Experiment 1

Method

Participants

Five male and six female Harvard University undergraduates aged 18-22 participated in this experiment. One female undergraduate was excluded from analysis for clearly not completing the task in good faith, thus leaving 5 male and 5 female undergraduates in the study.

Card Scheme

A card scheme identical to that of past experiments (Bechara et al., 1994; Bechara et al., 1996; Bechara et al., 1997) was used in this study. The card scheme is described completely in Figure 1 and Table 1.

As in previous experiments (Bechara et al., 1994; Bechara et al., 1996; Bechara et al., 1997), subjects were given a $2000 loan of play money to begin the game. This amount ensured that subjects who only chose from the bad decks never lost more money than they were given to begin the game.

Differences with the Previous Gambling Task Studies

The main differences in methodology between the present study and previous gambling task experiments are twofold. First, the subject populations differed in terms

of age and the fact that one was a Harvard University population whereas the other was not. Second, different sets of SCR recording equipment were used. Although both these differences are significant and may account for some differences in results, neither should account for subjects' performance, either behavioral or psychophysiological, on the gambling task.

Results and Discussion

Behavioral Results

Card Choice

In previous studies, control subjects selected more cards from the good decks (decks C and D) than from the bad decks (decks A and B; Bechara et al., 1994; Bechara et al., 1996; Bechara et al., 1997). It was expected that a similar pattern of card choice would be found in experiment 1.

Patterns of card choice are presented in Figure 2. As expected, subjects chose more cards from the good decks than the bad decks in proportions very similar to those previously reported (Bechara et al., 1994). Levene's test of equality of error variances, which tests the null hypothesis that variance is homogeneous across groups, revealed a homogeneity of variances across decks [$F(3,36) = .659$, $p = .58$], thus suggesting that an ANOVA could be performed. A one-way ANOVA found a statistically significant effect of deck [$F(3,36) = 14.27$, $p < .001$], and post-hoc Tukey HSD tests suggested that subjects selected significantly more cards from decks C and D than in decks A and B.

Further, a two-tailed t-test comparing card choice for good versus bad decks also found a highly significant difference in number of cards selected [$t(38) = -6.47$, $p < .001$].

Verbal Responses

In the gambling task study in which verbal reports of knowledge about the game were recorded (Bechara et al., 1997), four distinct periods were identified. The "pre-punishment" period marked the card choices before subjects encountered their first punishment. The "pre-hunch" period was defined as the period before subjects reported any knowledge about the game. When subjects reported a hunch that the bad decks were riskier than the good decks, they had reached the "hunch" period. Finally, when subjects reported specific knowledge about why the good decks were advantageous and the bad decks disadvantageous to choose from, subjects were said to have entered the "conceptual" period. In that study, it was reported that all control subjects were in the pre-hunch period by card 20, and all had entered the hunch period by card 50. Finally, 7 of 10 controls reached the conceptual period. It was expected that similar results would be found in experiment 1.

While the pre-punishment period is clearly defined and was demarcated for each subject in experiment 1, the following three periods were less easily identified. In contrast to the earlier study (Bechara et al., 1997), several subjects indicated significant knowledge of the game by card 20. Further, the highly interpretive and vague definitions of the pre-hunch and hunch periods in Bechara et al. (1997), as completely described in the previous paragraph, make the task of classifying subjects' responses during the gambling task into one of these particular categories impossible. In general,

subjects' verbal responses were widely varying in terms of both length and content, and it was determined that they could not be classified into either the pre-hunch or hunch categories.

Finally, by the given definition of the conceptual period (Bechara et al., 1997), 2 of 10 subjects in the present study were judged to have reached this period. However, it is unknown how much of the difference between these results and previous ones is due to actual differences in the knowledge of the subjects or to differences in the questioning procedure. For example, in experiment 1, only the two published questions were asked: "Tell me all you know about what is going on in this game?" and "Tell me how you feel about this game?" (Bechara et al., 1997). No follow-up questions were asked and very little clarification was given to subjects in an effort to avoid influencing their answers. This may not have been the case in the earlier study (Bechara et al., 1997).

