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Brief article

Anticipatory emotions in decision tasks: Covert markers of value or attentional processes?

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ABSTRACT

Anticipatory emotions precede behavioral outcomes and provide a means to infer interactions between emotional and cognitive processes. A number of theories hold that anticipatory emotions serve as inputs to the decision process and code the value or risk associated with a stimulus. We argue that current data do not unequivocally support this theory. We present an alternative theory whereby anticipatory emotions reflect the outcome of a decision process and serve to ready the subject for new information when making an uncertain response. We test these two accounts, which we refer to as emotions-as-input and emotions-as-outcome, in a task that allows risky stimuli to be dissociated from uncertain responses. We find that emotions are associated with responses as opposed to stimuli. This finding is contrary to the emotions-as-input perspective as it shows that emotions arise from decision processes.

1. Introduction

As cognitive science continues to seek connections between biological and social factors, it will become increasingly critical to understand the role that emotion and physiology play in information processing. One central finding in this pursuit is that physiological markers of emotion (i.e., skin conductance responses; SCRs) occur prior to particular types of choices in decision-making tasks, suggesting that covert emotions can affect cognition. While a variety of theories attempt to characterize the causal factors that generate these emotions, as well as the psychological function of emotions, most extant theories assume that these *anticipatory emotions* carry information about the value of particular choices, and thus serve as inputs to the decision process. In this paper, we develop an alternate account in which emotions arise from the decision-making process, and carry information about the uncertainty or contextual novelty associated with a decision. We develop a framework that helps to clarify the functional role and theory behind these two descriptions of anticipatory emotions, which we refer to as *emotions-as-input* and *emotions-as-outcome*, and suggests ways in which these two views can be dissociated. We use this framework to understand how emotions affect performance in choice tasks in general and test the framework's predictions in a categorization task in particular.

The canonical example of anticipatory emotions in a cognitive task comes from work on the Iowa Gambling Task (IGT; Bechara, Damasio, Tranel, & Damasio, 1997). In this task, there are two primary types of stimuli: decks of cards that are associated with overall positive outcomes and decks that are associated with overall negative outcomes. Importantly, the individual trial outcomes associated with either stimulus type are variable, and thus are difficult for subjects to learn. However, the variability in outcome is not constant across stimuli; in standard versions of the task the negative decks are appreciably more variable and produce large rewards as well as large losses.

The key finding in this task is that neurologically intact subjects show increased skin conductance responses (SCRs) prior to making choices involving the negative stimuli (Bechara et al., 1997). Because SCR has historically been

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used as an indicator of emotion (Dawson, Schell, & Filion, 2000) and patients with damage to putative emotional centers, such as the amygdala (Bechara, Damasio, Damasio, & Lee, 1999) and ventromedial prefrontal cortex (Bechara, Tranel, Damasio, & Damasio, 1996; Bechara et al., 1999; for review see Bechara, Damasio, & Damasio, 2000), fail to exhibit these responses and make poor choices, SCR is considered to be indicative of emotional involvement in the decision process. While no physiological measurement can capture the subjective quality of emotional experience, we will refer to these SCRs as markers of emotion throughout the paper for consistency with this literature.

In terms of our dichotomy, many interpretations of these SCRs conform to the emotions-as-input perspective (e.g., the Somatic Marker Hypothesis; SMH; Damasio, Tranel, & Damasio, 1991; see Fig. 1, for an outline of both perspectives). This account posits that emotion contributes to decision-making on a trial-by-trial basis by providing information about the value associated with a particular stimulus (Damasio, 1994; Loewenstein, Weber, Hsee, & Welch, 2001; Slovic, Finucane, Peters, & MacGregor, 2004). For example, in the standard IGT, anticipatory emotions are said to provide a marker of the value of a choice by triggering the negative feelings that were previously experienced during encounters with the stimulus (e.g., during monetary loss or negative feedback) and "act as covert biases on the circuits that support processes of cognitive evaluation and reasoning" (Bechara et al., 1997, p. 1294). The psychological role of anticipatory emotions from an emotions-as-input perspective is to drive decision-making performance in cases of uncertainty, prior to subjects' conceptual mastery of the task (Bechara et al., 1997; but see Maia & McClelland, 2004). Importantly, anticipatory emotions, from this perspective, do not depend on any subjective beliefs or explicit decision processes, and arise from early sensory processing of the stimuli.

