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THE EFFECT OF SEX AND HUMOR IN THE IOWA GAMBLING TASK: A BEHAVIORAL AND ELECTROPHYSIOLOGICAL STUDY

By

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I started this journey with the idea in mind that we could do something fun, converging knowledge from different areas such as reinforced learning models, experimental psychology, and affective and cognitive neuroscience. It was fun but wasn't an easy task, because we wanted to use a psychological resource at hand for everyone (humor is everywhere!) and to orient this work for practical possibilities in the near future. I think this is a nice first step. Thank you all for helping me grow as a researcher and person. Thank you to each and every one of you for your unique contribution to this project!.

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CHAPTER ONE

Theoretical and empirical background

1.0 *The relevance of emotion in decision-making and the use of the Iowa gambling task.*

An important step in the understanding of how emotion and cognition are related in decision-making is due to Damasio's work with patients with damage of ventromedial prefrontal cortex (VMPFC) (Damasio et al, 1991, Dimitrov et al, 1999; Barrash et al 2000). During these early investigations, Damasio found that VMPFC patients despite having most of their cognition unimpaired, had serious problems controlling both emotions and decisions (Damasio et al, 1991; Saver & Damasio, 1991). To understand this problem, along with Bechara, they designed and implemented the Iowa Gambling Task (IGT; Bechara et al, 1994). An ingenious card task by which participants had to learn through exploration which of the four available decks of cards (A, B, C, and, D) were the best to accumulate gains until the end. This task is not simple because participants do not know in advance what the odds of each deck are in terms of monetary rewards and punishments, neither the duration of the task, nor that every deck of cards can provide both monetary consequences (rewards and punishments) but with different frequency and magnitude (Damasio, 1996). When VMPFC patients are trying to solve IGT, they present problems to clearly differentiate and exploit choices that maximize their profit, when compared with healthy control participants (Damasio et al., 1993). The use of skin conductance response (SCR) as a measure of arousal during risky IGT choices, allowed the researchers to have additionally physiological measures when participants tried to solve the task. The results of the combined use of behavior and SCR measures indicated that anticipatory SCR responses during risky choices were associated with successful learning in healthy control participants and that VMPFC patients did not show this anticipatory SCR response, which in conjunction with the behavioral data was interpreted as VMPFC damage hinders the integration of emotional information during decision-making, which result in low IGT performance (Dunn et al., 2006).

1.1 *Main possible explanations to sex related differences in IGT performance.*

Over time IGT has become one of the most popular tasks to evaluate decision-making, mostly because it allows to measure how people learn to integrate emotional and cognitive information through experience (see review van den Bos et al., 2013). This advantage is valuable because it could be generalized to other populations different from VMPFC patients (see review Dunn et al., 2006). What is particularly interesting is that it is well stablished that healthy men and women differ in IGT decision-making performance: men choosing more monetarily efficient choices than women within the standard number of 100 trials (Bechara, 2005; Bolla et al, 2004), as consequence, the budget of women is slightly lower than men across the different trial-blocks (van den Bos 2013). Several explanations have been proposed regarding this difference in performance, for instance menstrual cycle: while there is evidence showing that this could affect the processing of rewards, especially follicular phase when compared to luteal phase (Justice & de Vit, 1999) which could potentially affect IGT performance. Nevertheless, no data thus far have shown a clear effect of the menstrual cycle on IGT performance. First, neither Reavis and Overman (2001) (phases based hormonal assays) nor van den Bos et al (2007) phases based on interviews. Additionally, sex differences in IGT performance emerge at an age before the menstrual cycle is activated, for instance, differences have been reported from the age seven onwards (Overman, 2004; Crone, 2005). Another option is emotional reaction: For instance, previous research has demonstrated that women exhibit more intense nervousness and more fear than men during punishment anticipation, decreasing the economic utility of a risky choice (Brody, 1993; Fujita, Diener & Sandvik, 1991; Croson & Gneezy, 2009). Furthermore, women with high trait anxiety have shown to perform worse in IGT than women with low trait anxiety (Miu, Heilman & Houser, 2008). So, considering the abovementioned data, emotion regulation becomes an important variable, especially considering that during IGT, punishments -losing money- occur in all options, including the monetarily efficient deck choices. For that reason, people need to suppress the tendency to respond to these losses (e.g changing an efficient strategy after experiencing punishment) a situation that could be more demanding for women.

1.2 Sex differences in emotion regulation as a possible explanation to women's IGT performances.

Emotional information could give preferential access to neurocognitive resources, conversely an improper emotional activation is associated with emotional and cognitive disruptions (Mitchell, 2011). Consequently, if emotional reaction open access to process relevant emotional information, we additionally need emotional regulation to disengage or to minimize emotional processing when is not relevant. A recent study about the neural correlates of cognitive reappraisal showed that women regulate their negative emotions differently to men. Men, more than women, were shown to down-regulate negative emotions by decreasing amygdala activation, which may suggest a focus on diminishing negative emotions. On the other hand, women, more than men, up-regulate ventral striatum (VS) activation while performing the same down-regulation of negative emotion. These results suggest that to successfully regulate negative emotions women, but not men, may require qualitatively transform a negative emotion into a positive one (McRae, Ochsner, Mauss, Gabrielly & Gross, 2008). Therefore, we propose that emotion regulation could be an important variable during IGT, because it may minimize the effect of emotional reaction and allow to use cognitive resources to deploy cognitive control.

The idea that emotion regulation is an important step between emotional reaction and cognition driven decisional behavior, is in very good agreement with the proposal of Bechara (2005). He stated that decision-making depends on two neural systems: An "emotional" and a "cognitive" one. The emotional system, depending on the amygdala, signals the pain or pleasure of immediate decisional prospects (i.e., potential value of reward vs punishments). The second one, mostly constituted by prefrontal brain structures allows cognitive control of decisional behavior. According to Bechara (2005) once certain rules are learned (e.g., social rules), the cognitive system would dominate the emotional system, which ensure that monetarily efficient decisions are made. Implying that when emotional control- arguably through emotional regulation- is not efficient, it may hinder an effectively cognitive control over IGT decision-making.

1.3 Boosting women's emotion regulation through humor and possible impact in IGT decision-making performance.

Humor is one way to increase positive emotions, and evidence suggests that positive emotions have several benefits, including but not limited to reducing negative emotions (Frederickson, 1998) and buffering against stress (Speer & Delgado, 2017). Sex differences in humor processing suggests that women activate some humor-related brain structures more than men. For instance, there is evidence that under humorous condition, women show greater activation of nucleus accumbens (a part of ventral striatum), and recruit left prefrontal cortex more than men, suggesting a larger reward network response (Azim, 2005). According to these authors, the observed women's brain activation under humorous conditions is in very good agreement with other studies (Diekamp, 2002; Weinberger, 1993; Ueda, 2003; Gray, 2002) indicating a possible advantage for women in processing positive emotions and the increase of their executive function through humor. According to this, humor may have a positive impact in IGT decision-making in women.

CHAPTER TWO

Objectives and hypothesis

2.0 *General purpose that encompasses the three investigations included in the present thesis.*

Our general purpose was to determine behaviorally and through neural correlates, whether humor and sex could positively modulate decision-making. Due to the complexity of this general purpose. We divided it into three studies.

In the first study we used the traditional 100 trial task IGT and we examined the effect of using either humorous videos (Hc) or non-humorous videos (NHc) in the IGT performance of male and female participants. The videos were interspersed in the task, therefore, each video was presented before each decision, until completing 100 videos and 100 decisions. We examined in detail the effect of performance using traditional Bechara's performance along with the expectancy valence model (EVM).

The second study explored the effect of using either Hc or NHc to modulate the neural correlates of cognitive control (as expressed in the Event related potentials (ERP) amplitudes of N2 and P3b) and IGT performance of men and women. Due to ERPs restrictions, we had to modify the task increasing the number of trials (from 100 to 500) and feedback presentation (from reward and/or punishment to net-value). We followed Cui et al (2013) guidelines for EEG adaptation of IGT task. The videos were also interspersed in the task, so that each video was followed by five decisions, until completing 100 videos and 500 decisions. We examined in detail the effect of performance using traditional Bechara's performance along with EVM and ERPs analysis.

The third study explored the effect of Hc or NHc to modulate the neural mechanisms related to cognitive effort (theta power) and top-down control (beta power) and IGT performance in men and women. We made a re-analyses of electroencephalography (EEG) data provided by the previous study to re-interpret EEG data in terms of oscillations and to evaluate its relationship with decisional behavior (IGT performance).

2.1 *Unitary set of objectives and hypotheses*

Obj1 to examine the effect of humor on IGT performance and whether the effect of humor differ by sex.

H1 Humor will increase women's IGT performance and impair men's IGT performance.

Obj2 to explore the effect of humor in the cognitive processes underlying decision-making according to the Expectancy Valence Model (EVM), and whether the effect of humor on these processes differ by sex.

H2 Humor will have a positive effect on the EVM parameters underlying decision making in women, but a negative effect on men's EVM parameters.

Obj3 to examine the effect of humor and sex on the neural correlates of cognitive control during IGT.

H3 Humor will increase women's and decrease men's neural correlates of cognitive control during IGT.

Obj4 to examine the effect of humor and sex on the neural correlates of cognitive effort and top-down control during IGT

H4 Humor will decrease women's neural correlates of cognitive effort and top-down control and increase men's neural correlates of cognitive effort and top-down control during IGT.

Obj5 to examine the effect of humor and sex on the relationship of both, neural correlates of cognitive effort and top-down control on IGT performance.

H5 Women under humor will exhibit no correlation between the neural correlates of cognitive effort and IGT performance nor between the neural correlates of top-down control and IGT performance. Conversely, men under humor will show a positive correlation between cognitive effort and IGT performance and a negative correlation between top-down control and IGT performance.

CHAPTER THREE

Methods

3.0 *Methodological plan covering all studies and articles involved*

To achieve the objectives and hypotheses previously presented, we designed two different studies. A fully behavioral one constituted by 100 trials and an electrophysiological one constituted by 500 trials.

Two different groups were evaluated in both studies, a control group named *non-humor* (NHc) and an experimental group named *humor* (Hc). There were two factors, each one of them with two levels, namely: sex (men and women) and condition (humor and non-humor), this allow obtaining 4 sub-groups (men humor/men non-humor, women humor/women non-humor). The number of participants for each condition varied across different studies.

For the behavioral study we analyzed Bechara's behavioral performance and EVM parameter measures. For the electrophysiological study we analyzed Bechara's behavioral performance, EVM parameter measures, along with ERPs amplitudes and power analyses for each frequency band of interest.

Finally, we conducted either MANOVA, mixed factorial ANOVA (main effects and interactions), Pearson bivariate correlations and/or Student's T test when required by the particular needs of each study.

3.1 Participants

Inclusion criteria for participation were (1) being an undergraduate student at the Pontificia Universidad Católica de Chile, (2) being between 18 and 30 years old, (3) speaking Spanish, and (4) having normal or corrected-to-normal vision. Exclusion criteria were (1) having been diagnosed with a psychiatric disorder, (2) presenting severe depressive symptomatology according to the Self-Report Questionnaire (SRQ), (3) presenting a neurological disorder, (3) having a history of drug abuse, and (4) having consumed alcohol, caffeine or drugs 24 hours before participating in the experimental task.

In order to estimate the sample size, we used the software G* Power 3.1 with parameters for large effect size Fs (.40), a probability error α (.05), and a statistical power of (.80), which leads to a minimum of 52 participants (26 women and 26 men). Nonetheless, for the behavioral study, when we reached the sample size of 26 women, there was not still enough men enrolled, so we decided to continue the recruitment till we got an equivalent number of men and women. As such, 72 participants (37 women and 35 men) completed the behavioral study. We not considered the data of four of these participants (one male and three female) in the analyses because they did not fulfill all participation criteria. Namely, one of these participants reported having consumed drugs before the experiments and three of them presented severe depressive symptomatology according to the SRQ. Therefore, we finally analyzed the data of 68 participants (34 men; mean age 22.02, *SD* = 4.3 and 34 women; mean age 22.3, *SD* = 4.1).

For the case of the electrophysiological study, we also needed to continue the recruitment due to lack of male participants, in consequence, 60 (30 women and 30 men) participants completed the electrophysiological study and were considered for analysis.

3.2 *General procedure*

The Ethics Committee of the Pontificia Universidad Católica de Chile (PUC) approved both the behavioral and the electrophysiological studies. All experiments were performed at the Neuro-dynamic Laboratory of the School of Psychology of the PUC. We invited participants to the study through an advertisement published in the PUC Student´s Website. Those interested in participation were informed about the inclusion and exclusion criteria and provided with more study details via email. If they reported that they accomplished with the inclusion criteria, we finally invited them to come to the Lab.

In-lab session. First, we provided participants with more details about the study and conducted the informed consent process. After it, participants completed a battery of questionnaires comprising the SRQ and STAI-t. Then, they sat down in a comfortable chair in front of a computer screen and completed the IGT. Tasks instructions were presented written in the computer screen. The distance from participant´s eyes to computer screen was

60 cms, visual angle 4.7°. Study duration was approximately one hour. Participants received one movie ticket in compensation for participation.

Each trial began with an image announcing the video presentation in which the word "*video*" appeared on the screen during 1500ms. Then the video itself appeared. Each video was followed by a decision-making trial. During these trials, participants saw four deck options (A, B, C, and D) and chose one of the available options by clicking on the deck with a USB mouse.

For the behavioral study, when participants selected a card, its perimeter lit up in red. After that, the screen changed to black during 200ms. Immediately after the black screen, the feedback appeared. Feedback was shown during 2000ms. Feedback could be a winning (e.g., you won +100) or a winning and a loss (e.g., you won 100, but loss -50). Each card's feedback depended on the probabilities according with Bechara IGT manual. During the screen showing the four deck options, on the central superior area of the screen, two bars appeared. A green bar showed participant accumulated winnings and losses and a red bar represented the lent money (all participants started the task with $2000 CLP virtual money).

For the electrophysiological study When participants selected a card, its perimeter lit up in red. After that, the screen changed to black during 300ms, which allowed for a clean baseline for ERP measurement. Immediately after the black screen, the feedback appeared. Feedback corresponds to "0" time to evaluate ERPs. Feedback was shown during 2000ms. Feedback could be a net winning (e.g +100) or a net loss (e.g, -50). Each card's feedback depended on the probabilities according with Bechara IGT manual, using modifications for an electrophysiological adaptation

For both experiments, after feedback, bars automatically updated with either won or lost values throughout the task. We emphasized to participants that positions and decks contingencies were fixed during the whole task, that they could change decks at will, and that there was no association whatsoever between videos and decks. Participants had no specific information about how to solve the task, nor did they know how long it would take. For the behavioral study participants completed 100 videos and 100 trials (divided in 5 blocks of 20 trials each). For the electrophysiological study Participants completed 100 videos and 500 trials (divided in 25 blocks of 20 trials each). We programmed two breaks (after 40% and 70% of total trials).

3.3 *Variables*

3.3.1 *Independent variables for behavioral and electrophysiological study*

(a) *Sex* (men and women)

(b) *condition* (Hc and NHc). Hc condition is constituted by 100 humorous videos and NHc by 100 non-humorous videos (more details in section 3.4.1).

3.3.2. *Dependent variables for behavioral and electrophysiological study*

(a) *Bechara's gambling performance* is calculated by computing the difference between monetarily efficient and monetarily inefficient choices [(C+D) - (A+B)]. This computation is made in five sets of twenty choices each called blocks for the behavioral study and twenty-five blocks for the electrophysiological study. As participants learn IGT, there is an increase in the net score magnitudes, which is an increase in monetarily efficient choices.

