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Enhancing emotion-based learning in decision-making under uncertainty

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Abstract

Background: The Iowa Gambling Task (IGT) is widely used to study decision-making differences between several clinical and healthy populations. Unlike the healthy participants, clinical participants have difficulty choosing between advantageous options, which yield long-term benefits, and disadvantageous options, which give high immediate rewards but lead tonegative profits. However, recent studies have found that healthy participants avoid the options with a higher frequency of losses regardless of whether or not they are profitable in the long run. The aim of this study was to control for the confounding effect of the frequency of losses between options to improve the performance of healthy participants on the IGT. **Method:** Eighty healthy participants were randomly assigned to the original IGT or a modified version of the IGT that diminished the gap in the frequency of losses between options. **Results:** The participants who used the modified IGT version learned to make better decisions based on long-term profit, as indicated by an earlier ability to discriminate good from bad options, and took less time to make their choices. **Conclusions:** This research represents an advance in the study of decision making under uncertainty by showing that emotion-based learning is improved by controlling for the loss-frequency bias effect.

Keywords: decision making, uncertainty, frequency of losses, learning, emotion.

Resumen

Mejora del aprendizaje basado en emociones en la toma de decisiones en ambiente de incertidumbre. **Antecedentes:** la Iowa Gambling Task (IGT) es ampliamente utilizada para estudiar la toma de decisiones entre poblaciones clínicas y saludables. A diferencia de los participantes sanos, los participantes clínicos tienen dificultades para elegir entre opciones ventajosas, que producen beneficios a largo plazo, y opciones desventajosas, que dan altas recompensas inmediatas, pero conducen a beneficios negativos. Estudios recientes han encontrado que los participantes sanos evitan las opciones con mayor frecuencia de pérdidas, independientemente de si son rentables a largo plazo. El objetivo de este estudio fue controlar el sesgo de la frecuencia de pérdidas entre las opciones, para mejorar el desempeño de los participantes sanos en la IGT. **Método:** ochenta participantes sanos fueron asignados aleatoriamente a la IGT original o una versión modificada que disminuye la brecha en la frecuencia de pérdidas entre opciones. **Resultados:** los participantes que usaron la IGT modificada aprendieron a tomar mejores decisiones basadas en el beneficio a largo plazo, discriminando antes las opciones buenas de las malas, y tardando menos tiempo en realizar elecciones. **Conclusiones:** esta investigación avanza en el estudio de la toma de decisiones bajo incertidumbre, mostrando que el aprendizaje basado en emociones mejora mediante el control del sesgo de la frecuencia de pérdidas.

Palabras clave: toma de decisiones, incertidumbre, frecuencia de pérdidas, aprendizaje, emoción.

Over the past twenty years, the Iowa Gambling Task (IGT) has become a widely used tool for evaluating impairments in real-life decision making among patients with several neuropsychological lesions (Labudda et al., 2009; Mimura, Oeda, & Kawamura, 2006). Bechara, Damasio, Damasio, and Anderson (1994) developed the IGT to demonstrate that, in situations of uncertainty, patients with ventromedial prefrontal (VM) cortex lesions often make decisions based on the immediate consequences without considering the long-term implications. Bechara and collaborators proposed the somatic marker hypothesis to explain this insensitivity to future consequences in decision making (Bechara et al., 1994; Bechara, Damasio, Tranel, & Damasio, 1997). According to this hypothesis, through the experience of the consequences in every selection, the participants generate an emotional response that indicates the expected value of their decisions. Patients with VM injuries would have difficulties identifying the future profits of their choices as positive or negative, and thus, their decision making would be primarily based on the immediate consequences (Bechara et al., 1994; Bechara et al., 1997).

In the IGT developed by Bechara et al. (1994), participants repeatedly select a card from a group of four decks. For each new card selected, participants will either gain money or lose money. Two of the decks, called A and B, yield twice as much money as the other decks, but they generate more losses than profits in the total account of the task. In contrast, the other two decks, called C and D, offer less money immediately but are advantageous in the long-term, yielding a positive balance between gains and losses.