An alternate formulation holds that emotions arise from the outcome of a decision process. According to the emotions-as-outcome view, people in choice tasks experience fluctuations in anticipation when confronted with uncertain stimulus-outcome contingencies, such as those present (particularly for the negative decks) in the IGT. While not the dominant view in research exploring emotion and choice, there are a variety of examples of this type of theory in the broader literature. One example is the locus coeruleus – norepinephrine theory advanced by Aston-Jones and colleagues (Aston-Jones & Cohen, 2005; Nieuwenhuis, Aston-Jones, & Cohen, 2005). This theory suggests that when the outcome of a comparator process indicates that a motivationally significant stimulus is present, a phasic burst of norepinephrine is delivered via connections from the locus coerulius to attentional regions of the brain to enhance subsequent processing of the stimulus. This burst of arousal can be likened to the Sokolovian orienting response (Sokolov, 1966; Sokolov, Spinks, Naatanen, & Lyytinen, 2002) in that it indicates a state of information readiness. A number of studies suggest that these kinds of responses may be crucial to enhancing an organism's ability to learn (Love & Gureckis, 2007; Ranganath & Rainer, 2003; Yu & Dayan, 2005) when their internal representations are insufficient to cope with contingencies present in the current environment.

Interestingly, for several reasons, the evidence is largely equivocal between the emotions-as-input and emotions-as-outcome views. First, when using a gambling task, it is difficult to determine whether choices made from particular decks are the result of implicit (or explicit) beliefs about the value (risk, etc.) of the deck or are exploratory (i.e., information gathering). Thus, it is difficult to decide whether anticipatory emotions reflect markers that code the value of a particular stimulus (emotions-as-input), or the outcome of a decision process involving a significant or uncertain choice (emotions-as-output). Second, because emotions-as-input theories are able to account for increased SCRs attributable to either positive or negative

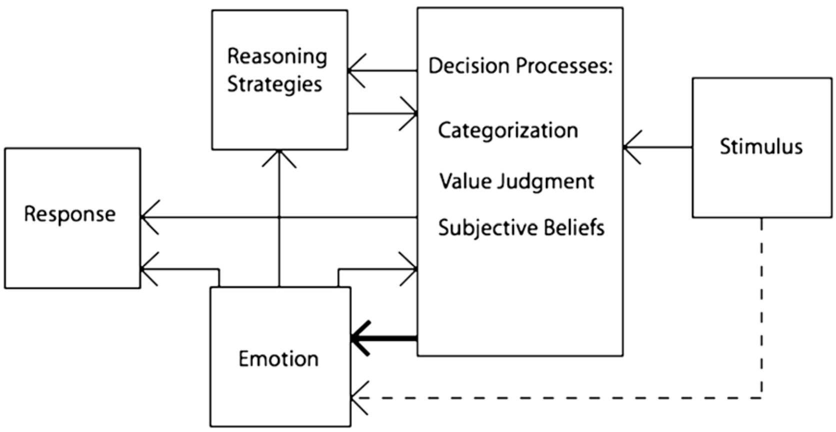

Fig. 1. Diagram illustrating the differences between the emotion-as-input and emotion-as-outcome perspectives (adapted from Bechara et al., 1997). The dashed line reflects the key feature of the emotion-as-input view; emotions arise directly from sensory processing of the stimulus and can affect responses unmediated by cognitive aspects of the decision process. Because emotions can by-pass the cognitive aspects of the decision process, they are interpreted, within the emotion-as-input perspective, as markers of value. The thick, solid line reflects the key feature of the emotion-as-outcome view; emotions arise from a decision about how to categorize the stimulus. Emotions from this perspective are interpreted as attentional mechanisms that do not carry information about value per se, but can, for example, facilitate the processing of value judgments. The other thin solid arrows represent pathways that are available to either perspective.

economic valence (see Tomb, Hauser, Deldin, & Caramazza, 2002 and reply Damasio, Bechara, & Damasio, 2002), when SCR is correlated with stimuli for which there is more uncertainty, the two views predict the same direction of effect. In the following, we introduce a rule-plus-exception category learning task (i.e., Palmeri & Nosofsky, 1995; Experiment 3) that can be used to address some of these problems by enabling examination of a subject's uncertainty about responses apart from the risk associated with the stimuli themselves.