(b) *EVM parameter measures*. EVM provides three cognitive latent parameters ("w", "a", and "c") that underlie decision-making. These parameters are useful to explain IGT performance. Being parameter "w" an estimation of whether attention is preferentially payed to the punishments or to the rewards. Parameter "a" -updating-rate- which is an estimation of the impact of recent/past experienced valences, and parameter "c" response consistency which is an estimation of whether choices are guided by expectancies or they are random.

3.3.3 *Dependent variables only for electrophysiological study*

(a) *Neural correlates of cognitive control (N2 and P3b ERPs amplitudes)*: We assessed the amplitudes of two Event Related Potentials (ERPs) which reflects cognitive control, namely the N2 and the P3b components. During IGT, the N2 component (also called mismatch detection) provides information about the detection of expectation violations when the participant received feedback about her/his performance and the P3b component provides information about attentional resource allocation to IGT performance.

(b) *Neural correlates of cognitive effort (theta power) and top-down control (beta power)*: Cognitive effort has been strongly associated with decision-making and have an impact in theta (4-8 Hertz) power. Top-down control depends on volitional shifts of attention derived from previous knowledge which allows to make predictions about the task outcomes. Beta activity (13-30 Hertz) power has been related to decision-making regarding top-down control of attention.

3.4 *Instruments*

For the two different studies (behavioral and electrophysiological) we used the same set of instruments, although some of them were modified due to specific requirements of each study. The set of instruments used will be described as follows.

3.4.1 *Humorous and non-humorous videos*

To induce humor, a selection of 200 videos (100 humorous and 100 non-humorous) was made from 240 public access videos (120 humorous and 120 non-humorous) available at *www.youtube.com*. The initial 240 videos were selected by the researcher. The criteria were the presence or absence of humor in ecological situations and an adequate duration of stimuli which must be suitable for EEG uses (mean duration = 12.84 secs; *SD* = 5.81 secs). The initial 240 videos selected by the researcher were presented in a randomized order to 50 subjects (25 men and 25 women) who were not part of the sample of the present research. These subjects were asked to rate the videos using a humor scale ranging from 0 to 10 points (0 “not humorous at all”; 10 “the most humorous thing ever”). To identify how each video was rated, participant´s ratings were plotted. We eliminated all individual videos that were less than three standard deviation away from the mean of the opposite condition, which result in the elimination of 40 videos (20 humorous and 20 non- humorous). The final video selection consisted in 100 humorous and 100 non-humorous videos. To examine whether there were statistically significant differences in the rating scores between both types of videos, we conducted a two-way factorial ANOVA (Sex x Video type [humor/non-humor]). Results showed a main effect of video type ($F_{1,198} = 220$, $p < .001$, $\eta^2 = .917$), indicating that humorous videos were rated as significantly more humorous than non-humorous videos. Neither the main effect of sex nor the interaction (Sex x Video Type) were statistically significant. Humorous videos were assigned to the experimental group while non-humorous to the control group. The mean duration of the humorous videos was 12.84 (*SD* = 5.81) and the non-humorous videos mean was 11.91 sec (*SD* = 4.62).

3.4.2 *Iowa gambling task (IGT)*

It was designed as a life-like decision-making task (IGT; Bechara et al., 1994). Participants must choose a card out of any of four card decks (A, B, C, and D). After each choice, participants can be rewarded with virtual money (reward) or punished with a loss of virtual money (punishment). Participants must learn as they play which are the monetarily efficient and inefficient decks to solve the task. Participants can change decks at will during the whole task; however, they're warned that some decks are worse than others in terms of payment and that decks positions are fixed during the whole task. Likewise, they are informed that the goal is to win as much money as possible, or to avoid losing money as much as possible.

Concerning outcomes, card decks A and B are monetarily risky/inefficient, and C and D are monetarily safe/efficient. Card decks A and B are associated with higher sums of immediate rewards (e.g, $100) but maintaining these card decks choices means accumulating less or no profit at all, because of occasional large monetary punishments. As a matter of fact, this strategy leads to a net loss from $250 during the 10 first trials, while card decks C and D could offer an immediate lower reward (e.g $50) but with small monetary punishments, allowing to accumulate profit and leading to a net winning from $250 during the first 10 trials. Consistent C and/or D choices allow participants to earn virtual money at the end of the task, while A and/or B consistent choices leads to owing money at the end of the task.

For the electrophysiological study we modified the original number of trials from 100 to 500 to make statistically valid ERP inferences and we also modified the feedback shown to participants, following Cui et al (2013) guidelines in which the presentation of win and losses observed in the original task is replaced by net scores of either wining or losses.
IGT performance is calculated by computing the difference between monetarily efficient and monetarily inefficient choices [(C+D) - (A+B)]. This computation is made in twenty-five sets of twenty choices each called blocks. As participants learn IGT, there is an increase in the net score magnitudes, which is an increase in monetarily efficient choices.

3.4.3 *Self report questionnaire (SRQ)*

The Self-report questionnaire (SRQ; Harding et al, 1980) was used to assessed depressive symptomatology. It consists of 25 Yes and No questions. The SRQ has been validated for Chilean population (Vielma et al, 1984). Subjects scoring higher than 11 points or answering affirmatively questions 21 to 25 (elevated probability of depressive symptomatology) were not included in the study sample.

3.4.4 *State-trait anxiety inventory (STAI)*

The State-Trait anxiety inventory (STAI; Spielberger et al, 1970) was used to assess anxiety symptoms. It consists of 40 questions divided in two subscales: the state anxiety (SA) and the trait anxiety (TA) scales. The STAI has been validated for Chilean population (Vera-Villarroel et al, 2007). We assessed this variable because higher TA scores are related with impairments in decision-making and could potentially affect our results (Miu, Heilman, & Houser, 2008).

CHAPTER FOUR

Research articles attached

Based on the two studies we previously described we created three independent articles. The first one based on the behavioral study entitled *"Humor impair men's but not women's performance in the Iowa Gambling Task"* the other two articles based on the electrophysiological study *"Humor facilitates decision-making in women and impairs it in men"* and *"The effect of humor and sex on theta and beta oscillatory activity and its relationship with IGT decision-making performance".* The complete articles are attached as follows.

4.0 *Humor impair men’s but not women’s performance in the Iowa Gambling Task (prepared to submit to PlosOne)*

Humor impair men´s but not women´s performance in the Iowa Gambling Task

Jorge Flores-Torres, Lydia Gómez-Pérez, Vladimir López & Eugenio Rodríguez

Abstract

The Iowa Gambling Task (IGT) is a popular method of examining real-life decision-making. During IGT participants must learn through exploration how to optimize their decisions. Research showed that men consistently outperform women, nevertheless the reason why for this difference remains unknown. Research shows that in real-life decision-making, emotional and cognitive neural systems must be adequately controlled to solve IGT. Evidence support that women display less emotional control than men, which negatively could affect their decisional performance. In the present study we use humor to modulate the emotional response of subjects performing IGT. Results from traditional Bechara's performance analysis showed that humor didn't affect women's IGT performance, but it did impair men's performance. Results using EVM analysis showed that humor affected negatively men's memory/learning of the task. Therefore, our results suggest that under humor men's ability to explore and to learn from experience was negatively affected so they were stuck in a suboptimal strategy.

The brain could be considered a decision-making device from which perceptual, mnemonic and motor capabilities evolved to support the decisions that determine our actions [1]. One of the most popular tests to measure decision-making is the Iowa gambling task [2,3], which mimics real-life decision-making. During the IGT, participants face four decks of cards. Each one shows a predetermined but fixed proportion of monetary punishments and rewards. Participants have to figure out through exploration which deck (or decks) will allow them to accumulate more monetary gains than losses. Participants must learn how to make monetarily safe/efficient choices as they play, based on the emotional consequences of their choices.

The idea that emotions are relevant during decision-making process is well stablished in decision-making research [4]. For instance, according to the Somatic Marker Hypothesis [5], emotions signal how likely it is to obtain an instrumental reinforcer (e.g., punishment or reward), guiding decision-making in situations of complexity and uncertainty [6]. According to this theoretical framework, decision-making depends on two neural systems: An "emotional" and a "cognitive" one [7]. The emotional system depends on the amygdala and signals the pain or pleasure of immediate prospects (i.e., potential value of reward vs punishments). The cognitive system is mostly constituted by prefrontal brain structures and allows cognitive control of decisional behavior. Once task-rules are learned, the cognitive system would dominate the emotional system, which ensures that monetarily efficient decisions are made.

There is consistent evidence supporting sex differences in IGT performance [8,9]. Research shows that, compared to men, during the IGT women usually make less monetarily efficient choices and need more trials to figure out which deck or decks will allow them to accumulate more monetary gains [8,9]. Researchers have suggested that these sex-related differences in performance may be related to sex-related differences in emotional processing [10,11,12,13]. For instance, women with high trait anxiety have shown to perform worse in IGT than women with low trait anxiety [13]. Furthermore, previous research has demonstrated that women exhibit more intense nervousness and more fear than men during punishment anticipation, which decreases the economic utility of a risky choice [10,11,12]. The results of a recent study about the neural correlates of cognitive reappraisal [14] showed that women and men not only differ in the way they react but also in the way they regulate their negative emotions. In this study, men were shown to down-regulate negative emotions by decreasing amygdala activation more than women, which may suggest a focus on diminishing negative emotions. On the other hand, women up-regulated ventral striatum (VS) activity more than men while performing the same down-regulation of negative emotions. These results suggest that, to successfully regulate negative emotions, women but not men may require qualitatively transforming a negative emotion into a positive one [14]. Nonetheless, more research on this regard is still needed.

Humor is one way to increase positive emotions. Positive emotions have shown to have several benefits, including reducing negative emotions [15] and buffering against stress [16]. Human and non-human females seem to activate some humor-related brain structures more than males [17,18,19,20,21]. For instance, there is evidence that under humorous condition, women show greater activation of nucleus accumbens (a part of VS) and recruit left prefrontal cortex more than men, suggesting a larger reward network response [17]. As such, it has been suggested that humor may increase women´s executive function [17,19,20,21]. However, this hypothesis remains to be tested.

The main objective of the present study is to examine the effect of humor on IGT performance and whether the effect of humor differ by sex. As such, we compared the IGT performance scores of four groups of participants: women under an experimental humorous condition (Hc), women under a control non-humor condition (NHc), men under the Hc, and men under the NHc. In line with the abovementioned research, we hypothesize that humor will increase women´s IGT performance. Therefore, women under the HC will exhibit higher IGT performance than women under the NHc (Hypothesis 1). By contrast, humor will not affect men's IGT performance. Therefore, we do not expect to find statistically significant differences in IGT performance between men under the Hc and men under the NHc (Hypothesis 2). Women under the NHc will obtain lower IGT performances than men (Hypothesis 3). Nonetheless, we do not expect to find differences in IGT performance between men under the Hc and women under the Hc (Hypothesis 4).

The second aim of the present study is to explore the effect of humor in the cognitive processes underlying decision-making according to the Expectancy Valence Model (EVM) [22], and whether the effect of humor on these processes differ by sex. In accordance with the the Expectancy Valence Model (EVM), three cognitive latent processes ("w", "a", and "c") underlie decision-making. These processes are vital to produce successful IGT performance [22, 23]. The parameter "w" indicates whether participants pay more attention to rewards or to punishments. The parameter "a" indicates whether participants learn in terms of updating their expected valences (the expected monetary value of each deck at each trial) with experience or whether they just remain with their initial valences. Finally, the parameter "c" indicates whether participants use the expected valences to guide their decisional behavior or whether their choices are random. Therefore, we expect to find that – among women – humor will have a positive effect on the parameters underlying decision making (Hypotheses 5). Namely, women under the Hc will present higher attention to punishment (parameter "w") and higher updating rate (parameter "a") than women under the NHc.

Furthermore, they will use their response consistency (parameter “c”) to a higher degree than women under the NHc. By contrast, we expect to find that – among men – humor will have a negative effect on the parameters underlying decision making (Hypotheses 6). Therefore, men under the Hc will present lower attention to punishment (parameter “w”) and lower updating rate (parameter “a”) than the men under the NHc. Furthermore, they will use their response consistency (parameter “c”) to a lower degree than men under the NHc. We additionally expect to find that women under Hc will present higher attention to punishment (parameter “w”), higher updating rate (parameter “a”) and higher response consistency (parameter “c”) than men under Hc (Hypothesis 7). By contrast, we expect to find that women under NHc will present lower attention to punishment (parameter “w”), lower updating rate (parameter “a”) and lower response consistency (parameter “c”) than men under NHc (Hypothesis 8)

Method

Participants.

Inclusion criteria for participation were (1) being an undergraduate student at the Pontificia Universidad Católica de Chile, (2) being between 18 and 30 years old, (3) speaking Spanish, and (4) having normal or corrected-to-normal vision. Exclusion criteria were (1) having been diagnosed with a psychiatric disorder, (2) presenting severe depressive symptomatology according to the Self-Report Questionnaire (SRQ) [24,25], (3) presenting a neurological disorder, (3) having a history of drug abuse, and (4) having consumed alcohol, caffeine or drugs 24 hours before participating in the experimental task.

In order to estimate the sample size, we used the software G* Power 3.1 with parameters for large effect size Fs (.40), a probability error α (.05), and a statistical power of (.80), which leads to a minimum of 52 participants (26 women and 26 men). Nonetheless, when we reached the sample size of 26 women, there was not still enough men enrolled, so we decided to continue the recruitment till we got an equivalent number of men and women. As such, 72 participants (37 women and 35 men) completed the study. We not considered the data of four of these participants (one male and three female) in the analyses because they did not fulfill all participation criteria. Namely, one of these participants reported having consumed drugs before the experiments and three of them presented severe depressive symptomatology according to the SRQ. Therefore, we finally analyzed the data of 68 participants (34 men; mean age 22.02, *SD* = 4.3 and 34 women; mean age 22.3, *SD* = 4.1).

Questionnaires.

The Self-report questionnaire [24] was used to assess depressive symptomatology. It consists of 25 Yes and No questions. The SRQ has been validated for Chilean population [25]. Subjects scoring higher than 11 points or answering affirmatively questions 21 to 25 (elevated probability of depressive symptomatology) were not included in the study sample, as depression have shown to affect decision making [26, 27].

The State-Trait anxiety inventory (STAI) [28] was used to assess anxiety symptoms. It consists of 40 questions divided in two subscales: the state anxiety (SA) and the trait anxiety scales. The STAI has been validated for Chilean population [29]. We assessed this variable because higher trait anxiety scores are related with impairments in decision-making and could potentially affect our results [13].

Humorous and neutral (non-humorous) videos. To induce humor, we initially selected 200 videos (100 humorous and 100 non-humorous) from 240 public access videos (120 humorous and 120 non-humorous) available at *www.youtube.com*. Selection criteria were the presence or absence of humor in ecological situations and an adequate duration of stimuli to present a video before each decision (video mean duration = 12.84 secs; video *SD*

= 5.81 secs). We presented these videos in a randomized order to 50 subjects (25 men and 25 women) who were not part of the sample of the present research. We asked them to rate the videos using a humor scale ranging from 0 to 10 points (0 “not humorous at all”; 10 “the most humorous thing ever”). In order to identify how each video was rated, we plotted participant´s ratings. We eliminated all individual videos that were less than three standard deviation away from the mean of the opposite condition, which result in the elimination of 40 videos (20 humorous and 20 non- humorous). The final video selection consisted in 100 humorous and 100 non-humorous videos. To examine whether there were statistically significant differences in the rating scores between both types of videos, we conducted a two-way factorial ANOVA (Sex x Video type [humor/non-humor]). Results showed a main effect of video type ($F_{1,198}$ = 220, p <.001, η^2 = .917), indicating that humorous videos were rated as significantly more humorous than non-humorous videos. Neither the main effect of sex nor the interaction (sex x video type) were statistically significant. Humorous videos were assigned to the experimental group while non-humorous to the control group. The mean duration of the humorous videos was 12.84 (*SD* = 5.81) and the non-humorous videos mean was 11.91 sec (*SD* = 4.62).