In the previous study (Bechara et al., 1997), it was reported that the 3 out of 10 subjects who did not reach the conceptual period still chose advantageously (i.e., chose more cards from the good than the bad decks). It was suggested that in these subjects, the unconscious biasing signals of somatic markers may have directed their decision-making. In the present study, 7 of the 8 subjects who did not reach the conceptual period still chose advantageously. A possible interpretation is thus that somatic markers guided the card choice of these subjects in the absence of conscious knowledge about the game. However, an alternative explanation is proposed.

Informal discussions with these subjects after completing the task indicated that many possessed much more knowledge about the game than they displayed when

answering questions during the task. Many of these subjects, when asked directly, were able to name the good and bad decks (which would have placed them in the conceptual period had they noted this during the game). Further, although none of these subjects technically reached the conceptual period, many did display significant knowledge about the game when answering the questions during the task. For example, 4 of the 8 subjects who did not reach the conceptual period listed significant information about 3 of the 4 decks (for example, a subject may have given reasons why decks C and D were good, and deck B was bad, but omitted any comment about deck A), but were not placed into the conceptual period because they did not mention specific knowledge about one of the decks. It is suggested, then, that a number of the individuals who failed to reach the conceptual period had partial, if not complete, knowledge about the game.

SCRs

Anticipatory SCRs

In a previous study of the gambling task, experimenters found that subjects' anticipatory SCRs prior to selections of cards from the bad decks were significantly greater than those generated prior to selections from the good decks (Bechara et al., 1996). It was expected that this key result would be replicated in experiment 1.

Anticipatory SCRs for each deck are shown in Figure 3. As in all figures and analyses of SCR data in the present paper, each subject's mean SCR value for each deck of cards is determined by averaging across all of that subject's SCRs associated

with a particular deck. These subject means can then be averaged across subjects and grouped by each individual deck or by good or bad decks. Values of anticipatory SCRs were higher for decks A and B than for decks C and D. Levene's test of equality of error variances assured the homogeneity of variances across decks [$F(3,36) = 2.13$, $p = .11$], and thus an ANOVA was performed. Although a one-way ANOVA on these SCRs did not show a significant effect of deck [$F(3,36) = 2.38$, $p = .09$], a two-tailed t-test comparing anticipatory SCRs generated before card selections from the good decks (C and D) compared to the bad decks (A and B) was statistically significant [$t(38) = 2.74$, $p < .01$].

In one previous study of the gambling task, the argument was made that the anticipatory SCRs of normal individuals developed during the gambling task such that responses to the bad decks increased over time, and responses to the good decks remained low across the task (Bechara et al., 1996). Although no statistical tests were given to support this assertion, a figure was presented showing the development of anticipatory SCRs across the gambling task for each deck. Figure 4 reproduces this chart (Bechara et al., 1996). Figure 5 presents the analogous chart for experiment 1. No clear increase or decrease across time can be identified from Figure 5. However, since no statistical measures were used in the earlier study to show a temporal increase in anticipatory SCRs (Bechara et al., 1996), any differences between Figures 4 and 5 remain unmeasurable.

Reward and Punishment SCRs

Although the analysis of reward and punishment SCRs for normal subjects is not central to the somatic marker hypothesis, and indeed calculations of these two classes of SCRs were not included in Bechara et al. (1997), these SCRs were analyzed to provide further comparison between experiment 1 and previous gambling task results. In Bechara et al. (1996), no differences were found between reward SCRs generated for each deck. Further, only one significant difference was found between decks for punishment SCRs: SCRs in deck B were found to be significantly higher than those generated in decks A and C (Bechara et al., 1996). No systematic differences between good and bad decks were found in the analysis of reward and punishment SCRs. Similar results were expected for experiment 1.