Rule-plus-exception tasks are typically used to test formal category learning theories predictions for learning and recognition memory performance (Palmeri & Nosofsky, 1995; Sakamoto & Love, 2004; Sakamoto & Love, 2006). In these experiments, subjects learn through trial-by-trial feedback to place each item into one of two categories based on its perceptual characteristics. The majority of items in rule-plus-exception tasks are *rule-following* and can be categorized based on their feature instantiation on a single *rule-relevant* dimension. Two items (one per category) are *exceptions* to this rule, because these items exhibit features consistent with the contrasting category. Exception items are associated with a larger numbers of errors and are more difficult to learn in comparison to the rule-following items. An advantage of rule-plus-exception tasks is that they mirror the structure of many real world categories. For example, animals that have wings can often be classified as birds based solely on this feature, but some animals that have wings (e.g., bats) are exceptions to this rule.

While there is no economic valence in a rule-plus-exception task, exception items are more risky because of the high number of errors that subjects make during learning. Thus, one hypothesis, derived from the emotions-as-input account, is that emotional responses, as measured by larger magnitude SCRs, will be associated with exception *items* independent of how subjects classify them. This is directly analogous to the description of anticipatory emotions in gambling tasks from an emotions-as-input perspective; emotions become associated with items that produce negative feedback and these emotions are re-experienced when the items are encountered, independent of the subject's beliefs about the stimuli (Bechara et al., 1997).

A second hypothesis, based on the emotions-as-outcome alternative, is that there should be larger magnitude SCRs when subjects make exception *responses* (irrespective of the item). According to the emotions-as-outcome view, because exception items are rarer, difficult to learn, and contextually novel, when a subject believes that an exception may be present, there should be a phasic increase in arousal.

2. Method

2.1. Subjects

Forty-four students enrolled in an introductory psychology course at the University of Texas at Austin participated in the experiment for course credit.

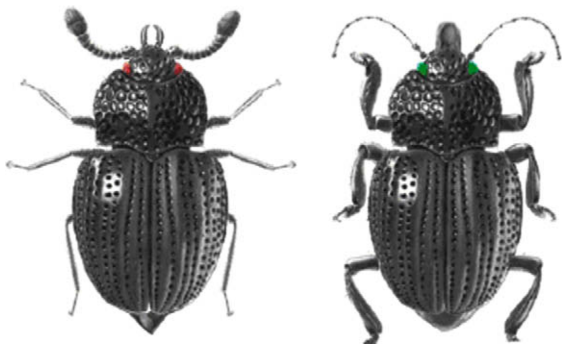

Fig. 2. Two representative stimuli from the experiment that have opposite feature instantiations on each dimension. The beetle stimuli varied in terms of five dimensions: eye color (red or green), legs (thin or thick), antennae (spindly or fuzzy), mandibles (pointy or round), and tail (triangular or oval). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2.2. Stimuli

Stimuli depicted beetles that varied along five perceptual dimensions (see Fig. 2). Stimuli were presented in the center of the computer screen on a white background along with two black rectangles on the left side of the screen that were labeled "Hole L" and "Hole K."

2.3. Design

Subjects were trained in a rule-plus-exception category learning task based on Experiment 3 in Palmeri and Nosofsky (1995). The abstract category structure is shown in Table 1 (see Fig. 2 for physical dimensions). The majority of the items (L2-L8 & K2-K8) are rule-following items, and can be classified correctly based on the value of the first dimension (denoted in Table 1 as a 1 for category L and 2 for category K). The other two items (L1 & K2) are exceptions that do not exhibit the modal category value on the first dimension. The mapping of each abstract dimension to a physical dimension was randomized for each subject. Subjects were trained on this stimulus set for 20 blocks. Each block involved the presentation of each stimulus in a random order.

Table 1
Abstract category structures are shown. Each numeric value (1 or 2) stands for a feature instantiation. The five columns denote the five stimulus dimensions. Each row stands for a unique stimulus. The rule-relevant dimension is the first dimension. Most hole L beetles have a 1 on the first dimension whereas most hole K beetles have a 2. The first two stimuli in each column are therefore the exceptions.

Stimulus #	Hole L	Hole K
1	2 1 1 1 1	1 2 2 2 2
2	1 1 1 2 2	2 2 2 1 1
3	1 2 2 1 1	2 1 1 2 2
4	1 1 2 1 2	2 2 1 2 1
5	1 1 2 2 1	2 2 1 1 2
6	1 2 1 1 2	2 1 2 2 1
7	1 2 1 2 1	2 1 2 1 2
8	1 1 1 1 1	2 2 2 2 2

2.4. Procedure

Subjects were encouraged to use a rule-plus-exception strategy. Instructions indicated the rule-relevant dimension and encouraged memorization of the exceptions to the rule. Subjects were instructed to remain as still as possible, and skin conductance was recorded from the fingertips of their non-dominant hand for the entire experiment.