The IGT. It was designed as a life-like decision-making task [2, 3]. Participants must choose a card out of any of four card decks (A, B, C, and D). After each choice, participants can be rewarded with virtual money (reward) or punished with a loss of virtual money (punishment). Participants must learn as they play which are the monetarily efficient and inefficient decks to solve the task. Participants can change decks at will during the whole task; however, they are warned that some decks are worse than others in terms of payment and that decks positions are fixed during the whole task. Likewise, they are informed that the goal is to win as much money as they can, or to avoid losing money as much as possible.

Concerning outcomes, card decks A and B are monetarily risky/inefficient, and C and D are monetarily safe/efficient. Card decks A and B are associated with higher sums of immediate rewards (e.g., $100) but maintaining these card decks choices means accumulating less or no profit at all, because of occasional large monetary punishments. As a matter of fact, this strategy leads to a net loss from $250 during the 10 first trials. By contrast, card decks C and D are associated with a lower sum of immediate rewards (e.g., $50) but with small monetary punishments, allowing to accumulate profit and leading to a net winning from $250 during the first 10 trials. Consistent C and/or D choices allow participants to earn virtual money at the end of the task, while A and/or B consistent choices leads to owing money at the end of the task.

IGT performance is calculated by computing the difference between monetarily efficient and monetarily inefficient choices [(C+D) - (A+B)] called net-score. This computation is made in five sets of twenty choices each called block, obtaining five net-scores (one for each block). As participants learn IGT, there is an increase in the net-scores magnitudes of each block, which reflects an increase in monetarily efficient choices.

Procedure

The Ethics Committee of the Pontificia Universidad Católica de Chile (PUC) approved the study. All experiments were performed at the Neuro-dynamic Laboratory of the School of Psychology of the PUC. We invited participants to the study through an advertisement published in the PUC Student´s Website. Those interested in participation were informed about the inclusion and exclusion criteria and provided with more study details via email. If they reported that they accomplished with the inclusion criteria, we finally invited them to come to the Lab.

In-lab session. First, we provided participants with more details about the study and conducted the informed consent process. After it, participants completed a battery of questionnaires comprising the SRQ and STAI-t. Then, they sat down in a comfortable chair in front of a computer screen and completed the IGT. Tasks instructions were presented written in the computer screen. The distance from participant´s eyes to computer screen was 60 cms, visual angle 4.7°. Study duration was approximately one hour. Participants received one movie ticket in compensation for participation.

Each trial began with an image announcing the video presentation in which the word "*video*" appeared on the screen during 1500ms. Then the video itself appeared. Each video was followed by a decision-making trial. During these trials, participants saw four deck options (A, B, C, and D) and chose one of the available options by clicking on the deck with a USB mouse. When participants selected a card, its perimeter lit up in red. After that, the screen changed to black during 200ms. Immediately after the black screen, the feedback appeared. Feedback was shown during 2000ms. Feedback could be a winning (e.g., you won +100) or a winning and a loss (e.g., you won 100, but loss -50). Each card's feedback depended on the probabilities according with Bechara IGT manual [30]. During the screen showing the four deck options, on the central superior area of the screen, two bars appeared. A green bar showed participant accumulated winnings and losses and a red bar represented the lent money (all participants started the task with $2000 CLP virtual money). After feedback, bars automatically updated with either won or lost values throughout the task. We emphasized to participants that positions and decks contingencies were fixed during the whole task, that they could change decks at will, and that there was no association whatsoever between videos and decks. Participants had no specific information about how to solve the task, nor did they know how long it would take. Participants completed 100 videos and 100 trials (divided in 5 blocks of 20 trials each).

Calculation of EVM parameter

The EVM is a reinforced learning model. As it was previously described in the introduction, it provides three cognitive processes parameters, "*w*", "*a*", and "*c*". According to Wetzels [23] the model assumes that, after selecting a card from deck *k*, $k \in \{1, 2, 3, 4\}$ on trial *t*, participants calculate the resulting net profit or valence. This valence v_k is a combination of the experienced reward W(*t)* and the experienced loss L(*t*):

(1) $v_k\ (t) = (1 - w)\ W(t) + \mathrm{w} \cdot L(t)$

This equation uses the parameter "*w"* of the EVM, which – as it was previously indicated – provides information about whether participants pay more attention to the rewards or to the punishments. Values of "*w"* range between 0 and 1. Values lower that .50 are indicative of paying more attention to rewards than to punishment, whereas values higher than .50 are indicative of paying more attention to punishment than to reward, and values equal to .50 are indicative of paying the same amount of attention to rewards and punishments. [23]

Based on the sequence of valences v_k experienced previously, the participants form an expectation Ev_k of the valence for deck *k*. Learning occurs when new valences change the value of the expected valence Ev_k. In a given time *t*, if the experienced valence differs from the expected one, then the value Ev_k needs to be adjusted. The way the value is adjusted is given by the following equation:

(2) $Ev_k\ (t+1) = Ev_k\ (t) + \alpha \cdot (\mathrm{v}_k(t) - Ev_k(t))$

In this equation the updating rate $\alpha \in [0, 1]$ determines the impact of recently experienced valences. Opting for the deck with the highest expected valence is a "greedy" strategy that in the long run can lead to a suboptimal solution, given it involves little exploration. To ensure initial deck exploration from the participants, an additional equation is added to the model. The equation is a standard reinforcement learning method called softmax selection or Boltzman exploration [31]:

(3) $\Pr[S_k\ (t+1)] = \frac{\exp(\theta(t) Ev_k)}{\sum_{j=1}^{4} \exp(\theta(t) Ev_j)}$

In this equation, $\frac{1}{\theta(t)}$ is the "temperature" at the trial t and $Pr(S_k)$ is the probability of selecting a card from deck *k*. Higher temperatures mean more random decisions, which means a higher level of exploration, while lower temperatures mean less exploration, and more exploitation of the decks with higher expected valences. A temperature of zero will make the participant decide only based on expected valence, choosing the deck with the highest expected valence.

In the EV model, the temperature changes given the number of observations according to the following formula:

(4) $\theta(t) = (\frac{t}{10})^c$

Where "c" is the response consistency or sensitivity parameter (also called the exploration parameter). When fitting to data, the parameter is constrained to the interval [-5, 5]. Positive values of "c" make response consistency θ values increase with the number of observations, which means $1/\theta$ values will decrease. This leads to lower "temperatures", meaning choices are guided more by expected valences. Negative values of "c" mean choices will become more and more random as the number of card selection increases.

Being "i" a given participant, the current IGT study calculated participant's specific parameters "w_i", "a_i", and "c_i" by minimizing the sum of the one-step-ahead prediction errors:

(5) $\sum_{t=1}^{T} - \ln p(y_t | y^{t-1}, w_i \,, a_i, c_i)$

The method of parameter estimation was applied to each individual participant separately. This was done using Python 3.6.0. The program started by reading text files that contained the decisions made by the subjects on the IGT study, files with a column of their decision in a given trial and other column for type of feedback. The results were saved locally in the program for further processing.

Values for Ev_k, v_k during time, were saved in two-dimensional arrays. The first dimension represented the *k* value between 1 and 4 (representing decks A, B, C, and D). The second dimension represented the value of *t*. They were initialized with the float value 0.0 for all *k* and *t* values. θ values when *t* was 0 were fixed to a constant depending on the value of "*c*", if "*c*" was a non-negative number then θ was 0, if "*c*" was a negative number then θ for *t*=0 was fixed to 999999999 (a large value to represent infinity).

For the search of the best parameters that fitted a given subject's EVM, the optimization method used was "differential evolution", which does a complete search of the solution space, finding the global minimum of the function and the parameters that make it minimum. The solution space was bounded so values for "*w*" were in [0.0, 1.0], values for "*a*" in [0.0, 0.0], and values for "*c*" in [-5.0, 5.0].

A given iteration of the optimization first randomly chooses three values from the solution space, that is a value in [0.0, 1.0] for "*w*", one in [0.0, 1.0] for "*a*", and one in [-5.0, 5.0] for "*c*". It replaces those values in the sum of the one-step-ahead prediction errors function, that is it iterates for every *t* value, calculating $- \ln p(y_t | y_{t-1} w_i, a_i, c_i)$ and does the sum of those values (EQ5). This sum returns the value we are trying to minimize. Consequent iterations of the optimization choose different values for the parameters. It ends when it finds the ones that minimizes the function's value, these are used for further analysis.

Data analysis.

Trait anxiety has shown to affect IGT performance and women seem to present higher trait anxiety than men [13]; therefore, to examine whether there were differences between the groups in this variable, we first conducted a two-way factorial ANOVA [Sex x Condition (Humor/Non-humor)] in which the dependent variable was trait anxiety. The main effect of sex, the main effect of condition, and the interaction were not statistically significant, indicating that there were no significant differences in trait anxiety among groups. Therefore, this variable was not considered in further analyses.

To test whether women under Hc exhibit higher IGT performance than women under NHc (Hypothesis 1) we conducted a two-way ANOVA [Condition x Block] considering only the women sample. To examine whether men under Hc and men under NHc present differences in IGT performance (Hypothesis 2) we conducted another two-way ANOVA [Condition x Block], this time using only the men sample. To test whether under NHc women present lower IGT performance than men (Hypothesis 3), we conducted a two-way ANOVA [Sex x Block] using only the data from participants under NHc. And finally, to test whether under Hc men and women present differences in IGT performance (Hypothesis 4), we conducted the last two-way ANOVA [Sex x Block], this time using only the data from participants under Hc.

To test whether women under Hc exhibit higher attention to punishment (parameter "w"), higher updating-rate (parameter "a") and higher response consistency (parameter "c") than women under NHc (Hypothesis 5), we conducted a MANOVA with the total sample of women and performed ANOVA contrasts for each parameter when needed. To test whether men under Hc exhibit lower attention to punishment, high updating-rate and higher response consistency than women under NHc (Hypothesis 6), we conducted a MANOVA with the total sample of men and performed ANOVA contrasts for each parameter when needed. To test whether women under Hc exhibit higher attention to punishment, higher updating-rate, and higher response consistency than men under Hc (Hypothesis 7), we conducted a MANOVA with the total sample of participants under Hc and performed ANOVA contrasts for each parameter when needed. To test whether women under NHc exhibit lower attention to punishment, lower updating-rate, and lower response consistency than men under NHc (Hypothesis 8), we conducted a MANOVA with the total sample of participants under NHc and performed ANOVA contrasts for each parameter when needed.

Prior to conducting the abovementioned analyses, we checked normality, linearity and sphericity assumptions. When needed, outliers were replaced using the mean plus two standard deviations method recommended by Field [32]. In case the sphericity assumption was violated, we used the parameter ε Greenhouse-Geisser to correct for such violations. We applied Bonferroni correction for post-hoc comparisons.

Results

Differences in IGT performance

The result of the two-way ANOVA [Condition (Hc/NHc) x Blocks (1-5)] conducted with the sample of women revealed a statistically significant main effect of blocks ($F_{3.06,98.15} = 6.42$, $p < .00$, $\eta^2 = .17$), indicating that regardless of condition, women learnt the task as it progressed. Nevertheless, neither the main effect of condition nor the interaction (Blocks x Condition) were statistically significant. Therefore, contrary to our expectations (Hypothesis 1), there were no differences in IGT performance between the women under the Hc and the women under the NHc.

The result of the two-way ANOVA [Condition x Blocks] conducted with the sample of men showed a statistically significant interaction effect (Blocks x Condition) ($F_{4,128}$ = 4.72, p < .00, η^2 = .13) indicating that men under Hc obtained lower IGT performance than those under NHc in block 2 ($t(1)$ = -3.16, p < .00, η^2 = .24) and block 5 ($t(1)$ = -3.42, p < .00, η^2 = .27). Additionally, we found a statistically significant main effect of blocks ($F_{4,128}$ = 10.28, p <.00, η^2 = .24) and a statistically significant main effect of condition ($F_{1,32}$ = 14.28, p < .00, η^2 = .31).

The result of the two-way ANOVA [Sex x Blocks] considering only the participants under the NHc revealed a statistically significant interaction effect (Blocks x Condition) ($F_{2.26,72.4}$ = 4.06, p =.02, η^2 = .11) indicating that men under NHc obtained lower IGT performance than women under NHc in block 4 $t(1)$ = -5.02, p < .00, η^2 = .44. We also found a significant main effect of blocks ($F_{2.26,72.4}$ = 6.31, p <.00, η^2 = .17).

Finally, the result of the two-way ANOVA [Sex x Block] conducted only with the participants under the Hc showed that the interaction effect was statistically significant, indicating that women obtained higher IGT performances than men during the block 2, $t(1)$ = 3.55, p < .00, η^2 = .28. We additionally found a statistically significant main effect of Sex, ($F_{1,32}$ = 5.91, p =.02, η^2 = .16) and a statistically significant main effect of blocks ($F_{2.79,89.38}$ = 9.65, p <.00, η^2 = .232).

[Please insert here Figure 1]

Differences in EVM parameters.

