cue information and the costs of searching for that information—the fast and frugal trees compared well in terms of sensitivity and balancing these information gains and costs, especially at smaller sample sizes.

Forecasting Elections With the Recognition Heuristic

Every couple of years, German political parties and candidates invest millions of euros in advertisements, hoping to embed their names in the recognition memories of the elector-

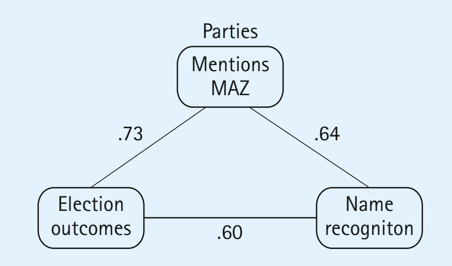

Figure 2. Recognition enables voters to forecast elections for 15 parties competing in the 2004 parliamentary election in the German federal state of Brandenburg. Shown are the gamma correlations computed between the number of mentions of the parties in the *Märkische Allgemeine* (MAZ) newspaper, the number of votes won by the parties, and proportion of eligible voters from Marewski et al. (2010) who recognized the name of a party.

ate. They are betting that elevating name recognition increases the chances that the electorate will consider voting for them. At the same time, throughout Germany, people are wondering who will emerge from the elections as winners. In three German elections, Marewski, Gaissmaier, Schooler, Goldstein, and Gigerenzer (2010) examined various strategies that people might use to forecast the election outcomes. One such strategy is known as the *recognition heuristic* (Goldstein & Gigerenzer, 2002). According to this simple rule of thumb, inferences can be based solely on a sense of *recognition,* which depends on a chain of correlations. Parties that tend to be successful in elections tend to be mentioned more frequently in the media prior to the elections than those that are less successful. As a result, more successful parties are more likely to be recognized, enabling voters to rely on recognition to identify likely winners. Figure 2 illustrates these correlations for the 15 political parties competing in the 2004 parliamentary elections in the German federal state of Brandenburg.

In examining whether German voters use recognition to forecast election outcomes, Marewski et al. (2010) also addressed concerns about the heuristic's adequacy as a model of behavior: Past experiments have led several authors to conclude that there is little evidence that people base inferences on recognition alone, as assumed by the recognition heuristic. Instead, they argue that recognition is integrated with other cues. In the context of forecasting political elections, such cues could be a candidate's party affiliation or knowledge about a party's political agenda. In past studies on the recognition heuristic, the competing hypothesis that recognition is integrated with other cues was never spelled out as a computational model. In their studies, Marewski et al. (2010) specified five competing models. In their model competitions, the recognition heuristic emerged as the best predictor of voters' election forecasts.

The Aging Decision Maker

The 21st century may become known as the century of centenarians: It has been argued by demographers that most babies born since 2000 in countries with long life expectancies, such as Germany or France, will likely live to be 100. Increasing life expectancy, among other factors, is leading to aging populations in such countries and forcing people to work longer and make important decisions about health and wealth very late in their lives.

But how does age-related cognitive decline impact individuals' decision-making abilities? Mata, Schooler, and Rieskamp (2007) found that both younger and older adults were able to select simple and complex strategies adaptively, that is, choose the strategy that matches the task environment. Nevertheless, older adults showed a stronger tendency to use simpler strategies, even in an environment in which a more complex one would be more appropriate. These age differences in strategy use were mediated by age difference in fluid intelligence. Mata et al.'s (2007) results suggest that the aging decision maker adapts to losses in cognitive functioning by relying increasingly on simple strategies. Pachur, Mata, and Schooler (2009) extended this line of research to the use of recognition in decision making, comparing younger and older adults' adaptive use of recognition in different environments. These authors found that both younger and older adults relied more on recognition when its validity was high (compared to when it was low) but also that older adults showed a stronger tendency to use the recognition cue relative to younger

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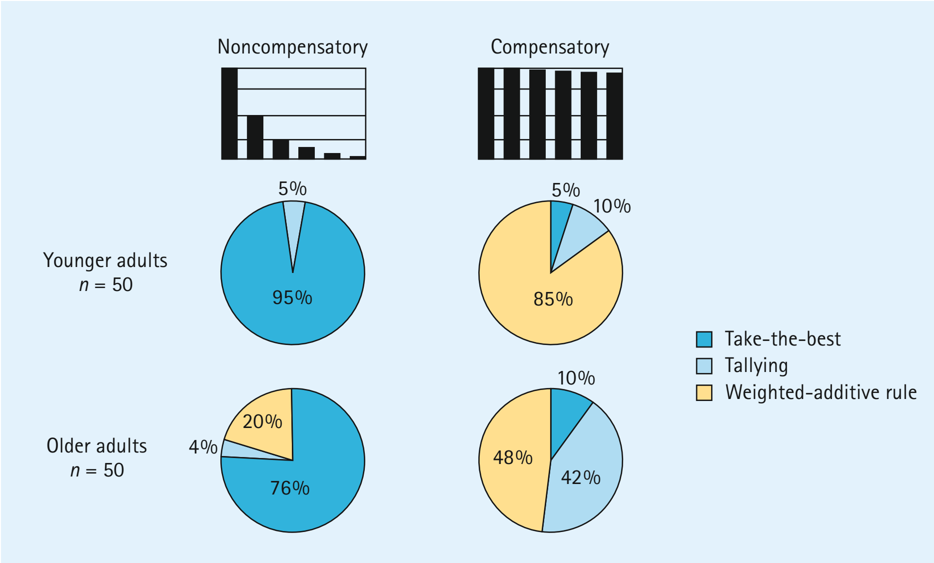

Figure 3. Older subjects learn to use strategies adaptively: Mata, von Helversen, and Rieskamp (2010) conducted an experiment in which the participants had to decide which of three company stocks would be more profitable. When making their inferences, participants were able to look up characteristics of each company (e.g., past revenue, shareholder ratings). In the compensatory environment, participants had to rely on all characteristics to infer which company would do best. In the noncompensatory environment, some characteristics were more predictive than others. Using a simple heuristic, take-the-best, would yield the higher payoff in the noncompensatory environment. The weighted-additive rule, which weights the attribute values based on how well they predict, would yield the higher payoff in the compensatory environment. Use of a third strategy, tallying, was also tested. Tallying simplifies the weighted-additive rule by assigning a unit weight (–1 or 1) to each cue. Participants were classified according to which decision strategy described their decisions best. As can be seen in the strategy classification results after an extensive learning period, the older participants had more difficulties adjusting to both environments on the basis of performance feedback compared to younger adults. However, while the majority of older adults were able to learn to select the take-the-best strategy in the noncompensatory environment, less than half were able to learn to select the more complex weighted-additive rule in the compensatory environment.

adults, even when this led to a reduced inference accuracy.

Mata, von Helversen, and Rieskamp (2010) investigated the ability of younger and older adults to adapt their decision strategies as a function of environment structure when provided with performance feedback. They modeled choice behavior using a reinforcement learning model that assumes that participants adjust the value of strategies through reward-based learning. Their results showed that, while both younger and older adults were adaptive in choosing the strategy that matches the task environment, older adults showed poorer learning relative to younger adults, particularly in an environment favoring the use of a more cognitively demanding strategy, the weighted-additive rule, which requires extensive information integration (see Figure 3).

In sum, while both younger and older adults are adaptive decision makers, age-related decline may lead older adults to rely on simpler strategies to make decisions. Overall, these studies illustrate how changes over the life course can be investigated in terms of changes in the selection and application of strategies from the adaptive toolbox. Moreover, these represent an important attempt to identify environments that may require intervention to ensure successful decision making by the elderly.

Ecological Rationality

The accuracy of a decision-making strategy depends on the structure of the environment in which it is used. Understanding the adaptive relationship between properties of decision strategies and the structure of the environment is a key area of research within the ABC Research Group, and we investigate the ecological rationality of various decision strategies using methods such as computer simulation and mathematical analysis. The study of ecological rationality aims to formalize statements about the relative success of decision strategies for different environmental structures. Success is measured by external criteria, such as speed, frugality, and predictive accuracy rather than by internal criteria, such as logical consistency. The interplay between the organism and its environment is the fundamental unit of analysis in our research, and here we will present a sample of our recent findings.

Robust Ordinary Information

One of the major findings in the study of ecological rationality is that heuristics implementing limited information search and noncompensatory processing of information, such as take-the-best, can make more accurate inferences than computationally more complex models, such as classification and regression trees and neural networks. A noncompensatory decision strategy uses the first piece information which allows a decision to be made and ignores all other factors. For example, a decision maker relying on the simple heuristic, take-the-best, might decide between which of two houses to buy using only a single cue, such as location. Findings such as these pose a challenge to the supposedly universal law of the effort-accuracy trade-off: If people invest more cognitive effort, such as considering more information, they achieve more accuracy in their choices and judgments. This challenge, however, has been criticized since heuristics, like more complex strategies, rely on underlying abilities which may themselves require complex computations. For example, take-the-best, like all lexicographic heuristics, relies on an ability to find a good ordering of cues before a decision can be made.

Katsikopoulos, Schooler, and Hertwig (2010) provided arguments and evidence against this criticism. First, they discussed ways for ordering cues, such as evolution, culture, and individual learning, which do not entail complex individual learning. Second, they argued that, when orders are learned individually, people's necessarily limited information will curtail computational complexity while also achieving higher accuracy. In a computer simulation, Katsikopoulos et al. (2010) tested the accuracy of various decision-making models in 19 real-world problems, from domains such as biology, economics, and sociology. For example, one inference problem required the decision maker to decide which one of two cities (e.g., Chicago or Berkeley) has a higher homelessness rate. Here, one of two objects (cities) must be selected as having the higher criterion value (homelessness rate). The inference is made on the basis of pieces of information (e.g., "Is the city a state capital?"), called cues, which correlate, albeit imperfectly, with the criterion.

All decision strategies use cues to make inferences, but they tend to differ in how they process these cues. Some models are computationally complex in that they weight and add cues (linear regression) or make probabilistic computations (naïve Bayes), whereas other models, such as simple heuristics, may use only one cue (e.g., take-the-best) or add cues without weighing their values (e.g., tallying). The parameters estimated by the models may include the regression weights in case of linear regression, or cue validities and directions in the case of take-the-best. The validity of a cue is a simple measure of the correlation between the cue and the criterion, and the direction of a cue is the sign of this correlation. Table 1 summarizes the nine decision strategies investigated by Katsikopoulos et al. (2010).

To compare the accuracy of each of these models, each of the 19 data sets was split in two parts and the parameters of each model were estimated on one part, the *training set.* These parameter estimates were used, for

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Table 1
The Nine Decision Strategies Compared by Katsikopoulos et al. (2010)

Model	*Decision strategy*	*Parameters*
Multiple linear regression with dichotomized cues (MR_D)	Select object with higher weighted sum of cue values	Regression weights
Multiple linear regression with undichotomized cues (MR_U)	Select object with higher weighted sum of cue values	Regression weights
Naïve Bayes with dichotomized cues and frequentist validity (NB_F)	Select object with higher probability of having higher criterion value	Cue validities
Naïve Bayes with dichotomized cues and Bayesian validity (NB_B)	Select object with higher probability of having higher criterion value	Cue validities
Tallying with dichotomized cues (TAL)	Select object with higher sum of cue values	Cue directions
Minimalist with dichotomized cues (MIN)	Select object with higher value on random cue that discriminates	Cue directions
Take-the-best with dichotomized cues and frequentist validity (TTB_F)	Select object with higher value on most valid cue that discriminates	Order of cue validities
Take-the-best with dichotomized cues and Bayesian validity (TTB_B)	Select object with higher value on most valid cue that discriminates	Order of cue validities
Take-the-best with undichotomized cues and frequentist validity (TTB_U)	Select object with higher value on most valid cue that discriminates	Order of cue validities

Note. Each decision strategy (detailed in column 2) must estimate the parameters (given in column 3) from the available observations.

