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The interaction between expected values and risk levels in a modified Iowa gambling task

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ABSTRACT

Performance on the Iowa gambling task (IGT) supports somatic marker hypothesis (SMH), which proposes that the process of decision making depends on emotion (Damasio, 1994). However, the bad decks in the IGT are also more risky and that confounds the results. To resolve this issue, the IGT-Yen, a variant of the IGT, was created to independently examine the effects of expected value and risk. After 20 trials, participants selected more high-risk bad decks than low-risk bad decks and more low-risk good decks than high-risk good decks. Greater anticipatory skin conductance levels (SCLs) were associated with choosing high-risk bad decks compared to choosing low-risk bad decks in trials 21–80, and greater anticipatory SCLs were associated with choosing low-risk good decks compared to choosing high-risk good decks in trials 81–100. Therefore, the anticipatory SCLs were associated with expected values of the decks and with their levels of risk.

1. Introduction

In studies of emotion and decision making, the somatic marker hypothesis (SMH) is one of the leading hypotheses for elucidating the processes of how an individual's decision making can be guided by emotional somatic activations (Damasio, 1994). The Iowa gambling task (IGT) was created to experimentally test the SMH (Bechara et al., 1994, 1996). During the IGT, participants make 100 selections from four decks of cards that have different schedules of gains and losses (see Table 1). The expected values of the decks distinguish the good decks (decks C and D) from the bad decks (decks A and B). Two factors determine the expected value of each deck: (1) immediate and for-sure gain and (2) delayed and uncertain loss. For each trial, a deck's immediate gain is fixed and certain, whereas its delayed loss is variable and uncertain. Decks A and B provide the same outcome for the gains and produce the same average loss over 10 trials. When the participants select deck A or deck B, a win results in 100 dollars; however, a loss occurs 1–5 times for each 10 trials. Decks C and D have the same outcome for the gains and produce the same average loss over 10 trials. When the participants select deck C or D, a win results in 50 dollars; however, a loss occurs 1–5 times for each 10 trials. However, the overall delayed loss eventually exceeds the overall gain for decks A and B, whereas the overall delayed loss never exceeds the overall gain for decks C and D. Thus, the expected values of decks A and B are negative, whereas the expected values of decks C and D are positive. As a result, a conflict exists between the immediate gain and the long-term consequences of choosing a particular deck.

Advantageous decision making in the IGT has been repeatedly shown among normal healthy individuals (Bechara et al., 1994). In the beginning of the task, the participants may not have experienced the full range of feedback from each deck, and the higher immediate gain led normal healthy subjects to select a greater number of bad decks. However, their selection preference changed to good decks after about 20 trials. More importantly, it has also been observed that, among normal healthy subjects, skin conductance level (SCLs) increase before the selection of bad decks. Given that the SCL activity is conventionally considered as an index of the level of emotional arousal, the above findings have led to the conclusion that emotion helps individuals to distinguish between the decks with different expected values. Moreover, emotion-related information helps participants make good decisions, even when they have not conceptually realized which deck is good. However, patients with ventromedial prefrontal cortex (VMPFC) damage have no ability to develop the advance warning effect that would allow them to predict a potentially bad-outcome choice (Bechara et al., 1994, 1996, 1999). These patients continuously choose the bad decks, even after fully realizing which deck is good and which

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Table 1
The card schedule of the original IGT from Bechara et al. (1999).

Deck	Immediate outcome	Delayed outcome	Net profit (over 10 trials)
A	Win $100 (100% trials)	Lose $150–350 (50% trials)	−$250
B	Win $100 (100% trials)	Lose $1250 (10% trials)	−$250
C	Win $50 (100% trials)	Lose $50–75 (50% trials)	+$250
D	Win $50 (100% trials)	Lose $250 (10% trials)	+$250

is bad. In other words, the normal participants can make advantageous decisions according to the emotion-related information without conceptual knowledge about the expected value of the decks, while VMPFC patients cannot make advantageous decisions based on emotion-related information (Bechara et al., 1997).

Although the IGT has been extensively used for the past 15 years to scientifically investigate and clinically evaluate decision-making processes, the risk level is a potential confounding factor in the original IGT. In the IGT, the expected values of the bad decks are negative, and the magnitude of the gain or loss is greater for the bad decks than for the good decks. The bad decks are less advantageous and are riskier than the good decks because the outcomes of the bad decks display greater variability than the outcomes of the good decks. Thus, the elevated somatic activation observed before a selection from a bad deck may reflect the deck's high risk instead of its negative expected value. Tomb et al. (2002) developed a variation of the IGT (the IGT-Tomb; see Table 2) in which the good decks were riskier than the bad decks. These authors observed that participants selected a greater number of cards from the good decks than from the bad decks but exhibited greater anticipatory SCLs while selecting from the good decks. This finding challenges the SMH because it suggests that the anticipatory SCLs that have been observed in previous studies (e.g., Bechara et al., 1996) may be more strongly related to the deck's risk level than to its expected value.