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Participants in the IGT are not informed of the structure of gains and losses characteristic of each deck a priori. Thus, over the course of the task, participants are expected to be able to realize which decks are advantageous and which are disadvantageous. IGT performance is assessed by computing a net score by subtracting disadvantageous selections from advantageous selections. Following the somatic marker hypothesis, healthy participants would select more cards from the advantageous decks across the task, achieving a positive net score at the end of the task; whereas, participants with neuropsychological impairments would select more cards from the decks that involve a greater immediate payoff, even if those decks are disadvantageous, thus achieving a negative net score. However, as Steingroever, Wetzels, Horstmann, Neumann, and Wagenmakers (2013) demonstrated in a literature review, healthy participants also have problems making advantageous decisions in the IGT. This issue is crucial, as most previous studies with clinical populations use a healthy population as a control group to highlight differences in decision making.

Researchers have explored several features of the IGT that could disrupt the decisions of healthy participants. Recent studies have noted that healthy participants perform poorly on the IGT because there is a confounding effect of loss frequency on decision making (Chiu et al., 2008; Huizenga, Crone, & Jansen, 2007). In the original IGT, there are two advantageous decks, A and B, and two disadvantageous decks, C and D. In addition, within each payoff group, one of the decks has a lower frequency of cards with losses than the other. The decks B and D have only one card out of ten with losses, whereas the other two decks, A and C, have a greater loss frequency: five out of every ten cards. It has been claimed that the IGT was designed with multiple decks and varying contingencies to support emotion-based learning (Bowman & Turnbull, 2004). Thus, Bechara et al. (1994) designed this loss frequency schedule to encourage participants to make decisions under uncertain conditions. However, recent studies suggest that the computed net score might mask the effect of the loss-frequency profiles on the IGT, and they suggest analyzing the selections of decks at an individual level (Buelow & Suhr, 2013). Research that assesses the selections of each deck separately has shown that healthy participants prefer to choose cards from decks with a lower frequency of losses, regardless of whether profits are made in the long run (Chiu & Lin, 2007; Horstmann, Villringer, & Neumann, 2012; Lin, Chiu, Lee, & Hsieh, 2007). Thus, there is a confounding effect between loss frequency and advantageous expectancies on decision making.

To demonstrate the confounding effect of the frequency of losses, Chiu et al. (2008) used a modified version of the IGT called the Soochow Gambling Task (SGT), which had a higher frequency of losses in the beneficial decks (eight out of ten) than in the disadvantageous decks (two losses out of ten cards). Participants who performed the SGT selected mainly cards from the decks with a lower frequency of losses, even if they were not profitable on the long-term. A preference for decks with a low loss frequency was observed regardless of the immediate amount of the reward or penalty (Lin, Chiu, & Huang, 2009), and this finding was replicated in a computerized clinical version of the SGT (Lin, Song, Chen, Lee, & Chiu, 2013). The aim of our study was to control for the confounding effect of the frequency of losses on decision making in the IGT to promote healthy participants' focus on the long-term consequences, as hypothesized by the study of Bechara et al. (1994).

According to previous studies, in the original IGT, the large gap in loss-frequency differences between decks would interfere in the decision-making process. Our main objective is to assess the effect of loss-frequency on the IGT. Our study examines decision making in a modified version of the IGT that has a smaller range of frequency of losses among decks than the original IGT. This modified IGT retains the original design with multiple decks and various contingencies but reduces the gap in loss-frequency differences to avoid bias in decision making. Following previous studies that assess emotion-based learning throughout the task, participants were requested to rate their subjective experience of each deck in blocks of twenty trials, and the participants' reaction time was recorded in each trial (Cella, Dymond, Cooper, & Turnbull, 2007; Evans, Bowman, & Turnbull, 2005).