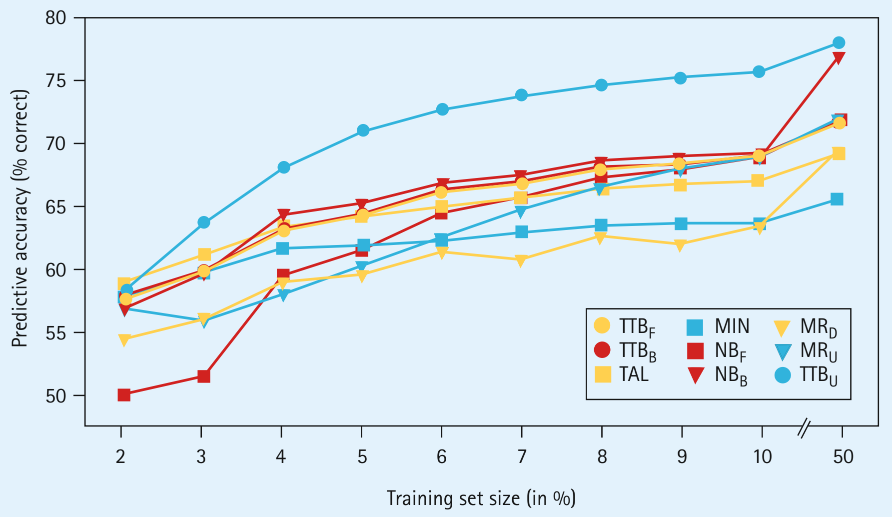

Figure 4. Mean predictive accuracy (across 19 environments) of fast and frugal heuristics and benchmark models as a function of the size of the training set. For small training samples, take-the-best with undichotomized cues is more accurate than the eight other heuristic and computationally complex models, such as naïve Bayes and linear regression. See Table 1 for a description of each model.

each model, to make inferences on the other part, the *test set.* This process was repeated 1,000 times. Besides the usual training set size of 50 % of the whole data set, the authors also tested minute training sets, from 2 to 10 objects (3 % to 15 % of the whole 19 data sets used), in order to simulate people's limited information. Model performance was assessed by measuring their predictive accuracy, which is the proportion of correct inferences they make on the test set. Figure 4 shows the average predictive accuracy of the models for all training set sizes.

As can be seen in Figure 4, models are differentially influenced by the information that small samples of 2 to 10 objects contain. The predictive accuracy of linear regression and naïve Bayes is compromised, presumably because training sets with 10 or fewer objects provide unreliable point estimates of regression weights and cue validities. The heuristics, in contrast, seem capable of making do with very limited information: Tallying excels when the training set contains only two objects, whereas take-the-best with undichotomized cues is the most accurate model for sets including between 3 and 10 objects, with a difference in accuracy of more than five percentage points on average.

Katsikopoulos et al. (2010) termed the information provided by small training samples "ordinary information." Another instance of ordinary information is laypeople's intuitions. Katsikopoulos et al. (2010) found that when heuristics, such as take-the-best and tallying, are fed with people's intuitions about cue directions and cue orders, they can match the predictive accuracy of the heuristics with a training sample of 50 % of the whole data set.

What is puzzling about the high accuracy of take-the-best with undichotomized cues was that take-the-best relies just on a single cue, the one with the highest validity estimate in the training sample. In the case of continuous cues, this cue will almost always discriminate between two objects. The solution to this puzzle remains unsolved, but a partial explanation can be found in the concepts of noncompensatory cue structure and the bias-variance dilemma. In an environment with a noncompensatory cue structure, the validity of the most valid cue is much higher than the validities of the other cues, and this leads to take-the-best achieving maximum accuracy (Katsikopoulos & Martignon, 2006). However, this explanation does not consider the criterion of predictive accuracy, used above, neither does it consider the process of sampling which is critical to take-the-best's success. In related work, Gigerenzer and Brighton (2009) took into account these factors and argued that heuristics achieve high predictive accuracy because their comparatively low variance compensates for their comparatively high bias. Reconciling these two perspectives on understanding the ecological rationality of heuristics is a current topic of research within the group.

Small and Large Worlds

A number of studies have investigated the ecological rationality of a diverse set of decision strategies, making it necessary to consolidate and review this literature with a view to identifying common underlying principles. For example, there have been syntheses of the available results for psychologists (Gigerenzer & Gaissmaier, 2011), and management scientists (Katsikopoulos, 2011). Gigerenzer and Gaissmaier (2011) emphasize the concept of large worlds where "… part of the relevant information is unknown or has to be estimated from small samples." Gigerenzer and Gaissmaier claim that the optimization models typically developed in economics, operations research, and management science may often fail in large worlds. This could be because in large worlds (a) the mathematical assumptions (e. g., linearity or normality) of optimization models may not be a good approximation to reality, and (b) the available data may not be of sufficiently high quality for estimating model parameters reliably. On the other hand, simple models, such as heuristics that rely on fewer parameters, are less sensitive to violations of these two conditions. In sum, in large worlds, it is an open question whether optimization models or heuristics perform better. In fact, we saw above that heuristics outperformed optimization models in a large world where information about cues was ordinary.

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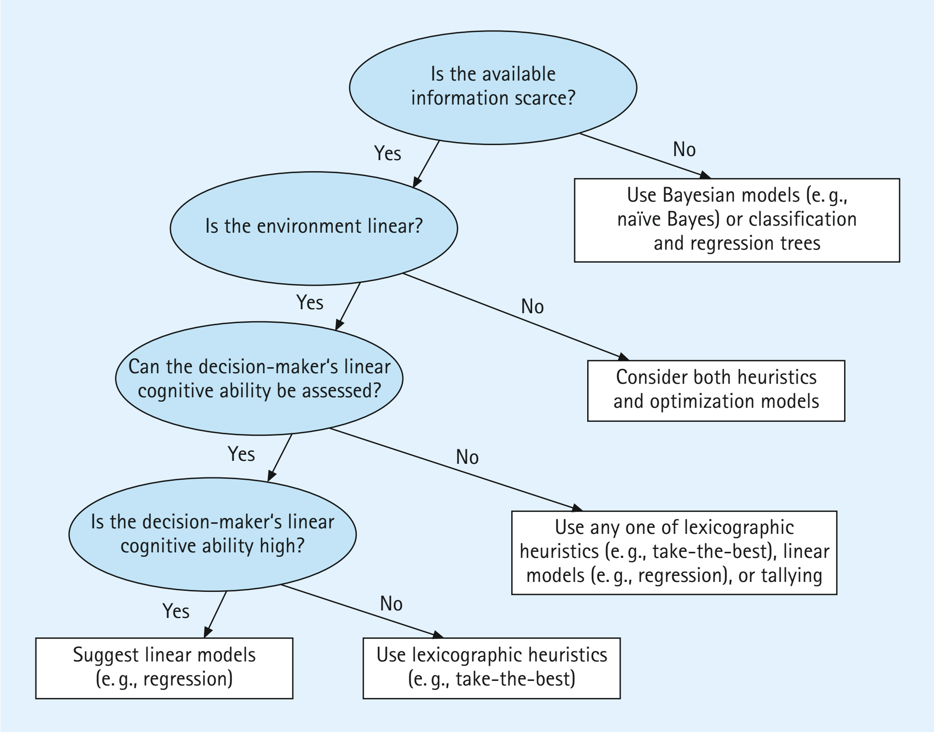

Figure 5. A fast and frugal decision tree used to guide the process of deciding which general approach to decision making is likely to prove effective. Three characteristics of the task environment are (potentially) considered: the scarcity of information, the linearity of the environment, the decision-maker's linear cognitive ability (Katsikopoulos, 2010a).

Katsikopoulos (in press) collected empirical and theoretical results that compare heuristics and optimization models and proposed the tree shown in Figure 5 for deciding which model to use, depending on the characteristics of the decision problem. In Figure 5, scarce information is an instance of information in a large world. For example, there may be only a few decision options or few attributes for each decision option. Another environmental characteristic is linearity, where the criterion value, or utility, of a decision option is a linear function of its attribute values. The linear cognitive ability of a decision maker is a measure of how well the decision maker applies a linear model in a linear environment.

Less Can Be More

Above, we considered under which conditions lexicographic heuristics, such as take-the-best, are successful. Next, we focus on an even simpler heuristic. Recall the inference problem discussed earlier: Which of Chicago or Berkeley has a higher homelessness rate? If you recognize Chicago but not Berkeley, you may infer that Chicago has a higher homelessness rate, and this would be consistent with using the recognition heuristic:

"In an inference problem, if you recognize one object and not the other, infer that the recognized object has a higher criterion value."

There has been more than 10 years of research on the recognition heuristic; Marewski, Pohl, and Vitouch (2010) edited two special issues of relevant research in *Judgment and Decision Making* (see Box 2). A key question is, under which conditions can the use of the recognition heuristic result in the *less-is-more effect.* This counterintuitive effect refers to how experiencing fewer objects lead the decision maker to make decision with greater accuracy.

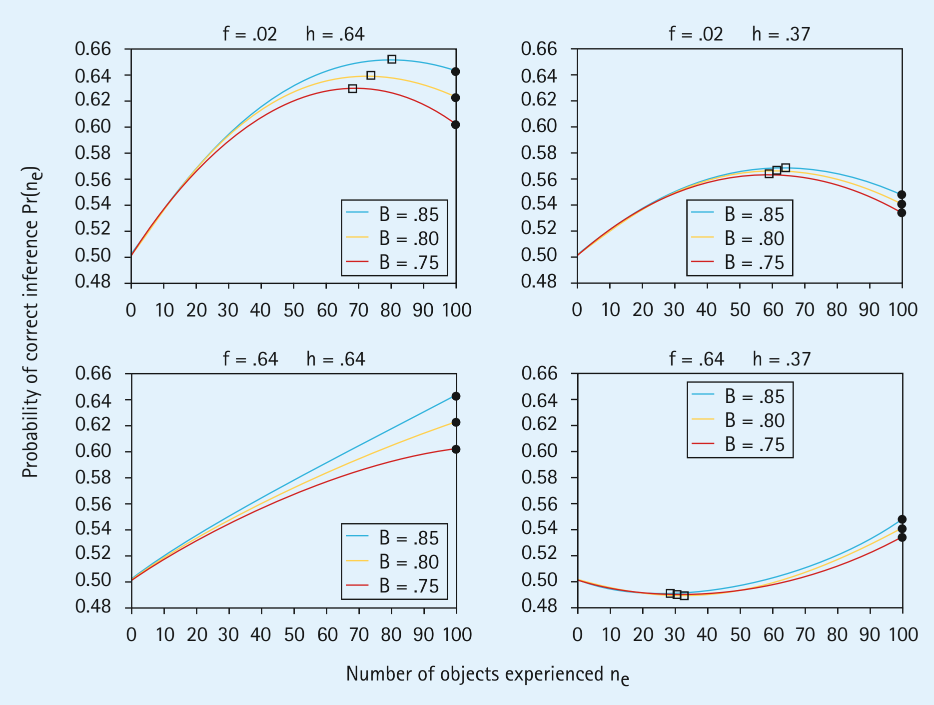

Figure 6. When are less-is-more effects likely to hold? Heuristic accuracy was fixed at .8, while knowledge accuracy B was set to either .75, .8, or .85. The four panels refer to four combinations of high and low values of hits (h) and false alarms (f). As can be seen in the two upper panels, if the false-alarm rate is low, less-is-more effects can occur even if heuristic accuracy is smaller than knowledge accuracy. Conversely, if the false-alarm rate is high, less-is-more effects may be absent.

