

Is knowing always feeling?

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In a recent issue of PNAS, Maia and McClelland (1) report findings that raise questions regarding the interpretation of a highly influential neuropsychological study of decision-making behavior (2). That study has been interpreted widely as evidence that decision-making behavior is governed by emotional factors outside of awareness. The impact of Maia and McClelland's study is not so much to challenge this idea in its own right, which most sophisticated observers of behavior would acknowledge has potential merit. Rather, it is to set a standard for what counts as evidence of an unconscious influence on behavior or, more accurately, to bring this standard from a long tradition of cognitive psychological research to bear on the rapidly growing field of research into the neural bases of decision-making.

Recent years have seen a dramatic surge in research seeking to understand the neural processes underlying how we make decisions and choices. These investigations have been initiated by both behavioral scientists, who have begun to see the usefulness of constraining theoretical models with information gleaned from studying the brain, and neuroscientists, who have become interested in using existing models of decision-making to examine neural processing.

Researchers in this growing field have used a variety of methods in their quest to describe how the brain makes decisions, including neuroimaging techniques such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), electroencephalography (EEG), direct neuronal recordings in nonhuman species, and work with brain-damaged patients. Among the most influential work using the last of these methods has been that of Bechara and colleagues (2–4). These researchers have conducted investigations of the decision-making capabilities of patients who have suffered injury to ventromedial portion of the frontal lobe (2–4). It has long been known, dating back to the famous case of Phineas Gage, that damage to this area of the brain leads to a deficit in certain types of decision-making (5).

In general, patients with ventromedial prefrontal cortex (vmPFC) lesions exhibit normal cognitive abilities as measured on standard tests of memory, language aptitude, and general intelli-

gence. However, as in Gage's case, the patients frequently demonstrate poor decision-making behavior, and family members and friends often complain of something amiss in the patient's postinjury personality (6). The patients are described by phrases such as “emotionally flat,” “decides against his best interest,” “doesn't learn from his mistakes,” “is impulsive,” “decisions lead to negative consequences,” and so on. Although these are useful observations, as yet it has proven difficult to convert them into firm behavioral and theoretical concepts.

The Iowa Gambling Task

Bechara *et al.* (2) sought to do so by constructing a controlled task in which participants search for monetary payoffs in an uncertain environment, often referred to as the “Iowa Gambling Task” (IGT). In the IGT, participants choose cards from any of four decks. Each deck has a different win/loss propensity, which can only be learned by the experience of sampling cards. Specifically, one pair of decks is associated with high rewards, but occasionally even higher losses, with an overall negative expected value. The other pair of decks is associated with more modest rewards, but lesser losses, with an overall positive expected value. Over time, most participants realize that the first two decks are “disadvantageous,” as they lead to accumulating losses, and therefore eventually gravitate toward the two “advantageous” decks. However, vmPFC patients tend not to switch but instead stick with choosing from the disadvantageous decks throughout the experiment.

Results from the IGT appeared to capture something important regarding the decision-making proclivities of these vmPFC patients, namely that patients persisted in making choices that were not in their long-term interests. These results led to the formulation of the “somatic marker hypothesis,” which broadly states that normal adaptive decision-making in complex, uncertain environments depends on somatic markers, that is, emotional signals that warn us when important events are about to occur and bias our decisions accordingly. A lack of somatic markers generated by the vmPFC patient population was hypothesized to explain their inability to switch to the higher-utility advantageous decks. Importantly, the somatic marker hypoth-

esis was also invoked to explain the finding that normal subjects seem to choose the advantageous decks in the IGT before being consciously aware of the relative advantage of one pair of decks over the other. It is this claim that is challenged by Maia and McClelland (1).

The pioneering work of the Iowa group should be recognized for the attention it has drawn to the potential value in studying the neural basis of decision-making, and in bringing this question to the laboratory through the use of structured decision-making tasks involving economic choices. However, the IGT and its variants have provoked vigorous exchanges since the publication of the initial results. In the intervening years, researchers have sought to explain the performance of both the normal controls and the vmPFC patients by appealing to factors other than the somatic marker hypothesis and the “myopia for the future” explanation favored by the Iowa group.

Many decision researchers have argued that the IGT may confound several factors known to play an important role in decision-making (7). For example, the disadvantageous decks, although yielding an overall lower expected value, do have higher, more conspicuous rewards (and correspondingly higher punishments) on each card than do the advantageous decks. Therefore, performance of the patient group could be explained by a hypersensitivity to reward, or perhaps reduced sensitivity to loss (however, see ref. 8). Additionally, the risk profiles of the advantageous and disadvantageous decks are different, with the bad decks featuring higher risk (as defined by the variance of the deck) than the good decks. Participants may therefore, in fact, be driven by the underlying risk profiles, with vmPFC patients demonstrating greater risk-seeking behavior. Supporting this hypothesis, research has shown that vmPFC patients do indeed appear to prefer riskier environments than normal controls (9). Finally, an inability to inhibit prepotent responses has also been suggested as a possible explanation for patient behavior, with

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the patient powerless to overcome the temptation to select the (initially positive) bad decks.