The result of the MANOVA examining the effect of condition (Humor/Non-humor) on the parameter "w", "a", and "c" conducted with the sample of women, showed a tendency to significant using Pillai's Trace, $V = 0.21$, $F\ (3,30) = 2.73$, $p = .06$ *n.s.*, $\eta^2 = .21$. Conversely, the results of the MANOVA examining the effect of condition in the three EVM parameters in the sample of men, revealed statistical differences using Pillai's Trace, $V = 0.31$, $F\ (3,30) = 4.4$, $p = .01$. Separate univariate ANOVAs on the outcome variables showed statistical differences for parameter "a" $F(1,32) = 10.79$, $p < .00$ indicating that the men under Hc obtained significantly lower updating-rate scores than the men under NHc, $t(1) = -3.29$, $p < .00$, $\eta^2 = .25$; $M_{\text{men Hc}} = .000$, $SD_{\text{men Hc}} = .000$; $M_{\text{men NHc}} = .003$, $SD_{\text{men NHc}} = .003$). The result of the MANOVA examining the effect of Sex on the three EVM parameters conducted with the sample under humor, showed statistical differences using Pillai's Trace as well, $V = 0.37$, $F\ (3,30) = 6.05$, $p < .00$. Separate univariate ANOVAs on the outcome variables showed statistical differences for parameters "w", "a", and "c". Parameter "w" $F\ (1,32) = 11.87$, $p < .00$, $\eta^2 = .27$ indicates that the men under Hc obtained significantly higher attention to punishments than the women under Hc, $t\ (1) = 3.45$, $p < .00$, $\eta^2 = .27$; $M_{\text{men Hc}} = .44$, $SD_{\text{men Hc}} = .41$; $M_{\text{women Hc}} = .08$, $SD_{\text{women Hc}} = .09$. Parameter "a" $F\ (1,32) = 8.16$, $p < .00$, $\eta^2 = .20$ indicates that the men under Hc obtained significantly lower updating-rate than the women under Hc , $t(1) = -2.86$, $p < .00$, $\eta^2 = .20$; $M_{\text{men Hc}} = .000$, $SD_{\text{men Hc}} = .000$; $M_{\text{women Hc}} = .002$, $SD_{\text{women Hc}} = .002$. and parameter "c" $F\ (1,32) = 5.84$, $p = .02$, $\eta^2 = .15$ indicates that the men under Hc obtained significantly lower response consistency than the women under Hc, $t\ (1) = -2.42$, $p = .02$, $\eta^2 = .15$; $M_{\text{men Hc}} = -1.40$, $SD_{\text{men Hc}} = 1.19$; $M_{\text{women Hc}} = -0.4$, $SD_{\text{women Hc}} = 1.21$. The result of the MANOVA examining the effect of Sex on the three EVM parameters conducted with the sample under non-humor revealed statistical significant differences using

Pillai's Trace, $V = 0.35$, F (3,30) = 5.41, $p < .00$. Separate univariate ANOVAs on the outcome variables revealed statistical differences only for parameters "w" and "a". Parameter "w" F (1,32) = 8.29, $p <.00$, $\eta^2 = .21$ indicates that the men under NHc obtained significantly higher attention to punishments than the women under NHc, $t\ (1) = 2.88$, $p < .00$, $\eta^2 = .21$; $M_{\text{men NHc}} = .47$, $SD_{\text{men NHc}} = .39$; $M_{\text{women NHc}} = .17$, $SD_{\text{women NHc}} = .21$. And parameter "a" F (1,32) = 9.91, $p < .00$, $\eta^2 = .23$ indicates that the men under NHc obtained significantly higher updating-rate than the women under NHc, $t\ (1) = 3.15$, $p < .00$, $\eta^2 = .23$; $M_{\text{men Hc}} = .003$, $SD_{\text{men Hc}} = .003$; $M_{\text{women Hc}} = .000$, $SD_{\text{women Hc}} = .000$.

[Please, insert here Figure 2]

Discussion

The first purpose of the present study was to examine the effect of humor on IGT decision-making performance and whether the effect of humor differed by sex. First, we found that, contrary to our hypotheses, humor did not affect women´s IGT performance, as there were no differences between the women under the Hc and the women under the NHc. Unexpectedly, humor showed to impair men's IGT performance, as men under the Hc presented lower IGT performances than the men under the NHc. Furthermore, contrary to our expectations, we found that regardless of the condition, women performed better than men.

Regarding our second objective – exploring the effect of humor in the cognitive processes underlying decision-making according to the EVM – we found that humor did not affect any of the three EVM parameters in women. Nevertheless, in men we found that those under Hc presented lower updating-rate scores (parameter "a") than the men under NHc.

Furthermore, we found that comparing men and women under Hc the men obtained higher attention to the punishment (parameter “w”), but lower updating-rate (parameter “a”) and lower response consistency (parameter “c”) than the women under the Hc. Finally, we found that the men under the NHc exhibited higher attention to the punishment and higher updating-rate than the women under the NHc.

Despite humor did not improve women’s IGT performance, it didn’t impair it either. Conversely for men, we observed a clear negative effect of humor on their performance, affecting their updating-rate (parameter “a”). The parameter “a” indicates the impact of recently experienced valences. Small rates as evidenced in our study are indicative of slow changes, weak recency effects, long associative memories and slow forgetting [23] So, our results suggest that under humor men’s ability to explore and learn from experience was negatively affected so they were stuck in a suboptimal strategy.

Sex differences indicate that something beyond the use of humor affected men´s performance, as they performed worse than women regardless of the condition they participated. In detail we observed that the men obtained higher scores in the “w” parameter than women regardless of condition. Parameter “w” results indicate that women payed statistically more attention to the rewards than men. This is striking, because paying more attention to the rewards is indicative of an underestimation of the effect of punishments, leading to more monetarily inefficient/risky choices [22,23] and therefore to lower performance or even failing in solving the task [40] Due to the abovementioned evidence it is expected that men would perform better than women, which was not the case. Conversely, despite of being more attracted to the rewards, women solve the task better than men. It is possible that women were not as affected as men by the videos, indicating that for women watching the videos (regardless of the content) while solving the task would help them to decrease their original emotionally-guided behavior (looking for high monetary rewards) and deploy a more cognitively-guided behavior over the task instead (change their initial-strategy to something better). Nevertheless, more studies of the influence of sex and video stimuli during IGT are needed.

In terms of sex differences under humor, the results showing higher updating-rate and higher response consistency for women than for men are in line with those reported by Azim [17] who found that exposing women to humorous pictures – but not to non-humorous pictures – could facilitate their cognition. Our results indicate that, under the Hc, women learnt more than men (in terms of updating their expected valences) and they used what they learnt to take less random choices than men.

It is difficult to explain why humor didn´t affect women performance nor EVM parameters. A closer look to the data showed that EVM analysis in women showed a tendency to significant (p = .06, η^2 =.21) indicating a tendency to changes under Hc benefiting their updating-rate. It is possible that an effect in IGT performance had been observed if women's participants would have had more time under humorous condition. For instance, in our study participants had a total of 12 minutes of humorous induction and approximately 8 minutes of IGT decisions, adding together 20 minutes of task in total. A study reported that after 30 to 40 minutes humor seems to have stronger physiological effects [33,34]. Therefore, future studies using more trials and/or longer periods of emotional induction are needed to test whether these closer to significant observed changes in women's learning under humor may ultimately lead to an improvement of women's IGT performance.

The men under the Hc presented lower IGT performances than the men under the NHc. This unexpected result could be a consequence of men's cognitive demands when processing humorous stimuli while solving IGT. Humor research indicates that men use more evaluative executive resources to process humorous than non-humorous stimuli [35], and therefore the men under the Hc may have had less available cognitive resources to solve IGT than the men under the NHc. By contrast, humor did not impair women's IGT performance scores. One may wonder why women performance was not negatively affected by humor as in the case of men. There is evidence indicating that women process humor differently than men [17,19,20,21]. Whereas men process humor mostly by using evaluative executive brain structures, women process humor mostly using affective brain structures, and through this activity their cognition may be facilitated [17,19,20,21]. Therefore, in our study, humor may have facilitated women's allocation of cognitive resources in the IGT task, and as result, it would have not impaired women's performance as in the case of men. Nevertheless, studies evaluating humor in IGT performance in which attention allocation is specifically measured during the IGT task remain to be conducted.

Contrary to our expectations, we did not find differences in IGT performance between women and men under the NHc. These results contradict previous research indicating that men seem to outperform women in the IGT [4]. Nevertheless, the men under the NHc presented higher parameter "a" scores than the women under the NHc, indicating that they seem to learn more than women in the sense that they update their expectancies with experience to a greater degree than women. Differences between our experimental procedure and the procedures used un previous studies may be explaining why we did not find differences between men and women when humor was not involved. The main difference between our study and previous studies is the use of videos that interspersed each decision (100 videos for 100 choices) which means that our participants need to split their attention between the videos and the decisions while performing the task. In a previous study [36], found that men had poorer IGT performance than women when their attention compete for resources between the IGT and another task. So, the exposure of our participants to a dual-task like paradigm, may have had a more negative impact among men than among women. We propose that choice behavior in men under NHc could be impaired by a decrease in attention, influencing more but in a disorganized exploration leading to a poor choice strategy.

Finally, we found that men obtained higher scores in the “w” parameter than the women regardless of condition. This contrasts with previous studies [37,38], in which it is stated that “w” parameter is not affected by sex. To our knowledge, no other previous studies have examined sex and humor differences in EVM, and more research about this topic is still needed.

In conclusion, this is the first study evaluating the effect of sex and humor in the IGT. additionally, is the first study to our knowledge that uses both IGT Bechara´s performance evaluation and EVM together to interpret results. We are aware of our limitations, especially in terms of the time that participants were under the humor condition, nevertheless it is a significant improvement when compared to previous studies measuring emotional effects on IGT. for instance, [39] carried out the induction of positive and negative emotional states during IGT. Unfortunately, their results were inconclusive, mainly because of their methodological decisions. Such as the no use of sex as a relevant study variable, and the use of single stimulus of short duration (i.e., a happy or sad video of 2.5 minutes before the task and not specifying why that time should be enough to induce an emotional effect across the whole task nor why they determined that specific time duration).

Our present study propose that relevant emotional stimulus must be presented closer to the task and during more time allowing emotional changes in participants as task progressed. The present study opens new and interesting possibilities for future research in which is possible to measure decision-making effects during the whole task and with different nuances for men and women. Future studies exploring sex related brain mechanisms of decision-making and humor by means of brain exploration techniques such as electroencephalography and/or fMRI to understand the biological bases of sex, emotion and cognition are needed.

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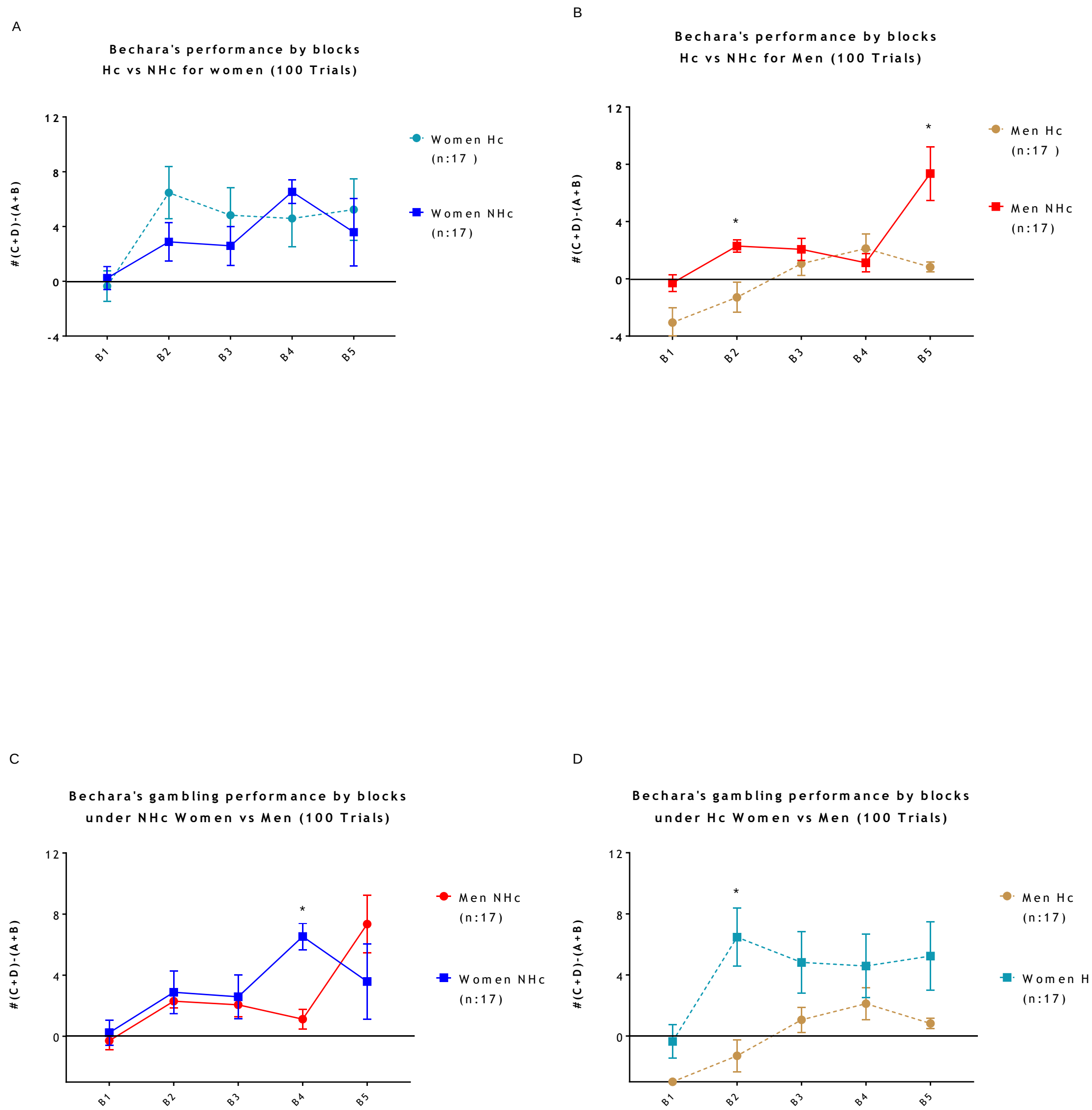

Figure 1: Results for Bechara´s Gambling performance under NHc (17 men and 17 women) and Hc (17 men and 17 women) with Standard Error of the mean (SEM). The 100 trial-task was divided in 5 blocks of 20 trials each. (A) Analysis for Blocks x Condition for women sample revealed no statistical differences between Hc and NHc. (B) Analysis for Blocks x Condition for men sample revealed a main effect of condition in which men under Hc performed poorer than men under NHc and a Block x Condition interaction indicating that men under Hc performed poorer than the men under NHc in Block 2 and 5. (C) Analysis for Sex x Block for NHc revealed no statistical differences between men and women under NHc. (D) Analysis for Sex x Block for Hc

revealed that men performed poorer than women under Hc in Block 2, we also observed a main effect of Sex indicating that men performed worse than women under Hc.

4.1 *Humor facilitates decision-making in women and impairs it in men (Submitted to Nature Neuroscience)*

Humor facilitates decision-making in women and impairs it in men

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Abstract

Decision-making is crucial for human life, allowing us learning from experience and correcting our course of action. When information lacks, new decisions are guided by the emotional consequences of previous decisions. Research shows that emotional and cognitive neural systems must be optimally controlled to achieve successful decision-making. Iowa Gambling Task (IGT) studies indicate that women display less emotional control than men, which negatively affects their performance. However, the reason for and the way to efficiently compensate for this difference remain unknown. In the present study we use humor to modulate the emotional response of subjects performing IGT. Our behavioral and electrophysiological results demonstrate that the mechanisms implied in cognitive control are differently affected by humor in men and women. Specifically, humor decreases men's mismatch detection, impairing their learning of the task. By contrast, in women humor boost their learning by increasing their ability to allocate attentional resources.

Introduction

The Iowa Gambling task (IGT)[1] has been designed to mimic real-life decision making, which means that participants learn to make consistent monetarily efficient choices from several available options without having explicit information about what choices are useful to meet that goal. Participants must learn based only on accumulated monetary punishments and rewards received as consequences of their choices throughout the task[2].

Its original authors[3,4] indicated that IGT learning reflects how emotional and cognitive brain systems interact to guide the decision-making process. Vast evidence supports that in the standard 100 trial version of the task, during the early phase (1-60 trials), participants focus on obtaining high rewards[5] while trying to minimize the emotional effect of the punishments they receive;[3,6,4] which implies that learning in the early phase relies mainly on emotional control. On the other hand, the later phase (61-100 trials) relies more on cognitive control,[4] because once the participant has learned the IGT rules, cognitive processes gain predominance over the emotional ones to ensure shifting from an inefficient strategy (centered on high rewards and high risk) to a more efficient one (centered on low rewards but even lower risk),[4] which is a process that requires cognitive control[7,8]

Multiple studies have shown that men and women perform differently on the IGT [9,10,11,12,13]. Although both men and women can eventually solve the task, men choose more cards from monetarily efficient ("good") decks in the standard 100 trial version of the task[14,15,16,17,18]. Additionally, on average, women require 40% to 60% more trials than men to achieve monetarily efficient performance[19].