On each trial, a stimulus was presented and subjects were asked to assign it to its respective category. Subjects were instructed to think about this decision and respond freely using keys L or K whenever the words "Respond Now" appeared on the screen. The duration from stimulus onset to the respond prompt was decided randomly and ranged from 2 to 6 s in 1-s intervals (mean = 3). After responding, corrective feedback was provided using the same variable duration parameters.

3. Analysis

Individual SCRs were extracted from the skin conductance time series using an algorithm that allows for isolation of overlapping SCRs (Alexander et al., 2005). Only SCRs exceeding 0.05 μMho's were retained (Boucsein, 1992). Anticipatory SCR magnitudes were calculated for each item/response combination for each subject by using the mean maximum amplitude SCR occurring 1 s after stimulus onset up until the feedback was delivered or zero, if no SCR was present. SCR magnitude was log transformed to remove skewness (log + 1; Venables & Christie, 1980), and standardized within subjects (Ben-Shakhar, 1985). To avoid task novelty effects, the first block of data from each subject was removed from magnitude calculations. Two subjects were removed from further analysis for making no correct exception responses after the first block. Their removal did not affect the nature of the results.

4. Results and discussion

The behavioral results replicated previous findings from rule-plus-exception studies. Subjects were more accurate on rule-following items (0.92; SD = 0.0851) than on exception items (0.46; SD = 0.289), $t(41) = 10.014$, $p < 0.001$, Cohen's $d = 2.174$. Importantly, for the SCR analyses that follow, exceptions proved more risky and difficult to learn.

The primary test of interest was whether the factors item (exception or rule-following) or response (exception or rule-following) were significant predictors of anticipatory SCRs. To foreshadow, the results were consistent with the emotions-as-outcome account – only the response factor was significant when both response and item factors were considered simultaneously.

The anticipatory SCR means for each item by response combination are shown in Table 2 and plotted in Fig. 3. As predicted by an emotions-as-outcome account, there was a significant effect of response, $F(1, 41) = 9.707$, $p = 0.003$, $\eta_p^2 = 0.191$. Contrary to an emotions-as-input account, the effect of item was not significant, $F(1, 41) = 0.0004$, n.s., $\eta_p^2 < 0.001$, nor did it interact with the response factor, $F(1, 41) = 0.007$, n.s., $\eta_p^2 < 0.001$. Consistent with the hypothesis that the SCRs signal attentional processes that aid in learning, subjects who performed better in the task exhibited a larger difference in anticipatory SCRs between exception and rule-following responses (0.158; SD = 0.263) in comparison to subjects who performed poorly (0.003; SD = 0.168), yielding a marginally significant interaction between the response and learning status (learners vs. non-learners[1]) factors, $F(1, 40) = 3.989$, $p = 0.053$, $\eta_p^2 = 0.091$.

These results clearly show that anticipatory SCR is governed by response type and is not strictly stimulus bound. The unique characteristics of our design allow for this conclusion to be drawn. Previous studies, such as those involving gambling tasks, do not allow for within-subject magnitude scores for item by response combinations and instead aggregate over items (e.g., positive vs. negative decks). Interestingly, analyzing our data using the logic of these designs yields a different and misleading view of our results. When the item factor is considered alone, it yields a significant result, $t(41) = 2.102$, $p = 0.042$, $d = 0.455$, and in the direction predicted by the emotions-as-input account (exceptions = −0.021, rule-following = −0.093). This underscores the value of being able to separate the outcome of subjects' decision processes from the stimuli themselves as is possible in the present experiment.

Although our theoretical focus is not on feedback SCRs, our findings are in accord with previous results from gambling tasks. Subjects who exhibit higher SCRs to negative feedback[2] (Suzuki, Hirota, Takasawa, & Shigemasu, 2003) tend to exhibit better performance. Thus, while there are potentially critical differences between the present task and gambling tasks in what constitutes feedback (monetary gain/loss in gambling tasks vs. corrective feedback in present task) and the overall task goal (learning the value of choices in gambling tasks vs. learning category assignment in present task), the data support the conclusion that both procedures tap similar underlying mechanisms. Indeed, had we not separated anticipatory SCR's by subjects' responses, all of the present analysis would have been consistent with the emotions-as-input hypothesis and related findings involving gambling tasks.

Overall, our results are consistent with the emotions-as-outcome hypothesis; when anticipatory SCRs were examined with respect to response and item factors simultaneously, only response was significant. This is inconsistent with the basic tenets of emotions-as-input theories, which suggest that implicit emotional markers arise prior to, and aid in the decision process. Instead, in this task, anticipatory emotions arise interactively with the decision process or after the decision of how to respond has been made.