Until recently, it was believed (Pleskac, 2007) that a necessary condition for the less-is-more effect is that the accuracy of the recognition heuristic is larger than the accuracy of strategies relying on further knowledge, where knowledge is a blanket term for any inference model that can be used except the recognition heuristic and pure guessing. Katsikopoulos (2010b), however, analytically showed that the less-is-more effect is also possible if heuristic accuracy is lower or equal to the accuracy of knowledge.

The inverted U-shape curves in the top two panels of Figure 6 illustrate that, when the false-alarm rate is low, a less-is-more effect can occur even though the accuracy of recognition knowledge is lower than other forms of knowledge. The bottom two panels show that, when the false-alarm rate is high, less-is-more effects are less likely.

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Social and Evolutionary Rationality

We live in a social world. Most other animals do too. The social world affords many opportunities and challenges for decision making, from the benefits of collective cognition and cooperation to the costs of groupthink and cut-throat competition. Some social situations appear, at least at the moment, to be uniquely human. For instance, morality in humans has been studied for millennia, with dozens of viewpoints on what behavior is morally permissible. But do morally relevant situations always require special sophisticated decision-making processes, or can simple heuristics play a role in moral behavior?

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Other social situations are not uniquely human, but are faced by a number of animal species. An evolutionary perspective can be useful here because it provides two advantages. First, it offers the ability to test hypotheses across different species that differ in their natural ecology. Thus, we can investigate ecological rationality with a potentially broad range of environments experience by different species. Second, an evolutionary view can offer a theoretical framework for thinking about the adaptive nature of decision making. Here, we explore how the study of heuristics and the core capacities underlying them are relevant to social decision making in humans and other animals by assessing the adaptive benefits of group decision making and cooperation.

Moral Satisficing

Every year, an estimated 1,000 Germans die waiting in vain for a suitable organ donor. Only 12 % of Germans have consented to donating their organs upon their death. Other countries, such as the United Kingdom and the United States, show only slightly higher levels of consent, 17 % and 28 %, respectively. In contrast, Austria, France, Hungary, Poland, and Portugal all have consent rates exceeding 99 % (see Figure 7). Why do we see such differences in organ donation across these countries? Whether to donate one's organs is a moral decision that we all face. How do we make decisions in these types of morally relevant situations? There are at least three primary perspectives. In the utilitarian view, the morally permissible action is the one that maximizes the overall utility of all individu-

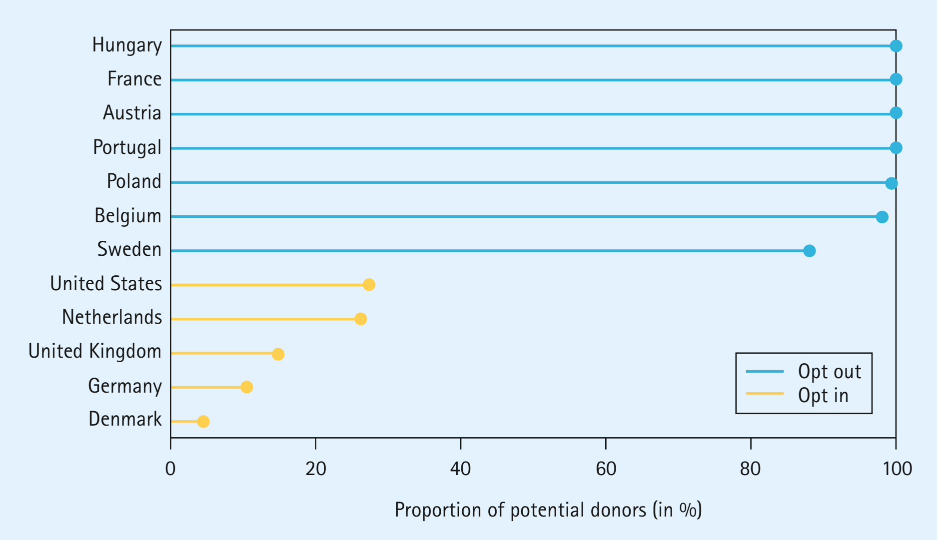

Figure 7. Countries differ dramatically in the proportion of potential organ donors. The clear disparity in consent rate is attributable to majority use of the default heuristic, and the countries' policy regarding whether residents must opt in to give consent or opt out of assumed consent (Johnson & Goldstein, 2003).

Source. Based on the figure of Gigerenzer (2010c) and Johnson & Goldstein (2003).

als involved, accounting for the costs and benefits of the potential outcomes. A virtue perspective, in contrast, highlights the moral character of individuals. Finally, the deontological perspective emphasizes the following of moral rules. Similarly, following commandments and other socially transmitted rules can govern moral behavior.

Gigerenzer (2010c) argues that there exists another possible mechanism underlying our behavior in morally relevant situations: heuristics. In some of these situations, we may exhibit consistent character traits, trade off the good and the bad of our actions, or follow the dictate of a moral rule or commandment. But in many cases, we may simply use a heuristic in morally relevant situations. Take the organ donor shortage (Johnson & Goldstein, 2003). Is it possible that a heuristic could account for the extreme differences in consent rates between countries? Rather than making sweeping claims about the moral character of residents of these countries, Gigerenzer (2010c) suggests that most people use the same default heuristic: If there is a default, do nothing about it. What differs across these countries is not moral character or commandments, but the government-imposed default for making an organ donation choice. In Germany, the United Kingdom, and the United States, individuals must actively opt in to consenting to donate their organs. In the other countries, the default is giving consent to donate, and individuals must opt out. Thus, a simple heuristic has potentially live-saving implications in the moral domain of organ donation.

In addition to the default heuristic, other heuristics are used in moral situations. Imitation heuristics are particularly relevant. In particular, *imitate-your-peers* is a powerful heuristic that ignites jealousy and propagates fads worldwide. It also applies to moral situations, enhancing donations to charity yet amplifying discrimination toward minorities. *Imitate-the-successful* and *follow-the-leader* are further examples of imitation-based heuristics that we use frequently in moral situations. The *equality heuristic* involves dividing a resource equally among all possibilities. Though proposed as a means to allocate investments over assets in a financial portfolio, this heuristic may be relevant to parents dividing their love, time, and attention among their children (Hertwig, Davis, & Sulloway, 2002). An even split tends to foster coherence in a group by generating a sense of fairness and justice. Finally, *tit-for-tat* is a heuristic of helping someone who helped you last time (and withholding help if he or she withheld it last time). In his 1984 book on *The Evolution of Cooperation*, Axelrod describes how tit-for-tat is used in the morally charged domain of warfare: a system of "live and let live" for the soldiers in the trenches during World War I. If the soldiers attacked their opponents' supply lines, the opponents would reciprocate in turn. Therefore, a system of mutual restraint developed, allowing both sides to have access to their food and supplies. Implicit ceasefire agreements would even result in night patrols openly walking in front of the trenches, exposed to their enemy. Nevertheless, a single shot from the enemy would unleash a barrage of retaliatory fire. The military command put a stop to this tit-for-tat-like response.

The heuristics we rely on may not be moral heuristics, but more general heuristics that are applied to morally relevant situations as well. The default heuristic applies not only to organ donation consent but also to environmental or "green" defaults (Pichert & Katsikopoulos, 2008), purchasing insurance, and choosing retirement plans. The equality heuristic is termed *1/N* when used as a method for distributing investments and may explain distributions in the Dictator Game (Keller, Gummerum, Canz, Gigerenzer, & Takezawa, in press). Thus, these heuristics work well in nonmoral situations and may often be applied in morally relevant situations as well.

The critical role of the environment is vital to understanding the heuristics discussed here. Like ecological rationality, the concept of *ecological morality* proposes that moral behavior results from the interaction between the mind's mechanisms and the environment. The organ donation case exemplifies this interaction. The striking difference in organ donation consent rates across countries can be attributed to using the same heuristic in different environments. When the default is

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consent, few people opt out. When the default is no consent, only a small percentage of people actively override that default (Johnson & Goldstein, 2003). This concept of ecological morality highlights the chance to engineer our environments to better reach our moral goals. If higher organ donation consent rates will help save lives, then changing the default may improve actual donation rates better and more cheaply than marketing campaigns. In summary, morally neutral heuristics may account for our behavior in many morally relevant situations. These heuristics depend on the environment, which gives us the opportunity to construct appropriate environments and shape the nature of decision making in the moral domain.

When to "Follow an Expert" and "Aggregate Information"

When confronted with a problem, social interaction can provide a solution that is not available to individuals. Two potential group decision-making mechanisms can yield solutions: (a) individuals can aggregate information across a group, thereby harnessing "collective cognition," or (b) individuals can follow specific "leaders," those experts with information particularly relevant to the decision at hand. A classic example of such social interaction involves a group of individuals deciding when to move toward a specific resource, such as foraging site or waterhole (Figure 8), or when to switch behavior (e.g., from resting to foraging). Biologists are now beginning to comprehend more fully the heuristics (which they refer to as *rules of thumb*) individuals use to make such social decisions. They find that individuals can exploit a higher order collective computational capability. Group members may come to a consensus not only about where to travel but also about what heuristics to use. Thus, groups may adapt to compute "the right thing" in different contexts, matching their collective information strategy with the statistical properties of their environment. This perspective lies at the heart of many research projects undertaken by the ABC Research Group. Importantly for the study of social decision making, ecological rationality emphasizes the importance of the social environment (Stevens & King, in press).

Katsikopoulos and King (2010) modeled the process of groups of individuals matching their collective information strategy with the statistical properties of their environment. They began by considering a hypothetical situation in which individuals have to choose between two options. In this situation, there is a correct choice for all individuals, and the level of information ("accuracy") varies across individuals and is sampled from a normal distribution. This is likely to be representative of a variety of choices faced by social animals (e.g., the presence or absence of a food resource or a predator). The model predicts that, when individuals favor the incorrect

Figure 8. A troop of baboons exhibit leader-follower behavior in the Namib Desert, Namibia.

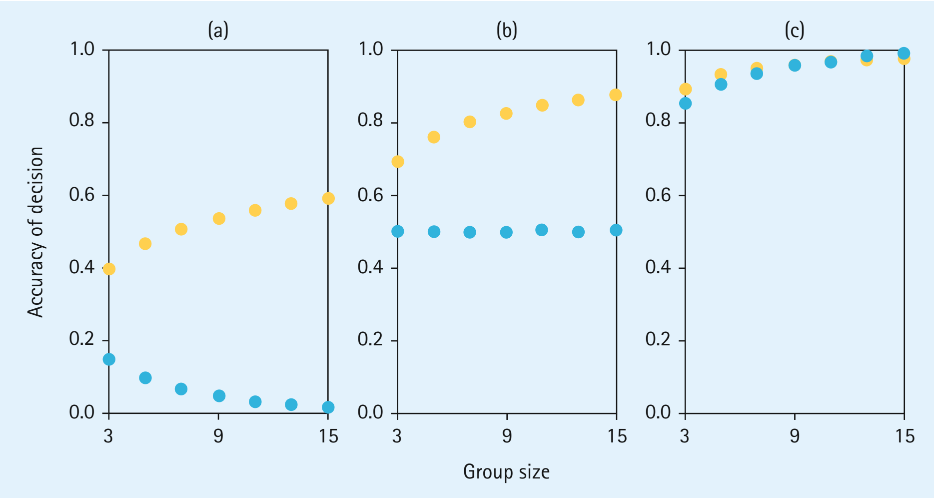

Figure 9. When should a group rely on a single individual to make a decision rather than aggregating the decisions of its members? The accuracy of decisions using an aggregated rule (blue circles) and an expert rule (orange circles) will depend on the group size. The three plots examine the effect of mean individual probability of choosing the correct option, m, and the standard deviation, s. From left to right, m = .1, s = m/1.96; m = .5, s = m/1.96; m = .9, s = m/1.96. For all but groups composed of highly informed individuals, relying on a single expert leads to greater accuracy.