Sex differences in IGT performance might be explained by differences in how men and women process both, information from the task and the resulting emotions, as the IGT unfolds[19,20]. Current research holds that women experience more intense emotional reactions than men during punishments, decreasing the economic utility of a risky choice.[21,22] Moreover, women with high trait anxiety perform consistently worse in IGT than women with low trait anxiety.[18] These results hint at the possibility that women's IGT performance could be impacted by negative emotions to a greater extent than men's performance. Complimentary neuroimaging evidence suggests that -during the later IGT phase- men seem to exert stronger cognitive control than women[19]. These findings are in agreement with IGT research holding that a successful emotional control is a requisite for a later predominantly cognitive decisional behavior[3,4]. Together, these results suggest that sex differences in IGT performance could reflect differences in how men and women control/regulate their emotions during the task and to what extent successful emotion regulation results in the execution of predominantly cognitive decisional behavior[6,4].

Sex differences in emotion reaction during the IGT suggest additionally sex differences in emotion regulation and cognitive control. For instance, in a study of the neural correlates of cognitive reappraisal[23], men were shown to down-regulate negative emotions by decreasing amygdala activation more than women, which may suggest a focus on diminishing negative emotions. By contrast, women up-regulate ventral striatum (VS) activation more than men while performing the same down-regulation of negative emotion. Considering that VS is a key brain region for positive emotions, humor, decision-making, reward, and emotional regulation processing[23,24,25], we speculate that when given the opportunity, women may up-regulate positive emotion to buffer negative emotions to a greater extent than men. The previous results suggest that positive emotions could help to control women's negative emotions and may, in consequence, positively affect women's decision-making on tasks such as the IGT.

Sex differences in emotion regulation may impact how men and women allocate their resources to control their cognition[55]. Research indicate that inducing stress by a situation non-directly related with IGT (i.e., to know in advance that participants have to give a public speech after performing IGT) impairs men's performance more than women's. The authors indicate that this occur because in men, but not in women, the first task (controlling stress) competes for cognitive resources with the second one (solving IGT). They suggested that these results reflect the consequences of the men's focus on cognitive processing, which could be more negatively affected by competition than for women.

Therefore, the existing literature regarding sex differences in emotional regulation and cognitive control suggest that positive emotions could help to regulate women's negative emotions and may, in consequence, positively affect women's decision-making on tasks such as the IGT. Conversely the men's advantage in regulating emotions and deploying cognitive control depends on the possibility of allocating cognitive resources to a single task at a time. Therefore, unlike women, when men are exposed to a cognitively complex task in which attention has to be divided, (e.g., observing positive emotion stimuli and at the same time paying attention to IGT performance), their cognitive control could be impaired.

Humor is one way to increase positive emotions,[26,27] and evidence suggests that positive emotions have several benefits, including but not limited to reducing negative emotions[27,28] and buffering against stress[27,29]. Sex differences in humor processing suggests that women activate some humor-related brain structures more than men. For instance, there is evidence that under humorous conditions, women show greater activation of nucleus accumbens (a part of the ventral striatum) and recruit left prefrontal cortex more than men, which suggests that they have a larger reward network response than men[30]. According to research, the observed women's brain activation under humorous conditions could indicate a possible advantage in processing positive emotions and increasing executive function through humor[31,32]. In support of this advantage, there is evidence of stronger dopaminergic pathway between emotional and cognitive brain structures in women than in men.[31,32,33,34] Therefore, it is possible that women under humorous stimuli may have better IGT performance than women under non-humorous stimuli. Conversely, men under humorous stimuli may exhibit lower IGT performance than men under non-humorous stimuli.

Given the relationship between humor and cognitive control, behaviorally and in the brain. The first aim of the present study is to examine the effect of humor on IGT performance. Participants (men and women) will be randomly assigned to an experimental Humorous condition (Hc) and a control Non-humorous condition (NHc). Participants in the experimental condition will watch humorous videos while performing the IGT task, whereas participants in the control condition will watch neutral videos. The videos will be interspersed with the card choices. We hypothesize that humor will increase women's IGT performance, therefore, women under the Hc will obtain higher IGT performances than women under the NHc (Hypothesis 1). By contrast, humor will impair men's IGT performance; therefore, men under the Hc will obtain lower IGT performances than men under the NHc (Hypothesis 2). We additionally expect to find that men under the NHc will obtain higher performances than women under the NHc (Hypothesis 3). By contrast men under Hc will obtain lower performance than women under Hc (Hypothesis 4).

Furthermore, we are interested to explore the specific cognitive processes that may be accounting for the hypothesized effect of humor over decision making. To achieve this aim, the Expectancy Valence Model[41] (EVM) provides three cognitive latent parameters ("w", "a", and "c") which underlie decision-making. These parameters are useful to explain IGT performance[41,42]. Being parameter "w" an estimation of whether attention is preferentially payed to the punishments or to the rewards. Parameter "a" -updating-rate- which is an estimation of the impact of recent/past experienced valences, and parameter "c" response consistency which is an estimation of whether choices are guided by expectancies or they are random.

Our second aim is to evaluate the effect of humor in the cognitive processes underlying decision-making according to the EVM in men and women. Therefore, we expect to find that – among women – humor will have a positive effect on the parameters underlying decision making (Hypotheses 5). Namely, women under the Hc will present higher attention to punishment (parameter "w") and higher updating rate (parameter "a") than women under the NHc. Furthermore, they will use their response consistency (parameter "c") to a higher degree than women under the NHc. By contrast, we expect to find that – among men – humor will have a negative effect on the parameters underlying decision making (Hypotheses 6). Therefore, men under the Hc will present lower attention to punishment (parameter "w") and lower updating rate (parameter "a") than the men under the NHc. Furthermore, they will use their response consistency (parameter "c") to a lower degree than men under the NHc. We additionally expect to find that women under Hc will present higher attention to punishment (parameter "w"), higher updating rate (parameter "a") and higher response consistency (parameter "c") than men under Hc (Hypothesis 7). By contrast, we expect to find that women under NHc will present lower attention to punishment (parameter "w"), lower updating rate (parameter "a") and lower response consistency (parameter "c") than men under NHc (Hypothesis 8)

Our third aim is to examine the effect of humor and sex over cognitive control of IGT performance using electrophysiology. As it was mentioned before and in light with previous literature[37,38,39] we expect that – among women – humor will increase cognitive control during the IGT (Hypothesis 9). By contrast – among men – humor will decrease cognitive control during IGT (Hypothesis 10). We also expect that under NHc women will decrease their cognitive control when compared to men (Hypothesis 11) and finally, that under Hc women will increase their cognitive control when compared to men (Hypothesis 12). We will assess the amplitudes of two Event Related Potentials (ERPs) which reflects cognitive control, namely the N2[37] and the P3b components. During IGT, the N2[37] component (also called mismatch detection) provides information about the detection of expectation violations when the participant received feedback about her/his performance and the P3b component[38,39] provides information about attentional resource allocation to IGT performance.

These three different objectives will be addressed by using behavioral and electrophysiology as in the following sections.

Methods

Participants

Inclusion criteria for participation were (1) being an undergraduate student at the Pontificia Universidad Católica de Chile, (2) being between 18 and 30 years old, (3) speaking Spanish, and (4) having normal or corrected-to-normal vision. Exclusion criteria were (1) have being diagnosed with a psychiatric disorder, (2) presenting severe depressive symptomatology according to the Self-Report Questionnaire[56] (SRQ), (3) presenting a neurological disorder, (4) having a history of drug abuse, and (5) having consumed alcohol, caffeine or drugs 24 hours before participating in the experimental task.

To estimate the sample size, we used Cohen's guidelines[57]. The software used was G* Power 3.1 with parameters for large effect size Fs (.40), a probability error α (.05), and a statistical power of (.80), which leads to a minimum of 52 participants (26 women and 26 men). Nonetheless, when we reached the sample size of 26 women, there was not still enough men enrolled, so we decided to continue the recruitment till we got an equivalent number of men and women. As such, 64 (33 women and 31 men) participants completed the study. The data of four of these participants (one male and three female) were not considered in the analyses because they did not fulfill all participation criteria. Namely, one of these participants reported having consumed drugs before the experiments and three of them presented severe depressive symptomatology according to the SRQ. Therefore, the data of 60 participants (30 men; mean age 22.02, SD = 4.3 and 30 women; mean age 22.3, SD = 4.1) were finally considered for analysis.

Questionnaires.

The Self-report questionnaire[56] was used to assessed depressive symptomatology. It consists of 25 Yes and No questions. The SRQ has been validated for Chilean population.[58] Subjects scoring higher than 11 points or answering affirmatively questions 21 to 25 (elevated probability of depressive symptomatology) were not included in the study sample.

The State-Trait anxiety inventory[59] (STAI) was used to assess anxiety symptoms. It consists of 40 questions divided in two subscales: the state anxiety (SA) and the trait anxiety (TA) scales. The STAI has been validated for Chilean population[60] . We assessed this variable because higher TA scores are related with impairments in decision-making and could potentially affect our results[61]

Humorous and neutral videos.

To induce humor, 200 videos (100 humorous and 100 non-humorous) were selected from 240 public access videos (120 humorous and 120 non-humorous) available at *www.youtube.com*. The initial 240 videos were selected by the researcher. The criteria were the presence or absence of humor in ecological situations and an adequate duration of stimuli which must be suitable for EEG uses (mean duration = 12.84 secs; *SD* = 5.81 secs). The initial 240 videos selected by the researcher were presented in a randomized order to 50 subjects (25 men and 25 women) who were not part of the sample of the present research. These subjects were asked to rate the videos using a humor scale ranging from 0 to 10 points (0 "not humorous at all"; 10 "the most humorous thing ever"). To identify how each video was rated, participant´s ratings were plotted. We eliminated all individual videos that were less than three standard deviation away from the mean of the opposite condition, which result in the elimination of 40 videos (20 humorous and 20 non- humorous). The final video selection consisted in 100 humorous and 100 non-humorous videos. To examine whether there were statistically significant differences in the rating scores between both types of videos, we conducted a two-way factorial ANOVA (Sex x Video type [humor/non-humor]). Results showed a main effect of video type ($F_{1,198}$ = 220, p<.00, η^2 = .917), indicating that humorous videos were rated as significantly more humorous than non-humorous videos. Neither the main effect of sex nor the interaction (Sex x Video Type) were statistically significant. Humorous videos were assigned to the experimental group while non-humorous to the control group. The mean duration of the humorous videos was 12.84 mins (*SD* = 5.81 mins) and the non-humorous videos mean was 11.91 mins (*SD* = 4.62 mins).

The IGT.

It is a life-like decision-making task[1,62] (IGT). Participants must choose a card out of any of four card decks (A, B, C, and D). After each choice, participants can be rewarded with virtual money (reward) or punished with a loss of virtual money (punishment). Participants must learn as they play which are the monetarily efficient and inefficient decks to solve the task. Participants can change decks at will during the whole task; however, they're warned that some decks are worse than others in terms of payment and that decks positions are fixed during the whole task. Likewise, they are informed that the goal is to win as much money as possible, or to avoid losing money as much as possible.

Concerning outcomes, card decks A and B are monetarily risky/inefficient, and C and D are monetarily safe/efficient. Card decks A and B are associated with higher sums of immediate rewards (e.g, $100) but maintaining these card decks choices means accumulating less or no profit at all, because of occasional large monetary punishments. As a matter of fact, this strategy leads to a net loss from $250 during the 10 first trials, while card decks C and D could offer an immediate lower reward (e.g $50) but with small monetary punishments, allowing to accumulate profit and leading to a net winning from $250 during the first 10 trials. Consistent C and/or D choices allow participants to earn virtual money at the end of the task, while A and/or B consistent choices leads to owing money at the end of the task. We modified the original number of trials from 100 to 500 to make statistically valid ERP inferences and we also modified the feedback shown to participants, following Cui et al[49] guidelines in which the presentation of win and losses observed in the original task is replaced by net scores of either wining or losses.[49]

IGT performance is calculated by computing the difference between monetarily efficient and monetarily inefficient choices [(C+D) - (A+B)]. This computation is made in twenty-five sets of twenty choices each called blocks. As participants learn IGT, there is an increase in the net score magnitudes, which is an increase in monetarily efficient choices.

Procedure

Each trial began with an image announcing the video presentation in which the word "*video*" appeared on the screen during 1500ms. Then the video itself appeared. Each video was followed by five decision-making trials. During these trials, participants saw four deck options (A, B, C, and D) and chose one of the available options by clicking on the deck with a USB mouse. When participants selected a card, its perimeter lit up in red. After that, the screen changed to black during 300ms, which allowed for a clean baseline for ERP measurement. Immediately after the black screen, the feedback appeared. Feedback corresponds to "0" time to evaluate ERPs. Feedback was shown during 2000ms. Feedback could be a net winning (e.g +100) or a net loss (e.g, -50). Each card's feedback depended on the probabilities according with Bechara IGT manual[5], using modifications for an electrophysiological adaptation[49]. During the screen showing the four deck options, on the central superior area of the screen, two bars appeared. A green bar showed participant accumulated winnings and losses and a red bar, representing the lent money. After feedback, bars automatically updated with either won or lost values throughout the task. We emphasized to participants that positions and decks contingencies were fixed during the whole task, that they could change decks at will and that there was no association whatsoever between videos and decks. Participants had no specific information about how to solve the task, nor did they know how long it took. Participants completed 100 videos and 500 trials (divided in 25 blocks of 20 trials each). We programmed two breaks (after 40% and 70% of total trials).

Calculation of Expectancy Valence Model (EVM).

The EVM is a reinforced learning model [41,42]. As it was previously described in the introduction, it provides three cognitive processes parameters, "w", "a", and "c". According to Wetzels[42] the model assumes that participants after selecting a card from deck k, $k \in \{1, 2, 3, 4\}$ on trial t, calculates the resulting net profit or valence. This valence v_k is a combination of the experienced reward W(t) and the experienced loss L(t):

$$v_k\,(t) \;=\; (1-w)\;W\,(t)\;+\;\mathrm{w}\,\cdot\,L\,(t) \tag{1}$$

This equation uses the parameter "w" of the EV model, the attention weight of losses relative to rewards, with $w \in [0, 1]$.

Based on the sequence of valences v_k experienced previously, the participants form an expectation Ev_k of the valence for deck k. Learning occurs when new valences change the value of the expected valence Ev_k. In a given time t, if the experienced valence differs from the expected one, then the value Ev_k needs to be adjusted. The way the value is adjusted is given by the following equation:

$$Ev_k\,(t+1) \;=\; Ev_k\,(t)\;+\;\alpha\,\cdot(\mathrm{v}_k(t) - Ev_k(t)) \tag{2}$$

In which the updating rate $\alpha \in [0, 1]$ determines the impact of recently experienced valences.

Opting for the deck with the highest expected valence is a "greedy" strategy that in the long run can lead to a suboptimal solution. To ensure initial deck exploration from the participants, an additional equation is added to the model. The equation is a standard reinforcement learning method called softmax selection or Boltzman exploration[50]:

$$\Pr[S_k\,(t+1)] = \frac{\exp(\theta(t)Ev_k)}{\sum_{j=1}^{4}\exp(\theta(t)Ev_j)} \tag{3}$$

In this equation, $\frac{1}{\theta(t)}$ is the "temperature" at the trial t and $Pr(S_k)$ is the probability of selecting a card from deck *k.* Higher temperatures mean more random decisions, which means a higher level of exploration, while lower temperatures mean less exploration, and more exploitation of the decks with higher expected valences. A temperature of zero will make the participant decide only based on expected valence, choosing the deck with the highest.