The finding reported by Tomb et al. (2002) could be critical to the IGT and even to the SMH. However, as pointed out by Damasio et al. (2002), the IGT-Tomb has no conflict between the immediate gain and the long-term consequences (i.e., expected value); that is, in the original IGT, the immediate gain is higher in decks A and B, whereas the long-term consequences are higher in decks C and D. This fact results in a conflict that makes the task more complicated and may demand involvement that is more emotional. In contrast, in the IGT-Tomb, the immediate gain and long-term consequences are both higher in the same decks. As a result, the subjects in IGT-Tomb preferred the good decks not because they know that the expected values of those decks are higher but because they favor the higher immediate gains. Moreover, because the relative expected value of the decks can be easily discovered in the IGT-Tomb, emotion would not play as important a role as in the original IGT. This feature can explain why the SCL activity was higher before selections of good decks, but subjects still selected more good decks in Tomb's study (Damasio et al., 2002).

To determine whether risk is a critical confounding factor in the IGT, another variant of the IGT (the IGT-Yen) was designed, in which the risk and expected values were independent from the decks and the important properties of the IGT were maintained (see Table 3). In the IGT-Yen, the gain was immediate and certain in every trial, but the loss was uncertain and variable. In addition, the average loss was identical for decks with the same expected value, but the variability of the losses was greater for the high-risk decks than for the low-risk decks. In the IGT-Yen, the risk level was defined by the coefficient of variation (CV) of losses, which was calculated by dividing the standard deviation of loss by the mean of loss. Dividing the standard deviation of loss by the mean of loss made the CV independent of the magnitude of the loss, which allowed for the comparison of the relative risk of losses that differed in magnitude. Previous studies have reported that the CV is more suitable than the variance or standard deviation when measuring the risk sensitivity of human and animal choice behaviors (e.g., Weber et al., 2004). In addition, decision conflict is reintroduced into the task because the good decks lead to long-term but lower immediate gains, whereas the bad decks result in long-term losses but larger immediate gains. Lastly, in the original IGT and the IGT-Tomb, the likelihood of a delayed loss (50% or 10%) covaried with the magnitude of the loss. As a result, greater losses were always less frequent. In the IGT-Yen, the likelihood of a delayed loss (40%) was constant across all of the four decks.

Table 2
The card schedule of the modified IGT from Tomb et al. (2002).

Deck	Immediate outcome	Delayed outcome	Net profit (over 10 trials)
A	Win $225 (100% trials)	Lose $200–400 (50% trials)	+$750
B	Win $225 (100% trials)	Lose $1500 (10% trials)	+$750
C	Win $25 (100% trials)	Lose $100–300 (50% trials)	−$750
D	Win $25 (100% trials)	Lose $1000 (10% trials)	−$750

The main purpose of the present study is to clarify confounds of SMH. With the IGT-Yen, we were able to reclassify whether the anticipatory SCL reflects expected-value or risk-level differences between decks. In the IGT-Yen, the conflict between immediate and long-term gain is included, and many other possible factors are controlled. If the SCL activity corresponds to the level of riskiness, as shown in Tomb et al. (2002), it might further confirm the idea that the emotions observed before decision making are not critical to the advantageous card selection in the original IGT. In contrast, if the SCL activity corresponds to the level of expected value but not to the level of riskiness, we might be able to strengthen the conclusions derived from the IGT as well as the SMH. Moreover, we subdivided the 100 trials into three sessions to understand the changes in choice behavior and anticipatory SCL through the time-course (Bechara et al., 2005). For the first 20 trials, participants were expected to explore the decks but were not expected to experience all kinds of feedback of each deck. We call this session the exploration session. After 20 trials, participants were expected to begin to develop the emotion-related signal (anticipatory SCL) and reveal their choice preferences. However, they might not consciously know which decks are good until they complete 80 trials. Thus, trials 21–80 are called the intuition session. In the conceptual session, trials 81–100, participants were expected to be consciously aware of their selection strategies. Therefore, the somatic marker (anticipatory SCL) in this session may not influence participants' choice behaviors. In the present study, we further examine the relationship between choice behavior and anticipatory SCL in the three sessions.

2. Method

2.1. Participants

Forty-one undergraduate students from National Chengchi University in Taiwan were recruited for the present study. Seven participants were excluded from the analysis. Two of these participants were excluded because of SCL recording errors, and the remaining five participants were excluded because they were classified as non-learned participants. Because of the task difficulty in IGT-Yen, someone may criticize that subjects might fail to learn the pattern of outcomes that were associated with the different decks within 100 trials. To rule out the criticism of non-learning, non-learned participants are excluded. The "non-learners" were identified as participants who selected cards from the four decks at random and did not exhibit a selection preference based on the expected value or level of risk during the last 20 trials. The criterion for non-learning was provided by the rule that $|AB–CD| + |AC–BD| \leq 2$. Specifically, the frequency of the selection of decks that differed in the expected value (AB–CD or CD–AB) and decks that differed in risk (AC–BD or BD–AC) did not exceed two cards over the last 20 trials.