Method

Participants

This study involved 80 undergraduate students who were taking an Introduction to Psychology course. Participants received course credit for their collaboration. The sample was composed of 53 women (mean age: 19.68 years, *SD* = 1.97) and 27 men (mean age: 19.70 years, *SD* = 2.12). Participants were randomly assigned to one of the two tasks: the original IGT or the modified IGT.

Instruments

Iowa Gambling Task

In this study, we employed a version of the IGT derived from the payoff structure of the original IGT (Bechara et al., 1994) and a modified version in which the gap in loss-frequency differences between decks was reduced. The two versions of the IGT were composed of four decks of cards, labeled A, B, C, and D; participants had to select a card from any of the decks for 100 consecutive trials. Every new card chosen yielded an amount of facsimile money to win or lose. The amount of money to win immediately in decks A and B was 100 euros, whereas it was 50 euros in the decks C and D. However, in decks A and B, every ten cards selected from the same deck subtracted more money than they gave, yielding a net loss of 250 euros. Decks C and D gave more money than they subtracted for each of ten selected cards, yielding a profit of 250 euros. As shown in Table 1, the original IGT includes two decks with a high frequency of losses (five cards out of ten) and two decks with a low frequency of losses (one card out of ten). The loss-frequency differences between decks were diminished in the modified version of the IGT: the two decks with a high frequency of losses had four cards with losses out of every ten cards, and the two decks with a low frequency of losses had two cards with losses out of every ten cards.

To assess whether participants gradually made less risky decisions, selecting a greater number of cards from the advantageous decks, the net score was calculated by subtracting the number of poor selections from the number of good selections: [(C+D) - (A+B)]. Disadvantageous decisions were represented by a net score below zero, whereas advantageous decisions were represented by a net score above zero (Bechara et al., 1994).

Subjective satisfaction and selection time

After each block of twenty trials, the participants were requested to rate their satisfaction toward each deck. This rate was registered on a Likert scale ranging from one to ten, with one being *very bad* and ten being *very good*. The net score was calculated by subtracting the satisfaction ratings of the disadvantageous decks from those of the advantageous decks: [(C+D) - (A+B)]. The time that the participants took to select a card in each trial was recorded in milliseconds. The average selection time was computed for the task set in blocks of twenty trials.

Procedure

The two IGT versions were administered in computerized form by using the Inquisit 4.0 Millisecond Software. All participants received the same instructions prior to the task, which were displayed in text on the screen. These instructions, following the original version of Bechara et al. (1994), indicated that: (a) participants had to pick a card from one of the four decks until the task ended, (b) for every chosen card, participants would either earn money or lose money, and (c) they began with 2,000 Euros, and the goal of the game was to win more money and avoid losing it. In addition, following previous studies employing a computerized version of the IGT, the participants were warned that the computer did not change the position of the decks during the game and that it was not a gambling game. Participants were unaware of how long the task would last (100 trials), and there was no response time limit.

Following the instructions, four decks appeared aligned horizontally in the center of the screen. There was a tag above each deck that represented a letter from A to D; the letters were arranged alphabetically from left to right on the screen. The sequence order of the decks was randomly assigned across participants according to a balanced 4×4 Latin square (Kirk, 1995); although the tag above each deck on the screen remained equal in all design conditions. There were no sequence order main effects or interaction with type of task, blocks or decks for any of the performance measures.

In each trial, participants had to select a card from any of the decks by clicking on it with the computer mouse. Upon choosing a deck, the amount of money earned (in green) or lost (in red) appeared below the selected card. A counter with the amount of money obtained before and after the last trial was displayed at the top of the screen throughout the task.

Participants were informed of the instructions prior to the task that they would have to assess their level of satisfaction with the decks in blocks of twenty trials. Thus, after twenty consecutive runs, the participants had to rate their degree of satisfaction with each deck by raising or lowering a central icon in a vertical bar under each deck. Participants' subjective satisfaction with the decks was transformed into a Likert scale from 0 to 10.