In the EV model, the temperature changes given the number of observations according to

$$\theta(t) = (\frac{t}{10})^c \quad (4)$$

Where "*c*" is the response consistency or sensitivity parameter (exploration parameter). When fitting to data, the parameter is constrained to the interval [-5, 5]. Positive values of "*c*" make response consistency θ values increase with the number of observations, which means $1/\theta$ values will decrease. This leads to lower "temperatures", meaning choices are guided more by expected valences. Negative values of "*c*" mean choices will become more and more random as the number of card selection increases.

Being "*i"* a given participant, the current IGT study calculated participant's specific parameters "w_i", "a_i", and "c_i" by minimizing the sum of the one-step-ahead prediction errors:

$$\sum_{t=1}^{T} - \ln p(y_t | y^{t-1}, w_i, a_i, c_i) \quad (5)$$

The method of parameter estimation was applied to each individual participant separately.

EEG data acquisition and preprocessing.

EEG data was obtained using 64 sintered Ag/AgCI electrodes arranged (Biosemi® Active two) according to the international 10/20 extended system. Horizontal and vertical eye movements were monitored using four external electrodes. Horizontal EOG was recorded bipolarly from the outer canthi of both eyes and vertical EOG was recorded from above and below of the participant's right eye. Two additional external electrodes were placed on the right and left mastoid to be used for later re-referencing. Data pre-processing was performed using Matlab 8.3.0.532 (The Mathworks, Inc.) with EEGLAB v13.6.5b toolbox (Swartz Center for Computational Neuroscience; http://sccn.ucsd.edu/eeglab/). The signal was down-sampled off-line at 512 Hz following Cui et al guidelines[49], all electrodes were referenced to averaged mastoids. A 2nd order infinite impulse response (IIR) Butterworth filter was used for band-pass filtering continuous EEG data, with a half amplitude cut-off frequency of 0.1 Hz and 30 Hz following Tanner et al guidelines[51]. For channels and artifact rejection we segmented data in 500 epochs from -1000 to 2000 milliseconds. This was done in a manner that was blind to experimental condition. We performed a semi-automated channel rejection coupled with visual inspection applying EEGLAB trim outlier function. We set a high upper bound rejection threshold of 200 µ V and a lower bound rejection threshold of 10 µ V. The total average of rejected channels was 0.6 channels per subject. Commonly recorded artefactual potentials (Crap)[36] detection was performed setting a high rejection criterion (100 μ V) threshold for the moving window peak-to-peak algorithm. This procedure allowed rejecting extremely noisy data which never exceeded 15% of total trials (75 out of 500 trials). We also performed manual inspection to detect muscle like activity. Then we performed independent component analysis (ICA)[52]. Through this method we eliminated an average of two ocular stereotypical artefactual components per EEG recording. Then we performed channel spherical interpolation function, being P2 the most frequently interpolated channel (12% of the subjects)

EEG data analysis.

EEG signal was segmented into 500 trials. For each trial, we selected 200ms previous to feedback up to 1000ms after feedback. The average number of epochs after artefactual rejection and correction was 460 (*SD*= 10). Epochs were averaged across trials for each subject and condition. Grand average ERPs grouped by condition were analyzed by means of paired t-test ($p < 0.05$) in search of statistically significant differences between conditions. The N2 amplitude was set between 80-180ms after feedback. A ROI for FZ, FCZ and CZ electrodes was used to determine N2 component for each subject and condition. P3b amplitude was set between 380-440ms after feedback. A ROI for CZ, CPZ and PZ electrodes was used to determine P3 component for each subject and condition.

Statistical analysis plan.

Trait anxiety has shown to affect IGT performance and women seem to present higher trait anxiety than men[61]; therefore, to examine whether there were differences between the groups in this variable, we first conducted a two-way factorial ANOVA [Sex x Condition (Humor/Non-humor)] in which the dependent variable was trait anxiety. The main effect of sex, the main effect of condition, and the interaction were not statistically significant, indicating that there were no significant differences in trait anxiety among the groups. Therefore, this variable was not considered in further analyses.

To test whether women under Hc exhibit higher IGT performance than women under NHc (Hypothesis 1) we conducted a two-way ANOVA [Condition x Block] considering only the women sample. To examine whether men under Hc exhibit lower IGT performance than men under NHc (Hypothesis 2) we conducted another two-way ANOVA [Condition x Block], this time using only the men sample. To test whether men under NHc present higher performance than women under NHc (Hypothesis 3), we conducted a two-way ANOVA [Sex x Block] using only the data from participants under NHc. And finally, to test whether under Hc men obtained lower IGT performance than women under Hc (Hypothesis 4), we conducted the last two-way ANOVA [Sex x Block], this time using only the data from participants under Hc.

To test whether women under Hc exhibit higher attention to punishment (parameter “w”), higher updating-rate (parameter “a”) and higher response consistency (parameter “c”) than women under NHc (Hypothesis 5), we conducted a MANOVA with the total sample of women and performed ANOVA contrasts for each parameter when needed. To test whether men under Hc exhibit lower attention to punishment, high updating-rate and higher response consistency than women under NHc (Hypothesis 6), we conducted a MANOVA with the total sample of men and performed ANOVA contrasts for each parameter when needed. To test whether women under Hc exhibit higher attention to punishment, higher updating-rate, and higher response consistency than men under Hc (Hypothesis 7), we conducted a MANOVA with the total sample of participants under Hc and performed ANOVA contrasts for each parameter when needed. To test whether women under NHc exhibit lower attention to punishment, lower updating-rate, and lower response consistency than men under NHc (Hypothesis 8), we conducted a MANOVA with the total sample of participants under NHc and performed ANOVA contrasts for each parameter when needed.

To test whether women under Hc exhibit higher correlates of cognitive control (larger N2 and P3B ERps mean amplitudes) than the women under NHc (Hypothesis 9), we conducted a MANOVA with the total sample of women and performed ANOVA contrasts for each ERPs when needed. To test whether men under Hc exhibit both shorter N2 and P3B ERP mean amplitudes than the men under NHc (Hypothesis 10), we conducted a MANOVA with the total sample of men and performed ANOVA contrasts for each ERPs when needed. To test whether under NHc women exhibit shorter N2 and P3B mean amplitudes than men (Hypotesis 11), we conducted a MANOVA with the total sample under NHc and performed ANOVA contrasts for each ERPs when needed. Finally, to test whether under Hc women exhibit larger N2 and P3B mean amplitudes than men (Hypothesis 12), we conducted a MANOVA with the total sample under Hc and performed ANOVA contrasts for each ERPs when needed

Prior to conducting the abovementioned analyses, we checked normality, linearity and sphericity assumptions. In case the sphericity assumption was violated, we used the parameter ε Greenhouse-Geisser to correct for such violations. Outliers were replaced using the mean plus two standard deviations method recommended by Field (2009). We applied Bonferroni correction for post-hoc comparisons.

Results

Behavioral results

Differences in IGT performance

The result of the two-way ANOVA [Condition x Block] conducted with the sample of women revealed a main effect of Blocks ($F_{4.23,118.50}$ = 11.13, p <.00, η^2 = .28), indicating that regardless of condition, women learnt the task as it progressed. We also obtained an interaction effect Blocks x Condition ($F_{4.23,118.50}$ = 1.99, p =.07, η^2 = .09) indicating that women under Hc performed better than women under NHc in Block 23 ($t(1)$ = 2.51, p = .01, η^2 = .18), Block 24 ($t(1)$ = 3.24, p < .00, η^2 = .27) and Block 25 ($t(1)$ = 2.48, p = .01, η^2 = .18). We did not find statistical differences for the main effect of Condition. Therefore, the women under Hc obtained significantly higher scores in IGT performance than the women under the NHc toward the end of the task (See Figure 1A).

The result of the two-way ANOVA [Condition x Block] conducted with the sample of men also revealed a main effect of Blocks ($F_{5.90,165.25}$ = 20.78, p <.00, η^2 = .43). We additionally found an interaction effect Blocks x Condition ($F_{5.90,165.25}$ = 2.42, p =.02, η^2 = .08) indicating that men under Hc obtained lower performances than men under NHc, in Block 2 ($t(1)$ = -2.58, p = .01, η^2 = .19), Block 3 ($t(1)$ = -3.11, p < .00, η^2 = .26), block 5 ($t(1)$ = -2.57, p = .01, η^2 = .19), Block 8 ($t(1)$ = -4.21, p < .00, η^2 = .39), Block 16 ($t(1)$ = -2.82, p < .00, η^2 = .22), Block 17 ($t(1)$ = -3.40, p < .00, η^2 = .29), and Block 19 ($t(1)$ = -2.73, p = .01, η^2 = .21). We also found a main effect of Condition ($F_{1,28}$ = 4.78, p =.04, η^2 = .15). Therefore, the men under Hc obtained significantly lower scores in IGT performance than the men under the NHc. (See figure 1B)

The result of the two-way ANOVA [Sex x Block] considering only the participants under the NHc revealed a statistically significant main effect of blocks ($F_{4.34,121.51}$ = 14.44, p <.00, η^2 = .34). We also found an interaction effect Sex x Blocks ($F_{4.34,121.51}$ = 4.03, p <.00, η^2 = .13) indicating that men under NHc performed better than women under NHc in Block 5 ($t(1)$ = 3.21, p < .00, η^2 = .27), Block 6 ($t(1)$ = 2.73, p = .01, η^2 = .21), Block 7 ($t(1)$ = 2.47, p = .02, η^2 = .18), Block 15 ($t(1)$ = 2.18, p = .04, η^2 = .15), Block 16 ($t(1)$ = 5.87, p < .00, η^2 = .55), Block 17 ($t(1)$ = 3.91, p < .00, η^2 = .35), Block 18 ($t(1)$ = 2.43, p = .02, η^2 = .17), Block 19 ($t(1)$ = 3.23, p < .00, η^2 = .27), Block 20 ($t(1)$ = 3.95, p < .00, η^2 = .36), Block 21 ($t(1)$ = 3.78, p < .00, η^2 = .34), Block 23 ($t(1)$ = 3.42, p < .00, η^2 = .30), Block 24 ($t(1)$ = 4.32, p < .00, η^2 = .40), and Block 25 ($t(1)$ = 3.14, p < .00, η^2 = .26). We also found a main effect of Sex ($F_{1,28}$ = 8.42, p <.00, η^2 = .23). Therefore, the men under NHc obtained significantly higher scores in IGT performance than the women under the NHc. (See figure 1C)

Finally, the result of the two-way ANOVA [Sex x Block] conducted only with the participants under the Hc showed only a statistically significant main effect of blocks ($F_{6.16,172.45}$ = 21.84, p <.00, η^2 = .44). We found no effect for the interaction Sex x Blocks, nor for the main effect of Sex. Therefore, under Hc the differences in IGT performance between men and women cancel each other out. (See figure 1D).

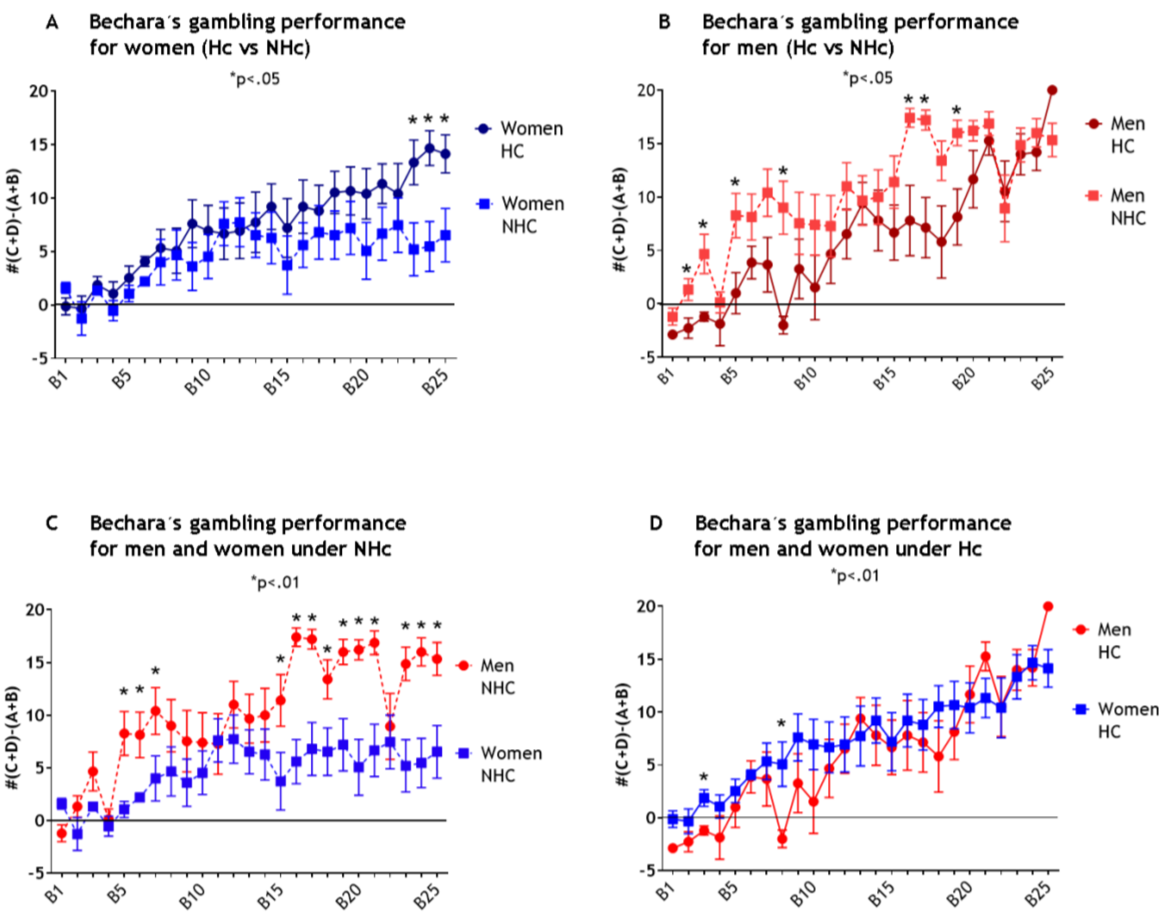


Fig.1. Results for Bechara's gambling performance by blocks, sex, and condition (30 men: 15 under the NHc and 15 under Hc, and 30 women: 15 under the NHc, and 15 under the Hc) error bars indicate standard error of the mean (SEM). The 500 trial task was divided in 25 blocks of 20 trials each. (A) The results considering only women revealed a significant interaction effect blocks x condition indicating better performances under Hc than under NHc in the last blocks. (B) Results considering only men revealed a significant interaction effect blocks x condition; however in the opposite direction, that is men obtained lower performances under Hc than under NHc. (C) Under NHc we found a significant main effect of Sex in which men performed better than women. (D) Under Hc we found no statistical differences among men and women, only a main effect of Blocks.

Differences in EVM parameters.

The results of the MANOVA examining the effect of condition (Humor/Non-humor) on the three EVM parameters ("w", "a", and "c") in the sample of women revealed no statistical differences.