Source. Katsikopoulos & King (2010).

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option (are misinformed) or are equally likely to choose between options (have very little information), groups should adopt the choice of a single expert, especially in larger groups (Figure 9). However, if individuals are informed, then the collective is equal in accuracy to the expert in aggregating information. In these situations, *follow-the-leader* or the policy of aggregating information would work equally well.

Katsikopoulos and King (2010), however, acknowledged that this model, although applicable to one-shot decisions, might not represent what goes on in more stable social groups, in which individuals encounter repeated collective decisions and can store and recall information. They therefore used a Bayesian model to predict the probability of groups using expert and aggregate rules across time, based on the outcome of past decisions. In this form of the model, the rule that aggregates information is always favored, unless the first decision that a group makes is correct with high probability, in which case groups marginally favor the expert rule.

How might a group choose between these two decision rules? King, Johnson, and Van Vugt (2009) discussed this issue in a recent review. On the one hand, the group-level heuristic can emerge passively as a consequence of the properties of the group. Otherwise, individuals can be more likely to follow certain “types” of individuals and thus be more likely to copy their actions. King et al. (2009) argue that, across species, individuals are more likely to emerge as leaders if they have particular morphological, physiological, or behavioral traits increasing their propensity to act first in coordination problems, and if they have superior knowledge.

King et al.’s (2009) review suggests that leadership shares common properties across humans and other animals, pointing to ancient roots and evolutionary origins. They suggest that identifying the origins of human leadership, as well as which aspects are shared with other animals and which are unique, offers ways of understanding, predicting, and improving leadership today. One of the most striking claims that King et al. make in their search for the evolutionary origins of leadership is that the same simple heuristics may underlie coordination of activities in humans and nonhumans alike. There are evolved

Key Reference

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rules of thumb that prescribe who to follow and when to follow them that have a deep evolutionary history. Thus, the mechanisms of group decision making are broadly adaptive, shaping social interactions across a broad range of species, including humans.

Memory Constraints on Cooperative Heuristics

Imagine that once a month you meet a colleague for lunch at an upscale restaurant. This month, your colleague pays for lunch. What should you do next month? And the following month? Should you pay for lunch, let your colleague pay again, or split the bill? A simple heuristic that one might use in this situation is *tit-for-tat,* which starts by cooperating and then copies a partner's previous action. This "you scratch my back, I'll scratch yours" heuristic has been successful in evolutionary and economic analyses of cooperative behavior. In fact, it has become the most studied solution to the problem of cooperation. Despite its popularity and apparent simplicity, few studies have explored the cognitive capacities required to implement tit-for-tat and similar heuristics.

Memory represents a primary cognitive capacity needed for heuristics like tit-for-tat that depend on past behavior. Tit-for-tat requires that players accurately remember the single last choice from each partner. Humans and other animals, however, sometimes forget. Given the nature of forgetting, Stevens, Volstorf, Schooler, and Rieskamp (2011) asked whether existing heuristics that promote cooperation (such as tit-for-tat and its variants) are cognitively feasible. They explored whether humans have the memory capacity required to implement these strategies. To address this capacity question, they conducted an experiment with human participants, in which a series of simulated partners chose to cooperate or defect. They measured participants' memory accuracy in recalling each partner's last action. To test the effects of

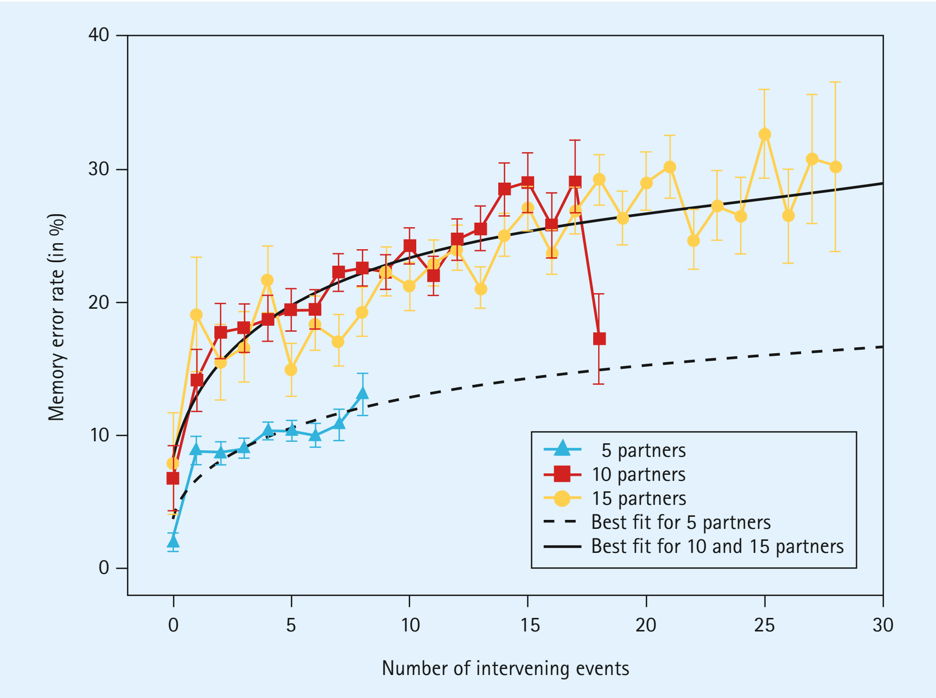

Figure 10. Can humans recall interactions with their partners well enough to accurately employ the tit-for-tat strategy? Memory error rate for this task (mean +/– SEM) increases with more intervening interactions. The smooth lines represent the least-squares best-fit power function of memory. With no intervening interactions, error rates where lower than 10 %. Error rate increases rapidly with just a single intervening interaction.

Source. Stevens et al. (2011).

memory interference on cooperation, they varied the number of simulated interaction partners. From these manipulations, they estimated how memory errors respond to increases in memory interference.

In this study, participants performed fairly accurately when tracking only 5 partners, but, with 10 or more partners, memory errors increased dramatically. In fact, the error rates in the 10- and 15-partner conditions suggest that participants were guessing in half of the trials. Thus, memory interference from tracking multiple partners sharply increased memory errors in this task. To further explore this memory interference, Stevens et al. (2011) examined error as a function of the number of intervening interactions. Between consecutive presentations of the same partner, there were other intervening partners. When consecutive interactions with the same partner occurred with no intervening interactions, participants performed well, with a mean error rate below 10 % (Figure 10). With even one intervening interaction, however, error rates doubled and continued to rise with more intervening interactions.

Estimates of memory accuracy alone, however, do not demonstrate the complete role of memory in cooperation. We must also assess how well specific heuristics cope with error caused by misremembering a partner's last actions. For instance, tit-for-tat's performance decreases when errors exist because of mistakenly defecting results in the lower payoffs of mutual defection. A more forgiving form of tit-for-tat called contrite tit-for-tat performs better when individuals make errors. Stevens et al. (2011) used agent-based simulations to systematically analyze the success of several heuristics proposed in the literature across a broader range of error rates.

Figure 11 shows, that at low error rates, GRIM—a heuristic that begins by cooperating, then permanently switches to defection

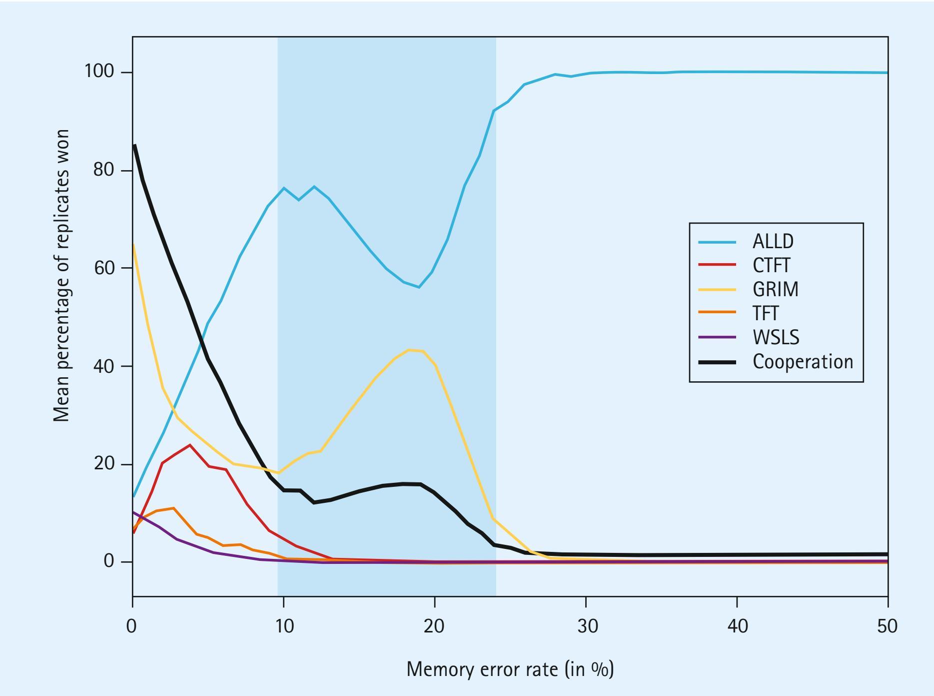

Figure 11. How do high error rates impact on the success of game-theoretic heuristics? This evolutionary simulation shows that, at low error rates, heuristic strategies GRIM, CTFT, TFT, WSLS, and ALLD persist. At the higher, experimentally observed, error rates (the shaded region), ALLD and GRIM outperform the other strategies. The proportion of cooperative choices made by all agents in the last generation decreases rapidly with increasing error rate.

Source. Stevens et al. (2011).

following the partner's first defection—outperformed all other heuristics. Tit-for-tat (TFT), contrite tit-for-tat (CTFT), and win-stay, lose-shift (WSLS) won a small percentage of the simulations, along with always defecting (ALLD). As error rates increased, ALLD and GRIM outcompeted TFT and the other cooperative heuristics. The poor performance of the cooperative heuristics resulted in the frequency of cooperative acts, employed by all agents in the population, decreasing dramatically as errors became more prevalent. Cooperation could not be sustained, even at low levels of error.

In summary, this study found that people make many mistakes when recalling past behavior. In addition, heuristics that require this kind of memory did not perform well in an evolutionary simulation when faced with the error rates observed in the experiment. Though these models have proven valuable in investigating cooperation for the last 30 years, they do not accurately reflect underlying cognition. Humans certainly use reciprocal strategies when cooperating, but they likely do not use strategies like tit-for-tat and its relatives. They simply cannot use these heuristics because the memory load is too great. To examine the types of reciprocal strategies that humans and other animals use, we must embed what we know about memory into new realistic cooperative strategies. Building psychology into these models is a crucial next step in better understanding the nature of cooperation.