Table 1
Deck characteristics on the Original IGT and Modified IGT every 10 trials

	Decks			
Variables (Original IGT)	**A**	**B**	**C**	**D**
Penalty range	-€350 to -€150	-€1250	-€75 to -€25	-€250
Reward/trial	€100	€100	€50	€50
Number of losses	5	1	5	1
Total loss	-€1250	-€1250	-€250	-€250
Net outcome	-€250	-€250	€250	€250
	Decks			
Variables (Modified IGT)	**A**	**B**	**C**	**D**
Penalty range	-€325 to -€300	-€625	-€75 to -€50	-€125
Reward/trial	€100	€100	€50	€50
Number of losses	4	2	4	2
Total loss	-€1250	-€1250	-€250	-€250
Net outcome	-€250	-€250	€250	€250

Data analysis

For both IGT versions, the 100 trials were divided into five blocks of twenty consecutive trials, and net scores were calculated for each block. Mixed factor 2 (task) × 5 (block) analysis of variance (ANOVA) and Eta partial square (η_p^2) were computed to analyze the between (tasks) and within (blocks) differences. Furthermore, we analyzed the selection rates of each deck separately to test the effect of the different loss-frequency schedules throughout the tasks. Satisfaction net scores and average selection time were analyzed by task and block.

Results

A mixed factor 2 (task) × 5 (block) analysis of variance (ANOVA) found a significant main effect for task version, F(1, 78) = 24.36, p<.001, η_p^2 = .24. The participants who used the modified version of the IGT obtained a higher average net score than those who used the original IGT version (M = -.66, SE = .29; M = 2.20, SE = .50, respectively). A Bonferroni-adjusted multiple comparison post hoc test of the net scores by type of task for each block indicated that there was no significant differences between the tasks in the first block, t(78) = -1.49, p = .14. However, there were significant differences between the selection net scores among tasks in the second block (t(78) = -3.11, p = .003, d = 0.70) and the remaining three blocks (t(78) = -2.89, p = .005, d = 0.65; t(78) = -3.86, p<.001, d = 0.86; and t(78) = -3.29, p = .001, d = 0.73, respectively). Figure 1 shows that from the second block of the task, the participants who completed the modified IGT selected more the advantageous decks than those who used the original IGT. An ANOVA with Greenhouse Geisser correction revealed a main effect of block, F(3.35, 261.17) = 11.79, p<.001, η_p^2 = .13; the net scores increased throughout the task in both the original and modified IGT groups. A Bonferroni-adjusted multiple comparison post hoc test indicated that all participants selected less advantageously in the first block (M = -1.20, SE = .50) than in the fourth block (M = 1.37, SE = .47; t(79) = -3.91, p = .002, d = 0.44) and fifth block (M = 2.87, SE = .59; t(79) = -5.01, p<.001, d = 0.56), but there were no significant differences between the remaining blocks. There was no significant interaction between task and block, F(3.35, 261.17) = .89, p = .47.

A mixed factor 2 (Task) × 4 (Deck) × 5 (Block) ANOVA found a significant main effect for deck, F(2.17, 169.15) = 23.63, p<.001, η_p^2 = .23, and a significant interaction between task and deck, F(2.17,

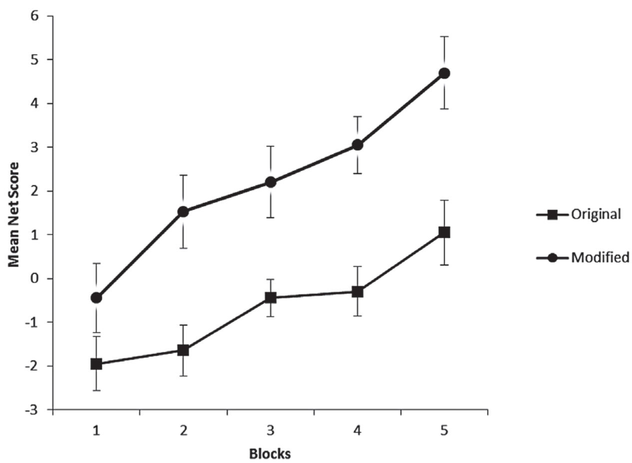

Figure 1. *Mean net scores by blocks of twenty consecutive trials. Error bars represent the standard error of the mean*