The result of the MANOVA examining the effect of condition on the three EVM parameters conducted with the sample of men, showed statistical differences using Pillai's Trace, $V = 0.36$, $F(3,26) = 4.77$, $p < .00$. Separate univariate ANOVAs on the outcome variables showed statistical differences for parameter "a" $F(1,28) = 8.34$, $p < .00$ indicating that the men under Hc obtained significantly lower updating-rate scores than the men under NHc, $t(1) = -2.37$, $p = .03$, $\eta^2 = .17$;M_{men}

$_{Hc}$ = .000, $SD_{men\ Hc}$ =.000; $M_{men\ NHc}$ = .002, $SD_{men\ NHc}$ = .002). We detect no statistical differences for parameter "w" nor for parameter "c".

The result of the MANOVA examining the effect of no-humor on the three EVM parameters conducted with the sample of men and women showed no statistical differences.

Finally, the result of the MANOVA examining the effect of humor on the three EVM parameters conducted with the sample of men and women, showed statistical differences using Pillai's Trace as well, V = 0.31, F(3,26) = 3.94, p = .02. Separate univariate ANOVAs on the outcome variables showed differences for the parameter "w" and for the parameter "a". Parameter "w" F(1,28) = 6.71, p = .02 revealed that the men under Hc obtained significantly lower attention to the rewards than the women under Hc, $t(1)$ = 2.59, p = .02, η^2 = .19; $M_{men\ Hc}$ = .07, $SD_{men\ Hc}$ =.10; $M_{women\ Hc}$ < .00, $SD_{women\ Hc}$ < .00. Parameter "a" F(1,28) = 4.34, p = .04 indicate that the men under Hc obtained significantly lower updating-rate than the women under Hc, $t(1)$ = -2.08, p = .04, η^2 = .13; $M_{men\ Hc}$ = .000, $SD_{men\ Hc}$ =.000; $M_{women\ Hc}$ = .001, $SD_{women\ Hc}$ = .001. We found no statistical differences for parameter "c".

Electrophysiological results

*Differences in the neural correlates of cognitive control***.**

The result of the MANOVA examining the effect of condition in the N2 and P3b ERPs amplitudes using the sample of women showed statistical differences using Pillai's Trace, V = 0.30, F(2,27) = 5.66, p < .00. Separate univariate ANOVAs on the outcome variables showed no statistical differences for N2 amplitudes (See Figure 2A), nevertheless showed significant statistical differences for P3b amplitudes F(1,28) = 10.01, p < .00 indicating that the women under Hc obtained significantly larger P3B amplitudes than the women under NHc, $t(1)$ = 3.16, p = .00, η^2 = .26; $M_{women\ Hc}$ = 13.34, $SD_{women\ Hc}$ = 5.37; $M_{women\ NHc}$ = 7.08, $SD_{women\ NHc}$ = 5.45). (See Figure 2B)

The result of the MANOVA examining the effect of condition in the N2 and P3b ERPs amplitudes using the sample of men revealed statistical differences using Pillai's Trace, V = 0.28, F(2,27) = 5.12, p = .01. Separate univariate ANOVAs on the outcome variables showed statistical differences for N2 amplitudes F(1,29) = 9.07, p < .00 indicating that the men under Hc obtained significantly smaller N2 amplitudes than the men under NHc ($t(1)$ = -9.01, p < .00, η^2 = .74; $M_{men\ Hc}$ = -2.27, $SD_{men\ Hc}$ =1.85; $M_{men\ NHc}$ = -4.31, $SD_{men\ NHc}$ = 1.86). (See Figure 2C) No statistical differences for P3b amplitudes were detected. (See Figure 2D)

The result of the MANOVA examining the effect of non-humor on N2 and P3b ERPs amplitudes conducted with the sample of men and women revealed no statistical differences neither for N2 (See Figure 3A) nor for P3B (See Figure 3B).

Finally, the result of the MANOVA examining the effect of humor on N2 and P3b ERPs amplitudes conducted with the sample of men and women, showed statistical differences using Pillai's Trace as well, V = 0.64, F(2,27) = 21.20, p < .00. Separate univariate ANOVAs on the outcome variables showed statistical differences for N2 and P3b ERPs amplitudes among men and women. N2 F(1,28) = 30.00, p < .00 indicates that the women under Hc obtained significantly larger N2 amplitudes than the men under Hc, $t(1) = 5.48$, $p < .00$, $\eta^2 = .52$; $M_{\text{men Hc}} = -2.27$, $SD_{\text{men Hc}} = 1.85$; $M_{\text{women Hc}} = -6.16$, $SD_{\text{women Hc}} = 2.04$ (See Figure 3C). For P3b $F(1,28) = 16.81$, $p < .00$ indicates that the women under Hc obtained significantly larger P3b amplitudes than the men under Hc as well, $t(1) = -4.10$, $p < .00$, $\eta^2 = .38$; $M_{\text{men Hc}} = 4.99$, $SD_{\text{men Hc}} = 5.78$; $M_{\text{women Hc}} = 13.34$, $SD_{\text{women Hc}} = 5.37$. (See Figure 3D)

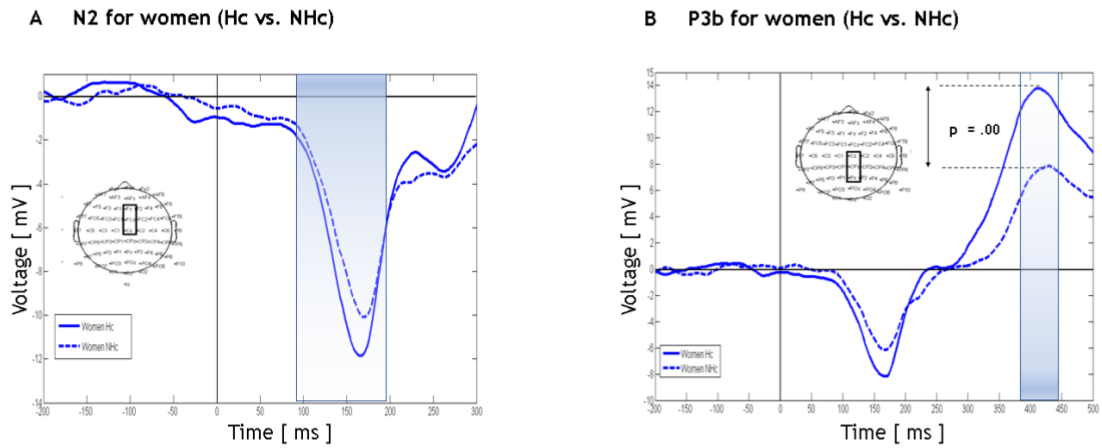
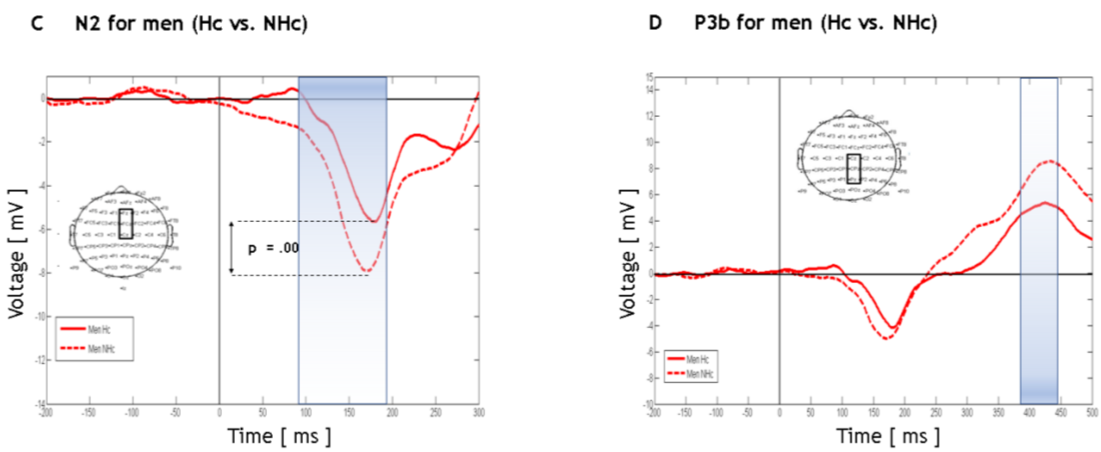


Fig.2. Results for N2 and p3b mean amplitudes for condition and sex (30 men: 15 under the NHC and 15 under the HC, and 30 women: 15 under the NHC and 15 under the HC). N2 Measures from electrodes FC, FCZ and CZ; P3b measures from electrodes CZ, CPZ and PZ (A) N2 amplitudes among women revealed no statistical



differences between Hc and NHc. (B) P3b amplitudes among women revealed significantly larger amplitudes under Hc than under NHc. (C) N2 amplitudes among men revealed statistically smaller amplitudes under Hc than under NHc. (D) P3b amplitudes among men revealed significantly smaller amplitudes under Hc than under NHc.

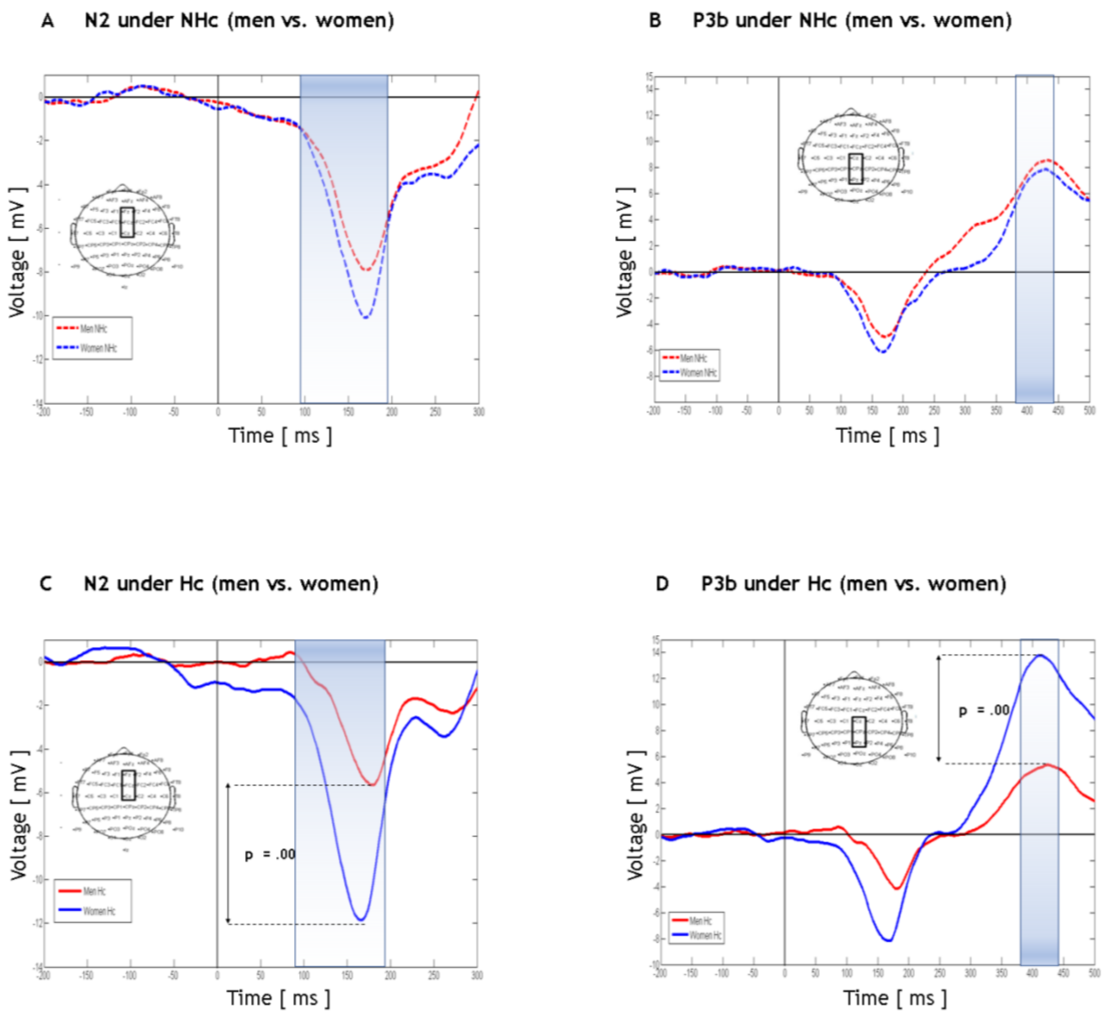


Fig.3. Results for N2 and p3b mean amplitudes for condition and sex (30 men: 15 under the NHC and 15 under the HC, and 30 women: 15 under the NHC and 15 under the HC). (A) N2 amplitudes among men and women under NHc revealed no statistical differences. (B) P3b amplitudes among men and women under NHc revealed no statistical differences either. (C) N2 amplitudes among men and women under Hc revealed statistically larger amplitudes for women than for men. (D) P3b amplitudes among men and women under Hc revealed significantly larger amplitudes for women than for men.

Discussion

Our results support that humor does facilitate IGT performance in women. Nevertheless, EVM results revealed no statistical differences of neither of the three parameters in the sample of women, so we need a more sensitive procedure to understand the reasons why of such difference. One possibility is provided by electrophysiological data. This analysis revealed that the women under humor obtained higher P3b amplitudes than the women under non-humor. P3b amplitudes are considered neural correlates of attention allocation which means that women under humor may increase their attention allocation toward the task which could be beneficial to their IGT performance.

Regarding men, our results indicate that humor impair their IGT performance. EVM analysis revealed that the men under humor obtained lower updating-rate scores than the men under non humor. In this context, lower updating scores means slower forgetting and slower learning based on new information. Additionally electrophysiological data indicates that the men under humor exhibited smaller N2 amplitudes than those under non-humor. N2 amplitudes are considered neural correlates of mismatch detection which means that under humor, the men's ability to detect pre-attentional environmental changes about the feedback is decreased, when compared to the men under NHc, which may ultimately impair their IGT performance.

Additionally, our results confirmed expectations from IGT literature, that is that the men exposed to non-humor obtain better performances than the women under non-humor. Unfortunately, we couldn't detect differences in EVM parameters nor in electrophysiological data supporting those previously mentioned performance differences.

Finally, we couldn't find empirical evidence supporting that the men exposed to humor obtain lower performances than the women under humor. Nevertheless, we found evidence of a cancellation of sex differences regarding IGT performances under humor, because women increased their performance and men decreased theirs. EVM data indicate that men under humor exhibit lower attention to the reward and lower updating-rate than the women under Hc. And electrophysiological results revealed that the women under Hc obtained both larger neural correlates of mismatch detection and larger neural correlates of attention allocation to the task than the men under Hc. Results that support a women's cognitive control facilitation in IGT decision-making through humor.

Sex differences in Decision-Making Performance under Humor

These results are consistent with previous research that suggests that men and women process emotions differently, especially in terms of how sex could mediate the neural mechanisms responsible for the down-regulation of negative emotions[21]. Thus, it seems that in order to improve performance in decision-making tasks, we must take into consideration the use of different strategies when used by women or men, because the way each sex processes information and regulate their emotions is mirrored in how well different strategies of cognitive control are implemented.

In detail, we can conclude that consistent with previous literature, Bechara's gambling task performance under NHc was better for men than for women. By contrast, we observed that under Hc the sex differences in performance cancel each other out, because humor facilitates performance in women and impairs it in men. More specifically, we observed that humor enhances women's performance, especially at the end of the task. Conversely, humor impairs men's performance early, and such effect is sustained across the task.

The EVM results revealed no differences regarding the use of humor in women. Nevertheless, among men we observed lower updating rate scores under humor than under non-humor. A decrease in this parameter is interpreted as smaller changes, weaker recency effects, long associative memories and slower learning.