Decision Making in the Wild

The study of bounded, ecological, and social rationality conceives behavior as the result of an interaction between cognition and environment. In this section, we report on a selected sample of our work outside the laboratory, focusing on physicians' and patients' health literacy, numeracy and graph literacy, defensive decision making, and consumer choice. Risk literacy in health is one of the most important and neglected cognitive competencies in modern society. Our group continues to play a pioneering role in improving the public understanding of risk, with 2009 seeing the official opening of the Harding Center for Risk Literacy (see Box 3). Also in 2009, Gerd Gigerenzer co-directed an Ernst Strüngmann Forum focusing on *Better doctors, better patients, better decisions: Envisioning health care 2020* (see Box 4).

2009 Marked the Opening of the Harding Center for Risk Literacy

www.harding-center.de

April 23, 2009, marked the official opening of the Harding Center for Risk Literacy. The day was celebrated with speeches held by Barbara Bludau, General Secretary of the Max Planck Society; Gerd Gigerenzer; Ulman Lindenberger; and David Harding, Director of Winton Capital, who made the Harding Center possible with a generous fund and after whom the Center is named. Apart from pursuing basic research, an important goal of the Harding Center for Risk Literacy is increasing awareness of risk literacy and equipping the general public and experts with the tools and skills to deal with risks and uncertainties in a more informed way, particularly in the health domain.

To attain this goal, 50 keynotes, talks, and workshops were given by members of the Harding Center to the medical community in 2009/10, ranging from invited symposia at international conferences, such as the 5th International Shared Decision Making Conference in Boston (2009) or the World Health Summit in Berlin (2009 and 2010), to intensive training for physicians and medical students in Germany and abroad. In October 2009, Gerd Gigerenzer and Sir Muir Gray organized an Ernst Strüngmann Forum that brought together 40 international experts in Frankfurt to analyze systematically the issue of health illiteracy—a problem that affects both patients and health-care providers and hinders the delivery of quality health care.

The Harding Center's work was prominently covered in editorials of the major international medical journals (Archives of Internal Medicine, British Medical Journal, Bulletin of the World Health Organization, Maturitas) as well as in an opinion piece in Nature (October 29, 2009). Additionally, the Harding Center publishes methods for understanding risks in journals that are regularly read by physicians, such as the leading journal of the German Medical Association, Deutsches Ärzteblatt, or in journals for the general public, such as Scientific American Mind in the United States and Gehirn & Geist in Germany. Finally, the Harding Center publishes key information about health topics on their website, such as the drug fact boxes for breast and prostate cancer screening shown in Tables 2 and 3.

Researchers at the Harding Center partake in a wide range of collaborations with opinion leaders in the field, both on the national and international level. Recently, the Harding Center established a collaboration with neurologists, lead by Christoph Heesen at the University Medical Center Hamburg-Eppendorf, who investigate how to best inform patients with multiple sclerosis and implement their results for communicating with real patients. Together with Norbert Donner-Banzhoff from the University of Marburg, the Harding Center received a DFG grant to study actual decision making by general practitioners in their practices. In collaboration with Jay Schulkin at Georgetown University, Washington, DC, the Harding Center is currently developing a scale to assess the numerical skills of physicians. Last, but not least, an interdisciplinary cooperation was established with David Skopec from the Zurich University of the Arts to develop and test intuitive visualizations of medical information.

Box 3.

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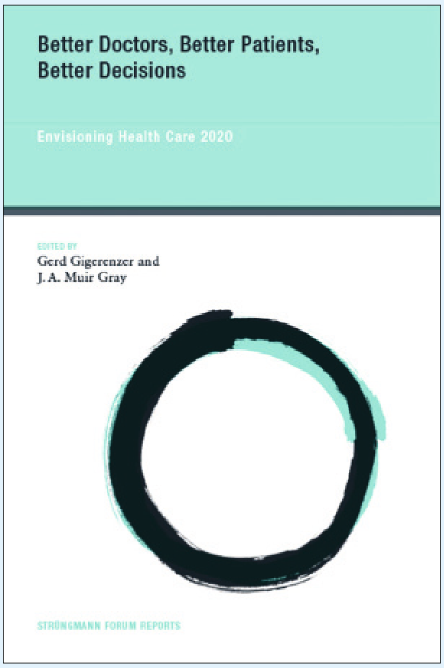
In April 2011, The British Medical Journal will launch the book *Better doctors, better patients, better decisions: Envisioning health care in 2020*

Efficient health care requires informed doctors *and* patients. The health-care system we inherited from the 20th century falls short on both counts. Many doctors and most patients do not understand the available medical evidence. We identify seven "sins" that have contributed to this lack of knowledge: biased funding; biased reporting in medical journals, brochures, and the media; conflicts of interest; defensive medicine; and medical schools that fail to teach doctors how to comprehend health statistics. These flaws have generated a partially inefficient system that wastes taxpayers' money for unnecessary or even potentially harmful tests and treatments, and for medical research that is of limited relevance for the patient. Raising taxes or rationing care are often thought to be the only alternatives in the face of exploding health-care costs. Yet, there is a third option: through promoting health literacy, getting better care for less money. The 21st century should become the century of the patient. Governments and health institutions need to change course and provide honest and transparent information, creating better doctors, better patients, and, ultimately, better health care.



Better doctors (Gigerenzer & Gray, in press-a) is based on an Ernst Strüngmann Forum in October 2009, which brought together 40 medical researchers, presidents of medical associations, editors of medical journals, health journalists, psychologists, and representatives from health organizations, health industries, and health insurances from eight countries.

Box 4.

Public Knowledge of Benefits of Breast and Prostate Cancer Screening in Europe

Women and men in countries with modern health systems are confronted with the question of whether or not to participate in screening for breast and prostate cancer. Because screening can lead to harms, such as overtreatment, citizens need to understand the potential benefits of these screening programs before they can make informed decisions about participating. The current knowledge about the benefits and harms of mammography and PSA screening is summarized in Tables 2 and 3. Gigerenzer, Mata, and Frank (2009) carried out the first European-wide assessment of citizens' knowledge of the cancer-specific mortality reduction (as opposed to the total cancer mortality reduction, which is equally important, but rarely communicated to the public). For mammography screening, this reduction is in the order of 1 in 1,000 (Table 2) and for PSA screening between 0 and 1 in 1,000 (Table 3). Note that these benefits are often communicated to the public in terms of more impressive relative risks, such as a "20% risk reduction" (e.g., from 5 to 4 in 1,000).

The study included nine European countries (Austria, France, Germany, Italy, Netherlands, Poland, Russia, Spain, and the United Kingdom). Face-to-face computer-assisted personal interviews were conducted with 10,228 persons selected by a representative quota method based on the official statistics concerning five variables: region, size of household, sex, profession, and age. Women were asked:

"1,000 women aged 40 and older from the general population participate every 2 years in screening for breast cancer with mammography. After 10 years, the benefit is measured. Please estimate how many fewer women die from breast cancer in the group who participate in screening compared to women who do not participate in screening."

Men were asked a corresponding question about PSA screening. Participants were also queried on the extent to which they consulted 14 different sources of health information. The percentage of women who have had mammography is 57 in Germany, 78 in France, 76 in Austria, 85 in the Netherlands, 66 in Italy, 75 in the United Kingdom, 52 in Spain, 47 in Poland, and 19 in Russia.

Ninety-two percent of women overestimated the mortality reduction from mammography screening by at least one order of magnitude or reported that they did not know (Table 4). For instance, in the United Kingdom, about 27% of women assumed a reduction of "200 in 1,000," possible due to their understanding of the popular "20% risk reduction" message. Eighty-nine percent of men overestimated the benefits of PSA screening by a similar extent or did not know (Table 5). The country in which men and women showed the least overestimation of the benefit of screening was Russia—not because Russians were better informed, but possibly because they were less misinformed. Women and men aged 50 to 69, and, thus, targeted by screening programs, overestimated the benefits of mammography and PSA screening more than the general public.

Citizens who searched frequently for health information on the Internet, TV, or in print media had no better understanding than those who did not. None of the 14 information sources, apart from health-insurance brochures, was associated with lower overestimation of the benefits. However, frequent consulting of physicians and health pamphlets tended to increase rather than decrease overestimation.

In sum, the vast majority of citizens in nine European countries systematically overestimate the benefits of mammography and PSA screening. In the countries investigated, physicians and other information sources appear to have little impact on improving citizens' perceptions of these benefits. One of the reasons why the public is systematically misinformed may be that many doctors do not know the scientific evidence either, and that many health brochures appear to pursue the goal of increasing participation rates (rather than of informing patients) and overstate the benefits while downplaying the harms. Whatever the causes, this study documents that information about the actual benefits of screening has not reached the general public. As a consequence, preconditions for informed medical decision making are not met in Europe, despite several governments' call for a 21st century of health care with informed patients.

HARDING CENTER FOR RISK LITERACY

Table 2
Transparent Fact Box Explaining the Benefits and Harms of Early Detection of Breast Cancer by Mammography

Breast cancer screening with mammography: per 1,000 women 50+		
	No screening	*Yearly screening over 10 years*
Benefits?		
Total cancer mortality	26	26
Breast cancer specific mortality	5	4
Risks?		
False positives with biopsies	–	50–200
Unnecessary treatments (e.g., lumpectomy)	–	2–10

Source. Gøtzsche, P. C., & Nielsen, M. (2006). Screening for breast cancer with mammography. *Cochrane Database of Systematic Reviews, 4*:CD001877.
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HARDING CENTER FOR RISK LITERACY

Table 3
Transparent Fact Box Explaining the Benefits and Harms of Prostate-Specific Antigen (PSA) Tests

Prostate cancer screening with PSA test: per 1,000 men 55+		
	No screening	*Screening over 9 years*
Benefits?		
Total cancer mortality	23.8	23.9
Prostate cancer specific mortality in the USA	2.3	2.3
Prostate cancer specific mortality in Europe	3.7	3.0
Risks?		
False positives with biopsies	–	50–200
Unnecessary treatments (e.g., prostatectomy)	–	10–30

Source. Andriole, G. L., Grubb, R. L., Buys, S. S., et al. (2009). Mortality results from a randomized prostate cancer screening trial. *New England Journal of Medicine, 360*(3), 1310–1319.
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Table 4
How Well Informed Are Women of the Benefits of Mammography Screening? Perceived Reduction of Breast Cancer Mortality Through Regular Participation in Mammography Screening. Question: "How Many Fewer Women Die From Breast Cancer in the Group Who Participate in Screening, Compared to Women Who Do Not Participate in Screening?" Best Correct Estimate is 1 in 1,000. Mean Across All Nine Countries is Weighted by Sample Size

	Percentage of responders									
Reduction out of 1,000?	*Mean*	*Germany*	*France*	*Austria*	*Nether-lands*	*Italy*	*United Kingdom*	*Spain*	*Poland*	*Russia*
None	6.4	1.4	0.8	2.4	0.7	5.3	2.0	3.9	4.2	16.1
1	**1.5**	**0.8**	**1.3**	**2.9**	**1.4**	**1.3**	**1.9**	**2.7**	**0.8**	**1.7**
10	11.7	12.8	15.7	11.0	10.7	10.6	10.3	6.9	9.7	12.4
50	18.9	21.3	21.7	22.1	22.6	17.4	13.9	11.7	20.5	20.1
100	15.0	16.8	21.5	20.8	22.5	13.9	17.0	11.3	14.8	10.8
200	15.2	13.7	23.7	11.0	20.1	15.2	26.9	15.7	17.1	6.8
Don't know	31.4	33.1	15.3	29.8	22.1	36.3	28.0	48.0	32.9	32.1

Table 5
How Well Informed Are Men of the Benefits of Prostate Cancer Screening? Perceived Reduction of Prostate Cancer Mortality Through Regular Participation in PSA Screening. Question: "How Many Fewer Men Die From Prostate Cancer in the Group Who Participate in Screening, Compared to Men Who Do Not Participate in Screening?" Best Correct Estimate is 0 or 1 in 1,000. Mean Across All Nine Countries is Weighted by Sample Size

	Percentage of responders									
Reduction out of 1,000?	*Mean*	*Germany*	*France*	*Austria*	*Nether-lands*	*Italy*	*United Kingdom*	*Spain*	*Poland*	*Russia*
None	**8.3**	**3.8**	**1.6**	**4.1**	**3.0**	**5.7**	**0.5**	**9.3**	**5.0**	**20.3**
1	**2.4**	**2.3**	**2.7**	**3.5**	**2.2**	**1.8**	**0.9**	**4.3**	**0.7**	**2.9**
10	14.4	17.7	16.9	24.4	11.5	11.9	15.9	17.0	13.9	10.7
50	19.3	23.0	21.6	27.1	20.2	18.5	17.3	25.1	17.9	15.0
100	14.0	17.2	21.1	20.8	20.3	9.2	15.6	18.8	14.5	7.3
200	11.8	9.7	20.2	14.2	14.2	12.2	19.5	17.9	11.3	3.4
Don't know	29.8	26.3	15.9	5.9	28.5	40.6	30.2	7.6	36.7	40.4

Do Doctors Understand 5-Year Survival Rates?