169.15) = 15.81, p<.001, η_p^2 = .17. A Bonferroni-adjusted post hoc test indicated that participants who completed the modified version of the IGT drew significantly more cards from the advantageous deck C (M = 5.34, SE = .33) than those who were engaged in the original IGT (M = 3.95, SE = .17), t(78) = -3.73, p<.001, d = 0.83. In contrast, the disadvantageous deck B was selected more often by the original IGT group (M = 6.59, SE = .18) than the modified IGT group (M = 4.69, SE = .19), t(78) = 7.10, p<.001, d = 1.59. Additionally, there was a significant interaction between deck and block (F(2.17, 646.66) = 6.11, p<.001, η_p^2 = .07). Bonferroni-adjusted post hoc tests revealed that in the first block, all participants selected significantly more cards from the disadvantageous deck B (p<.001), which had few losses and high immediate earnings. In contrast, in the fifth block, the most chosen deck was the advantageous deck D (p<.001). There was no interaction effect between task, deck, and block, F(8.29, 646.66) = .59, p = .85.

The set of results described earlier about the selection of each deck revealed that there were different selection patterns per block among participants who performed each of the IGT versions. Figure 2 shows that participants who used the modified version randomly picked cards from all of the decks at the beginning of

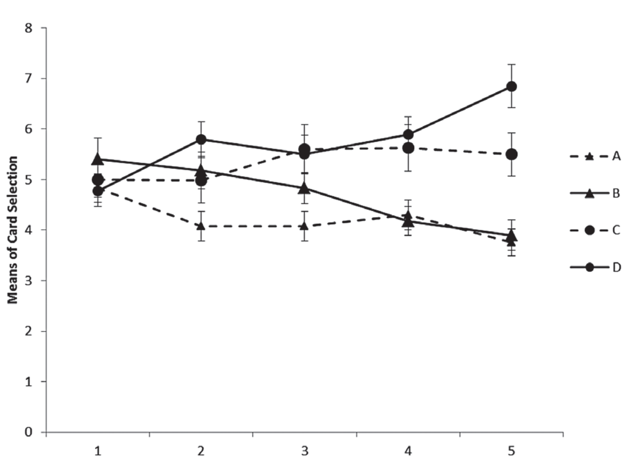

Figure 2. *Mean of card selection from each deck by block on the Modified IGT. Error bars represent the standard error of the mean*

the task, but they progressively shifted their choices to the decks with long-term benefits over those that yielded greater immediate rewards. Figure 3 shows that participants who used the original IGT version mainly selected deck B throughout the task and increasingly chose more cards from the good deck D, whereas these participants had the least preference for the decks with a high frequency of losses from the beginning of the task.

Figure 4 shows the net scores of subjective experience ratings by blocks of twenty consecutive trials. A mixed factor 2 (Task) × 5 (Block) ANOVA of the subjective experience net scores indicated that there was a significant difference by type of task, F(1,78) = 14.54, p<.001, η_p^2 = .16. Participants who completed the modified version of the IGT evaluated the advantageous decks more satisfactorily than the disadvantageous decks (M = 3.43, SE = .46) compared with those participants who completed the original IGT (M = 1.02, SE = .43). There was a significant effect of block, F(3.04, 236.92) = 3.29, p<.05, η_p^2 = .09; the favorable assessment of the beneficial decks increased throughout the task. There was no interaction between task and block in the ratings of subjective experience. However, Bonferroni-adjusted post hoc tests of the net scores by type of task for each block indicated that there were significant differences in the satisfaction rating by groups of participants from the second to fifth block (p<.05).