Other investigations of behavior on the IGT have focused on examining performance on the task itself in greater detail. This is the approach taken by Maia and McClelland (1), who have focused in particular on the status of participants' knowledge about the decks and the bases for their decisions. The primary question they asked is whether participants were truly unaware of explicit information about the relative value of the decks when they switched to the more advantageous ones.

Conscious Versus Unconscious Influences on Decision-Making

Maia and McClelland drew on well-hewn cognitive scientific methods for probing participants' awareness of the underlying trends in the four decks with which they were confronted. By specifying exactly what is meant by the participant "knowing the advantageous strategy," and probing more deeply for participants' knowledge about the information needed to compute expected value and their ability to do so, they make a strong case that behavior in the IGT could as easily be guided predominantly by conscious knowledge about the structures of the decks as by unconscious influences. Needless to say, care was taken to evaluate the possible impact that their methods themselves may have had on behavior and/or awareness. A control group was run, replicating the conditions (and the results) of the original study by Bechara *et al.*, with behavior of the experimental group comparable to that of the control group.

Of course, establishing that conscious knowledge is a possible influence is not the same thing as establishing that it is the sole or even primary influence on behavior. However, their findings do raise important new questions. First, at the very least, they call into question the necessity of the somatic marker hypothesis. Maia and McClelland pursue this question further by reviewing other lines of evidence that have been garnered in support of this hypothesis. They conclude that these lines of evidence are subject to reasonable alternative interpretations, and that as yet there is no

decisive evidence to support the claim that unconscious emotional processes are necessary and sufficient for the computation of expected value under uncertainty.

Perhaps one of the factors that made the original findings of Bechara *et al.* so striking, and the somatic marker hypothesis so influential, is that they ran against the grain of thinking in behavioral science at the time it appeared. The traditional view (at least within cognitive psychology) has been that

Were participants truly unaware of explicit information about the relative value of the decks?

certain types of higher-level decision processes, such as those involving the computation of expected value, do not rely on (and are not necessarily influenced by) emotional processes. The somatic marker hypothesis raised a serious challenge to this view, captured the interest and imagination of researchers ranging from neuroscientists to economists, and fueled a growing industry of research investigating emotional influences on decision-making. The present findings, and the arguments presented by the authors, represent a well-reasoned and carefully executed counter-challenge to the necessity, if not the viability, of the somatic marker hypothesis. This, of course, begs the question: How can it be established, beyond doubt, that conscious rather than unconscious knowledge determines participants' decision-making behavior; or, to favor the somatic marker hypothesis, whether unconscious processes are sufficient to explain this behavior? Maia and McClelland do not answer these questions (although they offer some possible future directions to pursue). However, importantly, they raise the standard of methodological practice in this important and interesting area of research.

Finally, in pursuing the relationship between emotion and decision-making, it is important to be clear about the questions being asked. As we noted at the outset, few would quarrel with the idea that emotional factors have an influence on decision-making. The more interesting questions are: To what extent are emotional processes necessary and primary, rather than one of many potential influences on decision-making? What sorts of decisions can be influenced by emotions? And, as addressed by the current work, to what extent are these influences unconscious? Based on a growing corpus of work at the intersections of psychology, behavioral economics, and neuroscience (10, 11), it is becoming increasingly clear that emotional processes do have an important role to play in many, and perhaps even most, decision processes. At the same time, recent work by our group and others suggests that the relationship between decision-making and emotion is better characterized as an interplay, rather than a dependency of one on the other (12–14). However, this work has only begun to scratch the surface of the complex dynamic interactions that occur between emotion and decision-making. Indeed, the very term "emotion" demands a more precise characterization. The most important work lies ahead, in characterizing these interactions and developing a deeper understanding of the mechanisms that govern them. Here again, we believe that Maia and McClelland make an important contribution, by highlighting the significant role that sophisticated methods, developed in the behavioral sciences over the past 30 years, have to play as an ingredient of meaningful progress.

More broadly, we also suggest that future studies examining the neuroscience of decision-making could fruitfully make use of the wide variety of judgment and decision-making tasks, and attendant theory, that have been developed by psychologists and economists over the years. Active collaboration between behavioral scientists and neuroscientists has great potential to elucidate the mechanisms that underlie how we make decisions and judgments. This is something that we not only feel, but also know.

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