Survival rates are perhaps the most common statistic used to report on the progress against cancer. Health brochures regularly inform that early detection of cancer results in high 5-year survival rates. Former New York City mayor Rudi Giuliani said in a 2007 campaign advertisement that survival rates for prostate cancer were 82 % in the United States as opposed to 44 % in England under "socialized medicine." A report by the UK Office for National Statistics noted that 5-year survival for colon cancer was 60 % in the United States compared to 35 % in Britain. Experts dubbed this gap "disgraceful" and former British Prime Minister Tony Blair set a target to increase survival rates by 20 % over the next 10 years, saying that "We don't match other countries in its prevention, diagnosis, and treatment" (see Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz, & Woloshin, 2007, p. 58).

In fact, despite these large differences in survival rate, the *mortality rate* for colon and prostate cancer in Britain is about the same as the rate in the United States. Improvements in 5-year survival are usually touted as unambiguous signs of success. It might not be surprising that most people conclude from an increased survival an "extended life" or "delayed death." But, in the context of screening, this conclusion is wrong. Here, changes in survival rates have no relationship ($r = 0.0$) to changes in mortality for the 20 most common solid tumors in the United States (Welch, Schwartz, & Woloshin, 2000). Why is this?

This disassociation occurs because *survival rates* depend on the time the cancer is diagnosed, whereas *mortality rates* do not. A 5-year survival rate is defined as "the number of patients diagnosed with cancer still alive 5 years after diagnosis, divided by the number of patients diagnosed with cancer." To calculate a mortality rate, the time of diagnosis is ignored. Instead, the mortality rate is "the number of people who die from a certain cancer over a certain period, divided by the number of all people in the population." This difference makes the mortality rate, but not the survival rate, resistant against two biases: *lead-time bias* and *overdiagnosis bias.* The term lead-time bias refers to the fact that screening moves forward the time of diagnosis, but may not move back the time of death (the $r = 0.0$ mentioned above). The term overdiagnosis bias refers to the fact that screening detects cell abnormalities that may meet the pathological definition of cancer, but never become clinically significant due to slow progress (so-called nonprogressive cancer). By definition, these patients will not die of that cancer within the next 5 years, but they are included in the numerator of the survival rate which inflates it. In contrast, mortality rates do not depend on these two biases and can actually measure whether screening can save lives. The differences in survival rates between the United States and the United Kingdom, for instance, are largely due to the fact that many more Americans participate in screening, not that more Americans live longer.

Physicians should know how to interpret survival and mortality rates in order to advise their patients properly. But do they? Wegwarth, Gaissmaier, and Gigerenzer (in press) tested 65 experienced German physicians specialized in internal medicine. Physicians were randomly allocated to one of two survival-rate settings: "group" and "time."

In the "group" setting, data on a comparison between a screened and an unscreened group were given, while, in the "time" setting, data from between 1975 and 2004 were given. Each physician in each setting received four presentations of the same data:

- 5-year survival rates (5Y);
- 5-year survival and annual disease-specific mortality rates (5YM);
- annual disease-specific mortality (M);
- 5-year survival, annual disease-specific mortality, and incidence (5YMI).

Data were from the *Surveillance, Epidemiology and End Result* (SEER) program for prostate cancer (Ries et al., 2005). To mask the fact that these four presentations of data referred to the same cancer site (prostate), screenings and tumors were labeled with capital letters. Physicians were asked whether they would recommend the screening based on the information they had and whether they

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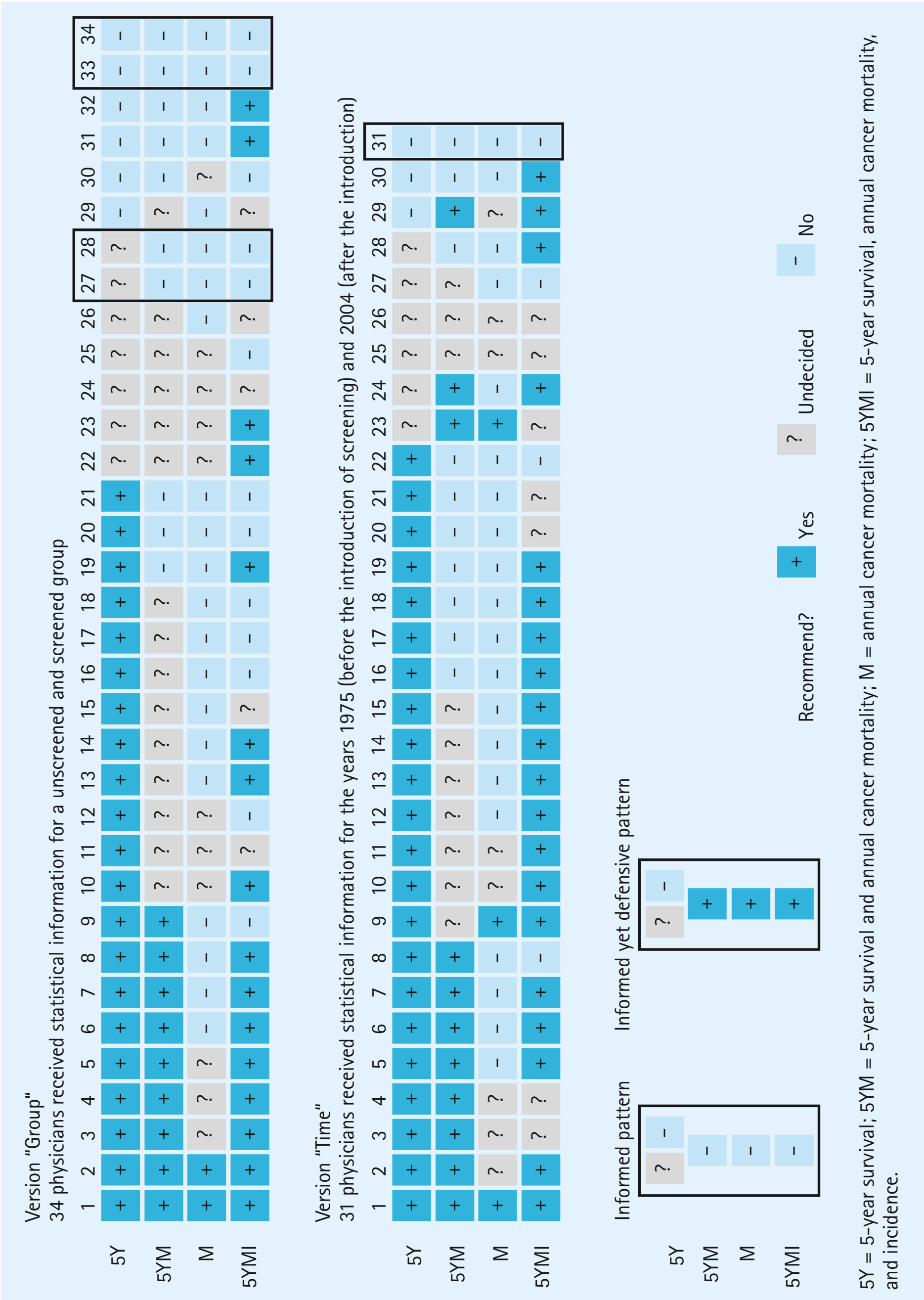

Figure 12. Do physicians understand that mortality rates allow for an unbiased judgment of the benefits of screening, whereas the 5-year survival statistic alone does not? If they understood, they would show either the "informed pattern" or the "informed yet defensive pattern." When asked if they would recommend screening, physicians showing the informed pattern would answer "no" or "undecided" for the condition "5-year survival rate alone" (5Y) and "no" for all other conditions because the mortality rates did not indicate any difference between the groups or time points. Those showing an informed, yet defensive, pattern would also answer "no" or "undecided" for the condition "5-year survival alone" (5Y), but "yes" for all conditions that include the mortality rates. The figure illustrates 65 physicians' screening recommendations: Across the two versions, only 5 physicians showed the informed pattern (highlighted by boxes) and none of them the informed, yet defensive, pattern. These results make clear that the majority of physicians are insufficiently trained to judge whether screening is effective or not, and, therefore, are unable to accurately inform their patients.

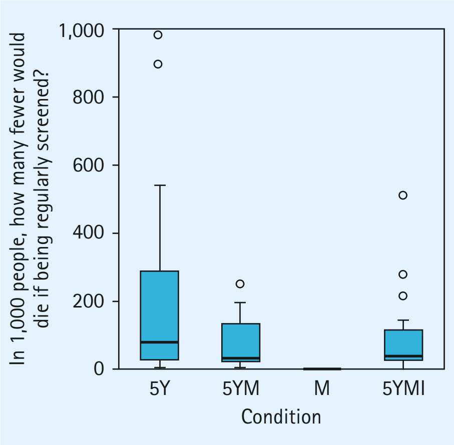

Figure 13. Physicians tend to overestimate the benefit of cancer screening when they are given information in terms of 5-year survival rates. Estimates were based on the question "Out of 1,000 people, how many fewer will die of tumor X if they regularly attend screening?" The absolute risk reduction was zero. Overestimation is highest when only 5-year survival rates are communicated. Conditions: 5Y = 5-year survival; 5YM = 5-year survival and annual disease-specific mortality; M = annual disease-specific mortality; and 5YMI = 5-year survival, annual disease-specific mortality, and incidence.

thought it to be effective. What would an informed recommendation look like? The 5-year survival statistic alone does not allow an unbiased judgment of the benefit of screening. Thus, if physicians are aware of this problem, they should choose either a "no" or "I can't decide" recommendation in condition 5Y. The other three conditions provide information on disease-specific mortality which allows an evaluation of the effect. Because the SEER study showed no decrease in mortality in the group receiving screening (setting "screened group" or "later time point"), but instead a slight *increase* in mortality, a statistically literate physician should choose "no" in these three conditions. Therefore, an informed pattern of recommendation over the four conditions should be: I can't decide/no, no, no, and no (Figure 12).