Our framework presents two rather constrained hypotheses about the role of emotion in decision-making. We have followed other authors (e.g., Dunn, Dalgleish, &

[1] Learners were subjects achieving greater than 50% accuracy in exception classification during the final five blocks of learning.

[2] Learners exhibited significantly higher magnitude SCR's for incorrect feedback (0.834; SD = .579) in comparison to non-learners (0.301; SD = 0.267); Welch's $t(39.873) = 4.073$, $p < 0.001$, $d = 1.180$.

Table 2
Anticipatory SCR means (std. score), standard deviations, and average number of responses per participant.

	Exception response			Rule-following response		
	Mean	SD	Avg. #	Mean	SD	Avg. #
Exception item	0.127	0.798	18	−0.105	0.298	20
Rule-following item	0.122	0.542	247	−0.097	0.069	19

Lawrence, 2006; Maia & McClelland, 2004) and early work on SMH (Bechara et al., 1997) in describing the emotion-as-input perspective as being a critical feature of SMH, and restricting SMH to positing that SCRs represent covert markers of emotion that arise prior to the development of subjective beliefs about the stimuli. However, given the breadth of SMH theory, it is likely that both emotion-as-input and emotion-as-outcome could be accommodated if SMH were defined broadly. Indeed, Fig. 1 is adapted from a diagram illustrating SMH (Bechara et al., 1997) and is able to support both perspectives. In this sense, our framework could be thought of as examining two empirically separable claims of SMH, and, thus, not a refutation of the theory as a whole.

In this spirit, it is worthwhile to examine different possibilities for how emotion could influence decision making within this framework, and how they relate to the present task. One way that emotions-as-outcome processes could impact trial-by-trial decision-making is by increasing attention on uncertain trials to facilitate the processing of information relevant to choosing between competing options. This is illustrated in Fig. 1 as the connection between emotion and decision processes. Another possibility is that subjects could develop a rule that whenever they are uncertain about a stimulus (which we suggest produces an SCR), they choose to classify it as an exception. In terms of Fig. 1, this would be the connection between emotion and reasoning strategies. While emotion in these examples could be described as an 'input' it is critically different from the role of emotion in the emotions-as-input perspective;

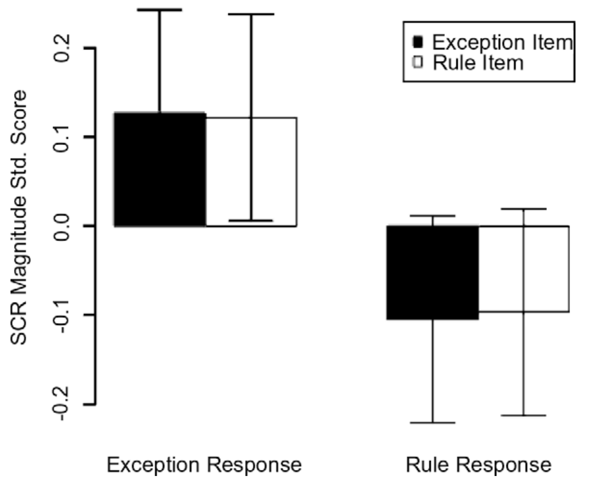

Fig. 3. Anticipatory SCR Magnitude (std. score). Standard scores are z-scores computed within subjects from the log-transformed, trial-by-trial, SCR magnitude.

it does not carry information about the feedback or value previously associated with the stimulus per se.

Still, in other cases, it is possible that emotions could operate in ways consistent with an emotion-as-input perspective. The present task involved rather brief training. Perhaps with extended training, emotions can become associated with stimuli and drive responding without cognition mediating. This proposal is close to ideas underlying Pavlovian conditioning. One direction for future research is examining the emotions-as-input and emotions-as-outcome perspectives in a variety of contexts to assess whether they are incompatible and whether both can operate depending on situational demands.

Another important direction for future research is to better approximate the continuous nature of real world decision making. In the laboratory, discrete trial tasks can be designed that isolate different aspects of the decision process, but outside the laboratory decisions are continuously made about objects. Our description of the emotion-as-outcome perspective anticipates this dynamic quality of behavior by suggesting ways in which individual decisions can give rise to processes that impact other decisions later in the trial or within the task. Approaching the study of emotions in decision making from an ecologically valid perspective will help to clarify issues, such as how and when emotions arising from the outcome of one decision process may serve as inputs to another.

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