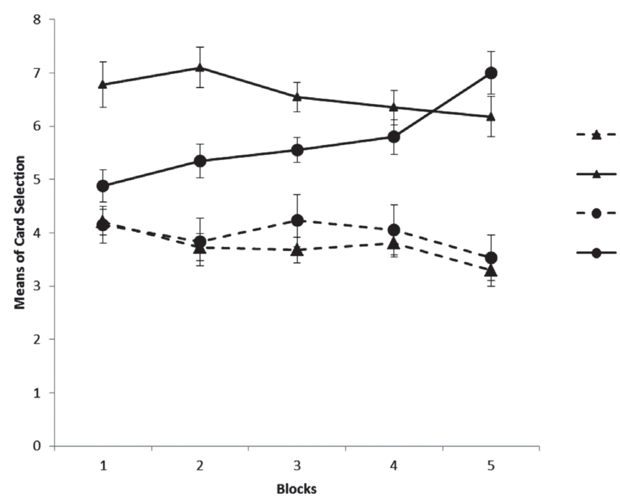

Figure 3. *Mean card selection from each deck by block on the Original IGT. Error bars represent the standard error of the mean*

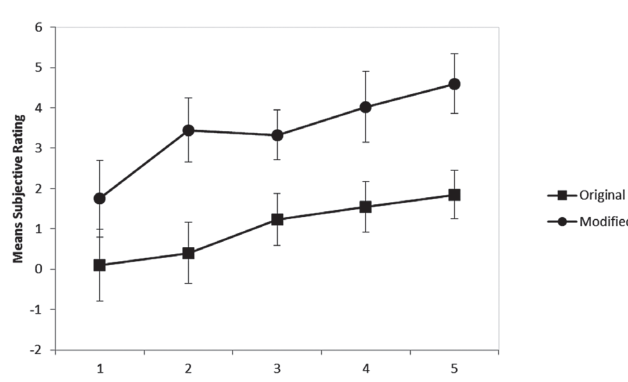

Figure 4. *Mean subjective experience ratings across the five blocks. Error bars represent the standard error of the mean*

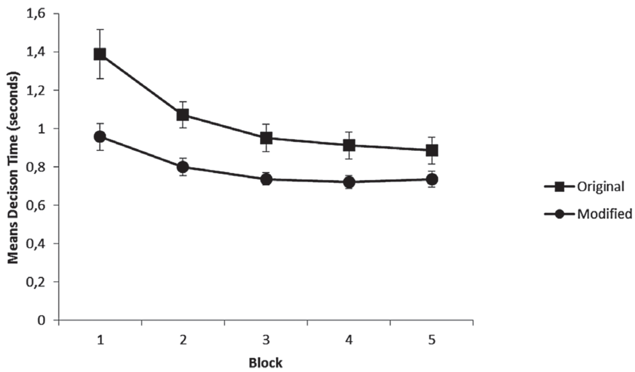

Figure 5. *Mean decision time in seconds across the five blocks. Error bars represent the standard error of the mean*

A mixed factor 2 (Task) × 5 (Block) ANOVA of the average reaction time indicated significant differences for type of task, $F(1, 78) = 9.76$, $p<.01$, $\eta_p^2 = .11$; and block, $F(2.04, 159.36) = 26.83$, $p<.001$, $\eta_p^2 = .26$; and an interaction effect between block and task, $F(2.04, 159.36) = 3.52$, $p<.05$, $\eta_p^2 = .04$. The response time of the participants tended to decrease between blocks throughout the task. Nevertheless, on average, the participants who performed the modified IGT version took less time to select a new card (M = .79, SE = .04) than those who completed the original IGT version (M = 1.04, SE = .07), $t(78) = 3.13$, $p = .002$, $d = 0.70$. A Bonferroni-adjusted post hoc analysis indicated that there was no significant difference in the reaction times by task in the fifth block.