Figure 12 shows the actual pattern of recommendations for each physician across the four conditions—ordered by the number of "yes" choices. The "group" and "time" settings yielded similar response patterns. Only 4 physicians in the "group" setting ($n = 34$) and 1 physician in the "time" setting ($n = 31$) answered correctly, that is, showed the informed pattern of recommendation. In contrast, the far majority of physicians recommended screening more often when the 5-year survival rate was given (5Y, 5YM, 5YMI) than in the condition with disease-specific mortality (M). For instance, 43 of 65 physicians recommended screening when presented solely with 5-year survival rates, whereas only 5 of these same physicians did so when presented solely with mortality rates. When asked for the reasons for their recommendation, physicians' most frequent answer was that the 5-year survival rates had increased over time or across groups. Many physicians described this increase as "meaningful," "clinically significant," or "exemplifying the merits of early detection." Recommendations against screening were mainly triggered by the lack of positive difference in mortality rates and the impression that the benefit was either negative or did not exist.

The misleading influence of 5-year survival rates on physicians' judgment of the screening's effectiveness was similar. Across settings, 51 of the 65 physicians judged the screening to be effective when presented with 5-year survival rates, but only 3 still did when shown mortality rates. Similarly, when physicians were asked how many fewer people would die (out of 1,000) from cancer if they were regularly screened, they overestimated the correct number (zero) in all conditions that included 5-year survival rates (Figure 13).

When asked about the lead-time bias, 54 of 65 physicians did not know what this concept means; and of the other 11 who thought they did, only 2 could explain the bias correctly. When asked about the overdiagnosis bias, only one thought he knew, but his explanation bore no resemblance with the phenomenon.

This study is the first to investigate whether physicians understand 5-year survival rates. It reveals that the far majority of physicians are misled by the differences in survival rates with which screening is commonly advertised, mistaking these for differences in mortality rates. Medical schools urgently need to begin teaching students to understand health statistics.

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Defensive Decision Making by Swiss Physicians

One might assume that doctors are free to treat their patients according to the best evidence. Yet, this is not the case. Tort law in many countries and jurisdictions not only discourages but actively penalizes physicians who practice evidence-based medicine. For instance, Daniel Merenstein, a young family physician in Virginia, was sued in 2003 because he had not automatically ordered a PSA test for a patient, but instead followed the recommendations of leading medical organizations and informed the patient about the pros and cons of the test. The patient later developed an incurable form of prostate cancer. The plaintiff's attorney claimed that PSA screening is standard in the Commonwealth of Virginia and that physicians routinely order the test without informing their patients. The jury exonerated Merenstein, but his residency was found liable for US$ 1 million. After this experience, Merenstein felt he had no choice but to practice defensive medicine, even at the risk of causing unnecessary harm: "I order more tests now, am more nervous around patients; I am not the doctor I should be." (Gigerenzer et al., 2007, p. 161)

The term "defensive medicine" refers to the practice of recommending a test or treatment that is not the best option for the patient, but one that protects the physician against the patient as a potential plaintiff. Defensive medicine is a reaction to the rising costs of malpractice insurance premiums and patients' bias to sue for missed or delayed diagnosis or treatment. The saying goes: "No one is ever sued for overtreatment." Almost all (93 %) of 824 surgeons, obstetricians, and other United States specialists at high risk of litigation reported practicing defensive medicine, such as ordering unnecessary CTs, biopsies, and MRIs, and prescribing more antibiotics than medically indicated (Studdert et al., 2005). Is defensive medicine a phenomenon particular to the United States or does it also occur in European countries, where trials, such as that of Dr. Merenstein, are unthinkable?

At a continuing medical education conference in Switzerland, 552 general physicians and internists were asked whether they believed that the PSA test is an effective test (that its benefits outweigh potential harms for the patient) and whether they generally recommend the test to patients (Steurer et al., 2009). Two hundred fifty (45 %) returned the questionnaire. Only about half of the physicians (56 % of the general physicians and 53 % of the internists) believed that regular PSA screening is an effective test and that its advantages outweigh potential harm. Yet, in both groups, 75 % recommend regular PSA screening to men older than 50 years of age. Forty-one percent of the general practitioners and 43 % of internists said that they sometimes or often recommend this test for legal reasons.

The result of this study indicates that defensive medicine exists in Switzerland. Apart from legal concerns, monetary motives could also affect physicians' recommendations. However, as a Swiss physician earns less than 10 Swiss francs for ordering a PSA test, monetary incentives may play a minor role. A further factor might be that some physicians do not know the legal situation. For instance, Australian guidelines also do not recommend regular PSA screening, but nearly all of the physicians, surveyed in an Australian study, recommend this test to men over 50 years of age and only about one quarter of them knew that they are legally protected when they do not conduct screening. The overdiagnosis documented in this study is consistent with the overtreatment among Swiss gynecologists, who perform hysterectomies on 16 % of the general public, compared to only 10 % on physicians' wives. Defensive decision making among Swiss physicians is a surprising result, given that in Switzerland physicians who do not recommend interventions whose effectiveness is controversial need not fear litigation.

Helping Patients With Low Numeracy to Understand Medical Information

If the chance of winning a car in a lottery is 1 in 1,000, what percentage of tickets win a car? For most academics, the answer 0.1 % is straightforward. Yet, this question proved to be the most difficult one in a simple numeracy scale (Table 6). Only 46 % of 1,001 Germans and 24 % of 1,009 Americans provided this

Table 6
Items of the Numeracy Scale and Percent of Germans (n = 1,001) and Americans (n = 1,009) in Probabilistic National Samples Answering Correctly

		Germany	*US*
(1)	Imaging that we flip a fair coin 1,000 times. What is your best guess about how many times the coin will come up heads in 1,000 flips?	72.6 %	73.2 %
(2)	In the Bingo Lottery, the chance of winning a $10 prize is 1 %. What is your best guess about how many people will win a $10 prize if 1,000 people each buy a single ticket?	67.6 %	57.7 %
(3)	In the Daily Times Sweepstakes, the chance of winning a car is 1 in 1,000. What percent of tickets for the Daily Times Sweepstake win a car?	46.3 %	23.5 %
(4)	Imagine that we roll a fair, six-sided die 1,000 times. Out of 1,000 rolls, how many times do you think the die will come up even (2, 4, or 6)?	63.5 %	57.1 %
(5)	Which of the following numbers represents the biggest risk of getting a disease? 1 in 100, 1 in 1,000, or 1 in 10?	71.8 %	75.3 %
(6)	Which of the following represents the biggest risk of getting a disease? 1 %, 10 %, or 5 %?	78.6 %	83.1 %
(7)	If the chance of getting a disease is 10 %, how many people would be expected to get the disease out of 1,000?	88.8 %	83.1 %
(8)	If the chance of getting a disease is 20 out of 100, this would be the same as having a ____ % chance of getting the disease.	72.8 %	70.3 %
(9)	If Person A's chance of getting a disease is 1 in 100 in 10 years, and Person B's risk is double that of A, what is B's risk?	54.5 %	57.3 %

answer (Galesic & Garcia-Retamero, 2010). This study is one of the few that used probabilistic national samples rather than selected convenience samples of participants. Most strikingly, variability in numeracy between people with lower or higher education was much larger in the United States than in Germany. Whereas college-educated Americans could answer as many items (about 80 %) correctly as their German peers, Americans with less than a high-school diploma could answer only 40 % of the items correctly, compared to 60 % among Germans. Differences in educational systems—in particular the stronger focus on mathematics and science education in Germany—are likely to be the main factor underlying this discrepancy.

Lack of numeracy in the general population has implications for medical decision making. For example, almost 30 % of the German and United States citizens could not say whether 1 in 10, 1 in 100, or 1 in 1,000 represents the largest risk. Although the focus of this study is on the patient, it should be added that 21 out of 85 of American physicians at grand rounds (= 25 %) were also not able to translate 1 in 1,000 into 0.1 % (see Gigerenzer et al., 2007).

How can we remedy the problem of low numeracy? One proposal is to communicate risks in graphs rather than numbers. It is often assumed that a picture says more than a thousand words. Bar charts, pie charts, and line plots were first used in the late 18th and early 19th centuries. William Playfair, an economist and author of *Commercial and political atlas* (1786) and *Statistical breviary* (1801) was one of the first to use these graphical formats (Figure 14). Icon arrays are even more recent: They began to be widely used only in the early 20th century, promoted by Otto Neurath (1882–1945), a prominent member of the Vienna Circle, to explain social and economic facts to the mostly uneducated Viennese (Figure 15). Will people with low numeracy understand such graphs intuitively?

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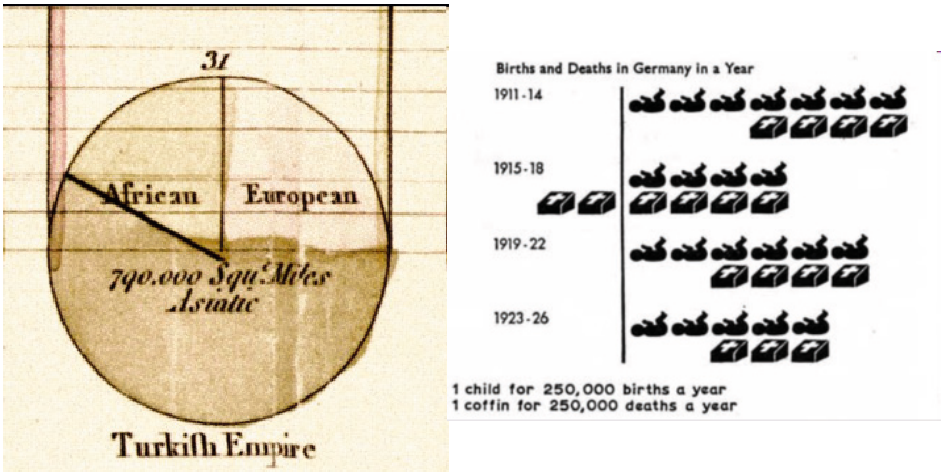

Figure 14. Example of the first pie charts by William Playfair (left, end of 18th century) and one of the first icon arrays by Otto Neurath (right, beginning of 20th century).

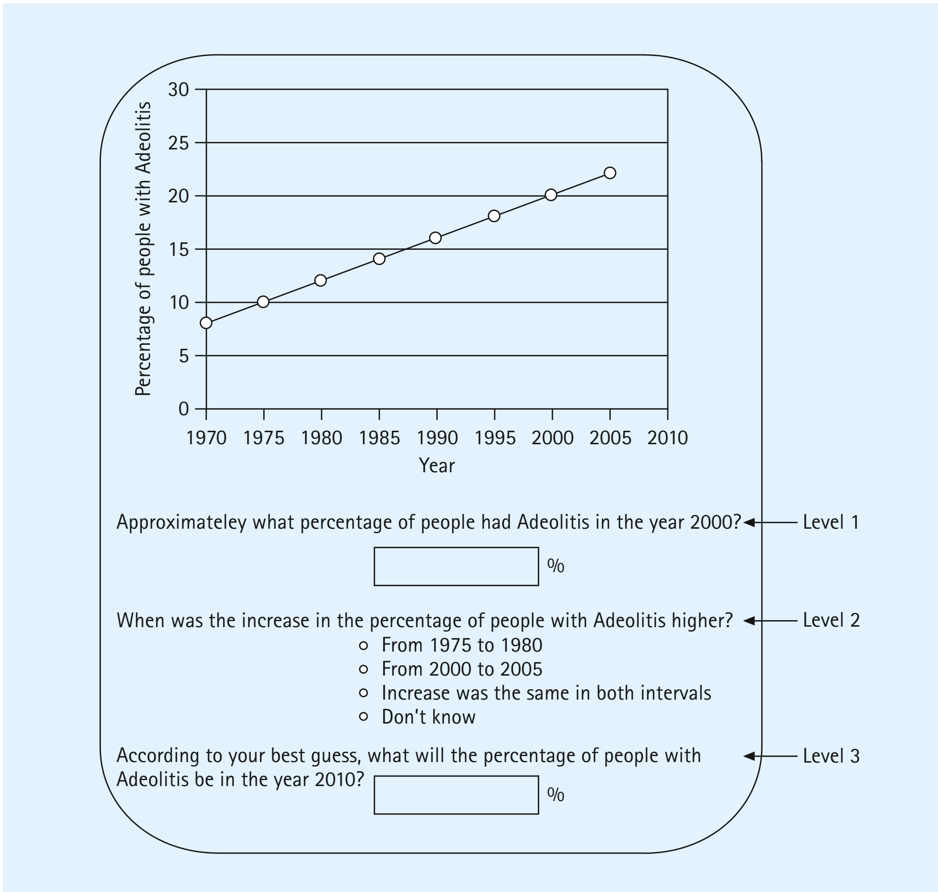

Figure 15. Example of an item from the graph-literacy scale (Galesic & Garcia-Retamero, in press-b)