Reward SCRs for each deck are displayed in Figure 6. Levene's test of equality of error variances revealed a homogeneity of variance across decks [$F(3,36) = .065$, $p = .98$], and thus an ANOVA was performed. A one-way ANOVA on these SCRs displayed no significant effect of deck [$F(3,36) = .158$, $p = .92$]. Further, a two-tailed t-test comparing the means of reward SCRs for the good decks (C and D) versus the bad decks (A and B) revealed no statistically significant difference [$t(38) = .345$, $p = .73$]. Punishment SCRs for each deck are displayed in Figure 7. Levene's test of equality of error variances revealed a homogeneity of variance across decks [$F(3,36) = .337$, $p = .80$], and thus an ANOVA was performed. A one-way ANOVA of punishment SCRs revealed no effect of deck [$F(3,36) = .03$, $p = .993$]. A two-tailed t-test comparing punishment SCRs between the decks A and B versus decks C and D also revealed no statistically significant difference [$t(38) = .27$, $p = .79$]. It is thus suggested that no

differences exist between the reward and punishment SCRs for the good decks versus the bad decks, as was expected.

Experiment 1 and Previous Results

These results suggest that two key elements of earlier experiments using the gambling task have been replicated. First, experiment 1 elicited very similar card choice responses to previous experiments (Bechara et al., 1994). Second, the critical anticipatory SCR difference between the good and bad decks (Bechara et al., 1996) was confirmed. These elements are crucial to the validity of experiment 2. Further, an analysis of reward and punishment SCRs, though not themselves crucial to conclusions about the somatic marker hypothesis, indicate a similarity of results with earlier gambling task studies (Bechara et al., 1996). These similarities indicate that the subject pool, the SCR recording equipment, and the experimental procedure are sufficiently similar between experiment 1 and previous gambling task experiments to ensure that differences found between previous studies and experiment 2 are not due to inter-experimental factors.

However, significant differences were found between subjects' verbal responses in experiment 1 and the previous study examining similar responses (Bechara et al., 1997). Specifically, in experiment 1, subjects' comments were not easily separated into the previously published periods, and fewer people in experiment 1 were classified as reaching the conceptual phase of the experiment compared to the earlier study. It is possible, however, that these differences are not due to discrepancies between subjects' knowledge across experiments but instead to a different questioning or

classification procedure. Whatever their cause, these discrepancies do not invalidate the replication of the card choice or anticipatory SCR data from experiment 1, and thus do not diminish the importance of running experiment 2 as a test of the somatic marker hypothesis.

Another difference between experiment 1 and previous gambling task experiments is the magnitude of the anticipatory SCRs. In experiment 1, the mean anticipatory SCRs (as seen in Figure 3) were approximately .14 Mhos for the bad decks and .07 Mhos for the good decks. In the earlier gambling task study in which total SCR means were reported (Bechara et al., 1996), values were approximately .55 Mhos for the bad decks and .3 Mhos for the good decks. Thus, previously reported SCRs were absolutely higher than the SCRs reported in experiment 1. This difference in overall amplitude across experiments may be due to differences in SCR recording equipment, as measurable SCRs are known to vary with different recording systems (Fowles et al., 1981). This absolute difference in anticipatory SCR magnitude across experiments does not detract from the replication of anticipatory SCR data in experiment 1.

Finally, a comparison of Figures 4 and 5 seems to suggest that whereas anticipatory SCRs in a previous study of the gambling task (Bechara et al., 1996) increased during the gambling task, no such increase was found in experiment 1. However, since no statistical analyses were performed to demonstrate an increase in SCRs across the gambling task, either for anticipatory SCRs as a whole or for anticipatory SCRs generated before selections of cards from the bad decks specifically (Bechara et al., 1996), the correct interpretation of Figure 4 is unknown. Thus, a

meaningful comparison of time courses for anticipatory SCRs between previous gambling task experiments and experiment 1 may not be possible. Given this lack of evidence for temporally increasing anticipatory SCRs across past studies of the gambling task, the difference in overall appearance between Figures 4 and 5 does not affect the replication of an anticipatory SCR difference between the good and bad decks in experiment 1.