Discussion

Previous studies have found that healthy participants tend to select more cards from the decks with a lower frequency of losses in the IGT even though some of these decks involve long-term negative consequences (Chiu & Lin, 2007; Horstmann et al., 2012; Lin et al., 2007). The aim of our study was to control for the confounding effect of loss frequency on decision making in the IGT to demonstrate that healthy participants focus on long-term profits, as proposed by the original studies of Bechara et al. (1994). In support of our main hypothesis, we found that the rate of advantageous decisions increases by reducing differences in loss frequency between decks. Participants who completed the modified version of the IGT improved in their decision making: they selected more decks that were advantageous in the long-term, expressed greater satisfaction toward the good decks, and chose a new card more rapidly than the participants who completed the original IGT.

The analysis of the net scores indicates that participants who completed the modified version of the IGT learned to make better decisions based on long-term profit. Although learning of the future consequences of the decks was observed in the two tasks, participants who used the modified IGT displayed an ability to discriminate good from bad decks more rapidly, and they obtained a greater profit over the course of the task.

The analysis of net score as a performance measure on the IGT often masks the effect of the frequency of losses; thus, it is most suitable to analyze the decks individually (Buelow & Suhr, 2013; Steingroever et al., 2013). Thus, we tested whether the loss frequency was a confounding factor on the IGT by analyzing the selection of each deck. The group of participants who used the modified version of the IGT selected the decks with long-term benefits, C and D, more often, whereas the group who used the original version of the IGT drew more cards from the decks with a low frequency of losses, B and D. These findings support the initial hypothesis about the confounding effect of loss frequency on decision making. As has been observed in previous studies, the original IGT leads decision makers to lean toward relatively short-term prospects by avoiding decks with a higher frequency of losses (Chiu & Lin, 2007; Horstmann et al., 2012; Lin et al., 2007). Therefore, closing the gap in loss-frequency differences encourages decision making based on long-term profits.

The subjective assessment of the decks more closely matched the registered decisions in the modified IGT version. With the exception of the first block, in which there were no differences between the tasks, advantageous decks were rated as more pleasant by the modified IGT group; in contrast, the participants who used the original IGT group had more difficulties differentially assessing the advantageous and disadvantageous decks. Previous studies have shown that the emotion-based learning of long-term consequences is associated with increased subjective appraisal of the advantageous options (Cella et al., 2007; Evans et al., 2005).

Finally, the analysis of the average time taken to select a deck revealed that all participants reduced their response latency as the task progressed. However, the participants who completed the original IGT version took more time to make their decisions on average. These differences between tasks are consistent with the selection performance and rated subjective experience of the modified IGT group. The modified IGT group favored advantageous over disadvantageous decks, and thus, the quick selection reveals less hesitation, more efficient behavior, and better decision-making accuracy (Cella et al., 2007).

In summary, the set of measures analyzed demonstrate that the modified IGT strengthened emotion-based learning to select the decks that provided better long-term outcomes. Participants who completed the modified version of the IGT selected the advantageous decks throughout the task more often, more accurately estimated the payoff profile of the decks, and made their choices more rapidly. The frequency of losses in the decks was the only feature changed in the modified version of the IGT; the total quantities of gains and losses remained equal to the original IGT version for both immediate and long-term outcomes. Therefore, reducing differences in loss frequency enhances learning of the future consequences in the task. As in the original IGT designed by Bechara et al. (1994), a wide range of loss frequency disrupts decision making such that the decks that display more losses are avoided regardless of whether they are profitable. The main findings of this study are that when the loss frequency is more similar between decks, the decision-making process is more often driven by the record of gains and losses: advantageous options are selected more frequently, lead to positive emotions, and an advanced decision trigger prompts selections. Bechara et al. (1994) developed the IGT to discriminate between the decision making of healthy participants and patients with ventromedial prefrontal lesions, who have difficulties in assessing the long-term consequences of their decisions. The aim of this study was to control the bias of loss frequency on the decision-making process. Therefore, the modified IGT version may be more suitable for the study of emotion-based learning in those clinical populations that have demonstrated decision-making deficits in the original IGT. In future studies, the results of our research with healthy participants must be contrasted with clinical populations.

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