To answer this question, Galesic and Garcia-Retamero (in press-b) developed a scale to measure basic graph-literacy skills needed to understand risks in the health domain. The items measure the ability to read the data in a graph, understand relationships, and project beyond the data (Figure 15). The scale has good psychometric properties and takes about 10 minutes to complete. It was used to investigate graph-literacy skills of the general population in Germany and the United States using probabilistic national samples. The results show that substantial parts of both populations cannot perform elementary tasks involving even the simplest graphs. For example, 16 % of Americans and 12 % of Germans do not know what a quarter of a pie chart is in percentages. Similarly, 15 % of people in the United States and 17 % in Germany cannot read the height of a bar chart with fully labeled axes and gridlines as an additional help.
Garcia-Retamero and Galesic (2010a) showed that patients with low numeracy can be helped with graphical aids. Icon arrays improved the performance of low-numeracy participants almost to the level of high-numeracy ones, but only if they had a sufficient level of graph literacy. The results indicate the possibility of compensating low numeracy by high graph literacy. They also point to the need for investigating graphical presentation formats that are intuitively understandable to the least educated patients, including the total number of icons, the kind of analogies, and the use of comparison risks rooted in patients' everyday experiences.

A Brief Analysis of Flawed Risk Communication: The "Swine Flu" Pandemic (H1N1) in 2009

The influenza pandemic (H1N1) in 2009 exemplified many of the difficulties policy makers have in communicating risk to the public: (1) Available and missing evidence was not communicated transparently and completely; (2) rather than informing citizens, officials treated them paternalistically; and (3) public trust in vaccinations and institutions was damaged as a result of (1) and (2).

Intransparent and Incomplete Information

In February 2009, the World Health Organization (WHO) redefined pandemics as diseases that spread across multiple WHO regions, without reference to disease severity. Two months later, the WHO released estimates of 2–7.4 million H1N1 deaths (and 2 billion infections) worldwide. Thus, when the WHO declared the H1N1 influenza a pandemic in June 2009, most citizens and many decision makers were misled to believe that the H1N1 influenza was spreading worldwide and had severe consequences. In reality, until July 2010, the WHO counted "only" 18,366 H1N1 deaths. Although the WHO knew as early as June 2009 that the H1N1 virus would not be as aggressive as expected, they did not inform the public accordingly.

Paternalism

In August 2009, the winter season in the southern hemisphere was over and had resulted in considerably fewer H1N1 deaths (130) than the seasonal flu deaths on average (1,500 to 3,000). Even then, officials did not change information policy. In October 2009, a German official predicted up to 35,000 H1N1 deaths in Germany. The same official stated later that such "early and dramatic warnings [were] necessary [because] many self-proclaimed and unauthorized experts were using all possible and assumed harms of the vaccination to argue against it." In reality, scientific evidence about benefits and harms of the vaccination was scarce. The media amplified this form of paternalism by inviting experts to argue for or against the vaccination rather than to provide evidence or point out the lack thereof.

Loss of Public Trust in Vaccinations and Institutions

Evidence-free controversies, intransparent communication of uncertain evidence, and a fairly benign course of the H1N1 influenza resulted in the emergence, rebuttal, and reemergence of conspiracy theories. Thus, the lack of transparent risk communication "may yet claim its biggest victim—the credibility of the WHO and the trust in the global public health system" (Cohen & Carter, 2010,

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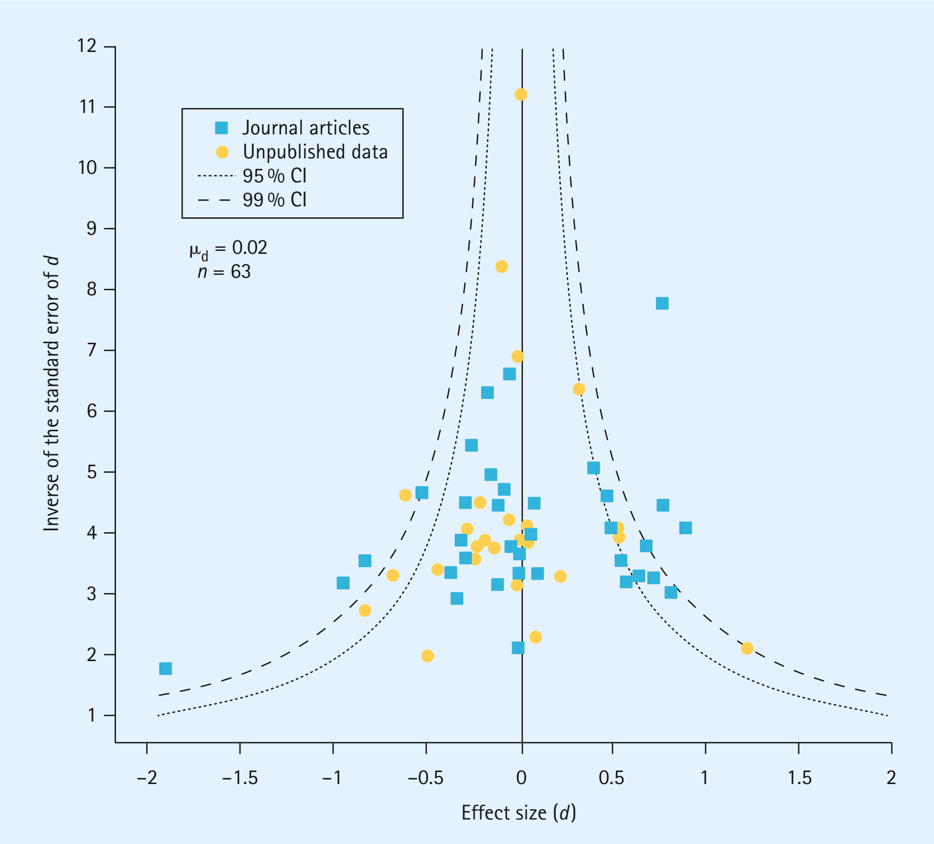

Figure 16. Does the too-much-choice effect exist? A meta-analysis of 63 experimental conditions in which the too-much-choice effect was investigated. Effect sizes are measured by Cohen's *d* and plotted against their inverse standard error, which determines the weight that each condition carries in the meta-analysis. A positive *d* indicates a too-much-choice effect, while a negative *d* indicates a more-choice-is-better effect. The dotted and dashed lines indicate confidence intervals (CI) under the assumption that the data set is homogeneous and normally distributed around the mean effect size.

p. 1279). To avoid this risk of risk communication, the following measures should be adopted by policy makers: transparent descriptions of situations instead of buzzwords, such as "pandemic;" transparent communication of existing and missing evidence instead of dramatic estimates; and disclosure of political decision processes and conflicts of interest.

The "Too-Much-Choice" Effect: A Mean Effect Size of Zero?

Customers face an ever-increasing number of options to choose from. While individuals may be attracted by this variety, some scholars argue that an overabundance of choice might eventually lead to a decrease in the motivation to buy or the satisfaction with the option finally chosen. For instance, a classic experiment in an upscale supermarket in Menlo Park, California, reported that with 6 varieties of jam offered at a tasting booth, 30 % of shoppers bought one or more, but with 24 varieties only 3 % did so (Iyengar & Lepper, 2000). This has been dubbed the too-much-choice effect. The possibility of a negative effect of large assortment sizes challenges neoclassical theories in economics and marketing, according to which expanding a choice set cannot be detrimental to decision makers. From an applied perspective, marketers and public policy makers might need to rethink their practice of providing ever-increasing assortments of mustards, olive oil, and chips.

In his dissertation, Scheibehenne (2008) tried to replicate the findings of the experiments reported by Iyengar and Lepper (2000). Yet, in a total of eight studies he could not find a too-much-choice effect, neither in supermarkets in Germany nor in the United States. This negative result called for a more systematic meta-analysis of published and unpublished studies. Scheibehenne, Greifeneder, and Todd (2010) analyzed 63 experimental conditions with a total of 5,036 participants. Figure 16 shows that the mean effect size of the too-much-choice effect across all conditions turned out to be virtually zero (mean d = 0.02, CI95 –0.09 to 0.13). The effect also did not depend on the difference in size between the small set and the large set, and there was no curvilinear relationship between assortment size and choice overload. A subsequent metaregression further indicated that a more-choice-is-better effect may be expected for studies that use (food) consumption as a dependent measure or if decision makers have strong preferences prior to making a choice. Also, published articles were somewhat more likely to report a too-much-choice effect, as compared to unpublished manuscripts. These results do not rule out that too-much-choice effects might exist in specific domains. But if one exists, it is essential for identification purposes to develop a more theory-driven understanding of the decision processes that people adopt.

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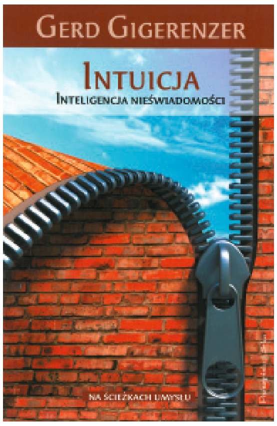

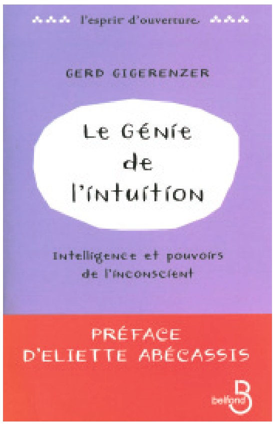

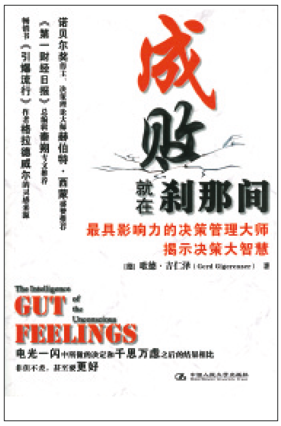

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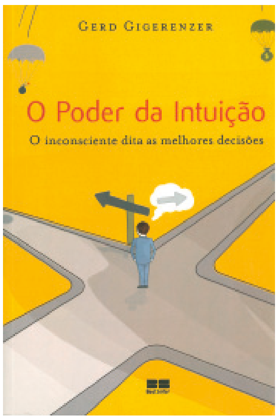

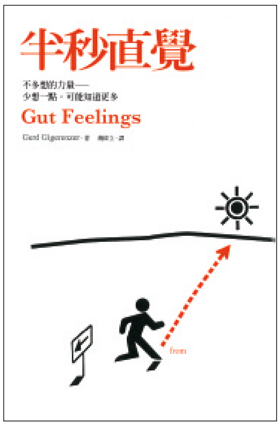

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