The effect of humor between men and women indicate that women's motivation under Hc is more focused in the rewards than the men under Hc. IGT literature indicates that paying more attention to the rewards usually is not beneficial for IGT performances because participants underestimate the effect of the punishments they receive. Nevertheless, we additionally observe that humor decrease the men's updating rate of the expected valences, which means that their smaller changes, weaker recency and slow forgetting may affect negatively their learning due to an extremely low exploration, getting stuck with an inferior option when compared to the women under the Hc.

Results from Bechara's gambling performance showed that women regardless of condition, began the IGT task having an equivalent slow learning ratio; however, those under Hc have a late positive effect on performance. This change implies having the flexibility to switch their choices toward more monetarily efficient options. On the other hand, men under the NHc quickly acquired a monetarily efficient strategy and they remember and use such strategy across the IGT. Conversely, men under the Hc learn more slowly than those under the NHc.

Sex Differences in the Neural Correlates of Cognition under Humor

Our electrophysiological results revealed that humor and Sex modulate the amplitude of the two ERPs component found: N2 and P3b (classically associated to visual mismatch and attention allocation respectively). The N2 component (80-180ms after feedback) and the P3b ERP component (380-440ms after feedback) that we observed, are in very good agreement with the classic topography and time course of visual mismatch negativity[48] and P3b respectively[38,39]. Recent years have seen a prominent interest in N2 components as functionally different from P300 components and useful for understanding the nature of cognitive processes.[48] For instance, a large literature is focus on the role of N2 amplitude in cognitive control, which is basically how monitoring of strategy and the processing of feedback that is informative for strategy regulation is mirrored in N2 amplitude. Additionally, the P300, specifically the posterior P300 amplitude (P3b) is sensitive to the amount of attentional resources voluntarily engaged. That means that when task conditions are undemanding, P3b amplitude is hypothesized to index attentional resources such that amplitude is relatively large. Hence, for task that require greater amounts of attentional resources, P300 amplitude is smaller as processing resources are used for task performance[38,39]

For women we observed that humor did not impact N2 amplitudes but it did P3b amplitudes in the way of obtaining higher amplitudes than the women under non-humor. This higher amplitudes may indicate that the beneficial changes observed under humor in performance may be related with an increment in attentional resource allocation which may be useful for performance[38,39]. On the contrary, for men we observed that humor impact N2 but it didn't affect P3b amplitudes. The men's modulation of N2 under humor we interpreted as a decreased detection of environmental changes, which may impact the monitoring and the regulation of their decisional strategy, affecting the learning of the task and ultimately their performance.

Implications of Behavioral and Electrophysiological results

In our study we provide evidence for sex differences in the effect of humor on IGT performance. Our N2 results indicate that humor negatively affect the degree to which men detect and learn from environmental changes (i.e, feedback) during IGT. Because this detection system could be pre-attentional, it is possible that they don't even notice that humor makes it more difficult for them to learn and apply changes when needed. We propose that men's impaired performance on the IGT under humor is a consequence of competition for cognitive resources. It is possible that in men, attempting to process humor, apply emotion regulation, and solve the IGT is overwhelming. The consequence is that when under humor, men become less cognitively efficient when trying to process relevant information while trying to learn the task.

Our P3b results indicates that under humor, it is possible to boost women's attentional resource allocation during IGT, which is instrumental for more monetarily efficient choice behavior. Our results suggest that humor may modify women's emotional experience by increasing positive emotions, resulting in an improvement of cognitive control, facilitating changing from a suboptimal decision strategy into an optimal one. Our findings are relevant because they suggest that humor could be a sex-specific strategy that could buffer negative affect in women through emotional regulation and could impact positively in the use of cognitive resources and in decision-making performance.

Limitations and Future Directions

It is important to highlight that the vast majority of studies focusing in emotion regulation, humor and decision-making comes from fMRI research. Because our study is behavioral and uses EEG as a brain exploration technique, we are aware that our methodological restriction lies in directly assessing specific brain areas involved in solving this task. Conversely, we have made a precise estimation of the time frame when humor impact the task in both sexes. So, our main contribution is that we estimated the time during which the cognitive processes required to solve IGT and to control emotion unfolds for both men and women.

The present study open new and interesting possibilities for future research. As our paradigm allows to effectively modulate emotion during decision making, with a different impact for both men and women. Additionally, this study opens the possibility of exploring cultural and gender differences in order to understand the biological and cultural bases of sex, emotion and cognition.

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4.2 *The effect of humor and sex on theta and beta oscillatory activity and its relationship with IGT decision-making performance (prepared to submit to Nature Human Behavior).*

The effect of humor and sex on theta and beta oscillatory activity and its relationship with IGT decision-making performance

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Abstract

Decision-making is a complex behavior that allow us to improve our future choices based on the consequences of our past actions. Research shows that in real-life decision-making, emotional and cognitive neural systems must be adequately controlled to achieve a successful performance. The Iowa Gambling Task (IGT) studies indicate that women display less emotional control than men, which negatively affects their IGT performance. However, the reason for and the way to efficiently compensate for this difference remain unknown. In the present study we use humor to modulate the emotional response of subjects performing IGT. Our behavioral and oscillatory results demonstrate that participants solve better the IGT applying either less cognitive effort or less top-down control. Ultimately, the way participants control their IGT performance is modulated by sex and condition. Women apply less cognitive effort under the humor condition and men use less top-down control under the non-humor condition.

Introduction

In our daily life, we must learn how to make efficient decisions even when we don't have clear information of our available options (Bechara et al., 1994). Deciding in these conditions of uncertainty and risk, imply that different systems regarding emotional reaction and regulation (McRae, 2008; Mitchell, 2011) must work together and in coordination with systems regarding cognitive control (Miller & Cohen, 2001; Busemeyer & Stout, 2002), so we ultimately can integrate emotional and cognitive information of the available options and use it to optimize our choices (Bechara, Everitt & Bishop, 2005; Busemeyer & Stout, 2002). The Iowa Gambling Task (IGT; Bechara et al., 1994) is a card game that mimics real-life decision-making, which means that during IGT, participants initially do not know what specific deck choices will help or impair them solving the task, they try to learn and optimize their decisional behavior as they play, based on the consequences of their choices (rewards vs. punishments). (Damasio, Everitt & Bishop, 1996).

Sex differences in IGT performance has accumulated an extensive empirical support (for review, see van den Bos, 2013). For instance, evidence show that compared to men, women usually obtain less monetarily efficient choices and need more trials to consistently choose from monetarily efficient decks of cards (Bolla, Eldreth, Matochik, & Cadet, 2004; Weller, Levin & Bechara, 2010). It has been proposed that differences in women's IGT performance may be related to emotional reaction. For instance, previous research has demonstrated that women exhibit more intense nervousness and more fear than men during punishment anticipation, which contributes to the decreased economic utility of their risky choices (Brody, 1993; Fujita, Diener & Sandvik, 1991; Croson & Gneezy, 2009). Additionally, women with high trait anxiety seem to perform worse in IGT than women with low trait anxiety (Miu, Heilman & Houser, 2008).

Emotional information could give preferential access to neurocognitive resources, conversely, excessive emotional activation is associated with emotional and cognitive disruptions (Mitchell, 2011). So, if cognitive resources may be attracted to emotional information, we need to efficiently regulate our emotions to disengage or to minimize cognitive processing when emotions does not provide relevant information. A recent study about the neural correlates of cognitive reappraisal showed that women regulate their negative emotions differently to men. Men were shown to down-regulate negative emotions by decreasing amygdala activation more than women (i.e, which is associated with emotional responding), suggesting a focus on diminishing negative emotions. Conversely, women up-regulate ventral striatum activation more than men (i.e, which is associated with reward processing) while performing the same down-regulation of negative emotion. These results suggest that to successfully regulate negative emotions men may expend less effort due to an automatic emotion regulation. Conversely, women may require qualitatively transforming a negative emotion into a positive one to do the same (McRae, Ochsner, Mauss, Gabrielly & Gross, 2008).

The idea that emotion regulation is an important step between emotional reaction and cognitively controlled decisional behavior, is in very good agreement with IGT research (Van den Bos, 2012). Monetarily punishments (losing money) occur throughout the whole task, even when participants have chosen the monetarily efficient decks. This is especially relevant because participants must inhibit the tendency of changing from monetarily efficient decks after harmless punishments. Because women are more emotionally sensitives to punishments, regardless of the amount of money they lose, they could switch from monetarily efficient to inefficient decks after receiving punishments. On the contrary, men might accept harmless punishments from efficient decks as part of a monetarily efficient strategy (Van den Bos, 2012).

According to Bechara (2005) an optimal control of emotional and cognitive brain systems is fundamental to solve the IGT. The emotional one, depending on the amygdala, signals the pain or pleasure of immediate decisional prospects (i.e., potential value of reward vs punishments). while the second one, mostly constituted by prefrontal brain structures allows cognitive control of decisional behavior. Once certain rules are learned (e.g., social rules), the cognitive system would dominate the emotional system, which ensure that monetarily efficient decisions are made. Implying that when emotional control is not efficient, it may difficult an effectively cognitive control over IGT decision-making performance. So, it is possible that an adequate emotion regulation could be crucial during women's IGT decision-making, minimizing the emotional effect of their reactions specially during punishments (i.e., increasing emotional control) and therefore allowing cognitive control over performance.

Based on the evidence discussed earlier, we carried out a previous study in which we evaluated the performance on the IGT (traditional Bechara's gambling performance and Expectancy valence model (EVM)) along with the brain correlates of cognitive control (men and women event-related potentials (ERPs) amplitude differences). Our analysis found that the commonly reported performance differences between men and women cancelled each other out under the humor condition (Hc), as women improved their performance and men worsened it. Analysis of amplitude of the ERPs indicated that men under the Hc worsened their ability to detect early environmental changes (lower amplitudes of the N2 component under Hc) when compared to men under NHc, which we interpreted as an impairment in the memory/learning of the task. Second, we found evidence that women under the Hc improved their ability to allocate attentional resources in IGT (higher amplitude of p3b component under Hc) when compared to NHc, which we interpreted as an advantage when using attention to change decisions from inefficient to more efficient ones. These results ultimately suggest that men - when under the non-humor condition- may use their automatic emotion regulation and therefore they can probably obtain with lower cognitive effort higher IGT performances. Nevertheless, the use of humor may impair their performance because they will require an additional cognitive effort to process humor, which may compete for cognitive resources with IGT. Conversely, for women – when under non-humor condition- they require to use cognitive resources for emotion regulation, demanding more cognitive effort to solve IGT. But, when under humor, the qualitative transformation into positive of emotion is facilitated and therefore they can probably obtain higher IGT performances with lower cognitive effort.

To further explore the neural mechanisms involving women's and men´s IGT performance under humor, we propose to analyze brain oscillations which has been proposed to be useful to understand the neurophysiological correlates of multiple cognitive processes related to decision-making performance, such as cognitive effort (Sederberg et al, 2003; Gevins, 1997) and top-down control (Buschman and Miller, 2007; Wang, 2010; Fries, 2015). Cognitive effort is the amount of concentration being used in the working memory (WM) to solve a task (Sweller, 1988). Working memory has a limited capacity, thus holding a great amount of information or holding it for longer periods require more cognitive effort (Diamond, 2013). Cognitive effort has been strongly associated with decision-making and have an impact in the amplitude of theta oscillations (4-8 Hertz) (Sederberg et al, 2003). Theta amplitude increases with practice in the task, suggesting this change reflects the increased concentration involved in focusing attention after longer time spent performing the task (Gevins, 1997). On the other hand, top-down control depends on volitional shifts of attention derived from previous knowledge which allows to make predictions about the task outcomes (Buschman and Miller, 2007). Beta activity oscillations (13-30 Hertz) have been related to decision-making regarding top-down control of attention (Buschman and Miller, 2007; for review, see Engel and Fries, 2010; Wang, 2010; Fries, 2015) in which beta-synchronization provides feedback communication of top-down predictions (Arnal and Giraud, 2012; Bastos et al., 2015; Michalareas et al.,2016) so it is expected that beta band should be enhanced when a cognitive task requires stronger top-down control (Fries, 2015). The relationship between cognitive effort and top-down control is clear during IGT, because learning the rules of the task imply that economic and emotional information provided by feedback must be maintained and updated in the working memory, while participants are regulating the emotional impact of monetary punishments and using their experience and predictions about the outcomes to build an optimal strategy through top-down control. What we still do not know is whether humor affects differently the neural correlates of cognitive effort and top-down control of men and women and whether these processes are related to different IGT performances in men and women.

The first objective of the present study is to examine the effect of humor and sex on theta and beta activity during IGT. In line with the abovementioned research, we hypothesize that humor will decrease women's theta oscillations (indicating lower cognitive effort) and beta activity (indicating that they will not require to additionally deploy top-down control during IGT). Therefore, the women exposed to humor (Hc) will exhibit lower theta activity and lower beta activity than the women exposed to non-humor (NHc) (Hypothesis 1). We also expect that Hc will increase men's theta oscillations, indicating higher cognitive effort, and increase beta oscillations, indicating that they will require to use more top-down control during IGT; therefore, the men exposed to Hc will exhibit higher theta activity and higher beta activity than the men exposed to NHc (Hypothesis 2). When no humor is involved, women will show higher theta activity and higher beta activity than men (Hypothesis 3). And finally, when humor is involved, women will show lower theta activity and lower beta activity than men (Hypothesis 4).

The second objective is to examine the effect of humor and sex on the relationship of both, theta and beta oscillations on IGT performance. We expect to find that the women under Hc will show no relationship between theta activity and IGT performance (because obtaining a high performance will not depend on the cognitive effort invested on the IGT task), and a negative relationship between beta and IGT performance (because using low top-down control will reduce the cost of monitoring the outcome of the task) (Hypothesis 5). Conversely, the women under NHc, will show a positive relationship between theta activity and IGT performance and a positive relationship between beta and IGT performance (Hypothesis 6). By contrast, we expect that among men, those under Hc will show a positive relationship between theta activity and IGT performance, and a negative relationship between beta activity and IGT performance (Hypothesis 7). And the men under NHc, will show no relationship between theta activity and IGT performance, but they will show a negative relationship between beta and IGT performance (Hypothesis 8).

These objectives will be addressed by using behavioral and time frequency analyses in the following sections.

Methods

Participants

Inclusion criteria for participation were (1) being an undergraduate student at the Pontificia Universidad Católica de Chile, (2) being between 18 and 30 years old, (3) speaking Spanish, and (4) having normal or corrected-to-normal vision. Exclusion criteria were (1) have being diagnosed with a psychiatric disorder, (2) presenting severe depressive symptomatology according to the Self-Report Questionnaire (SRQ, Harding, 1980; Vielma et al., 1984), (3) presenting a neurological disorder, (3) having a history of drug abuse, and (4) having consumed alcohol, caffeine or drugs 24 hours before participating in the experimental task.
To estimate the sample size, we used Cohen's guidelines (1988). The software used was G* Power 3.1 with parameters for large effect size Fs (.40), a probability error α (.05), and a statistical power of (.80), which leads to a minimum of 52 participants (26 women and 26 men). Nonetheless, when we reached the sample size of 26 women, there was not still enough men enrolled, so we decided to continue the recruitment till we got an equivalent number of men and women. As such, 64 (33 women and 31 men) participants completed the study. The data of four of these participants (one male and three female) were not considered in the analyses because they did not fulfill all participation criteria. Namely, one of these participants reported having consumed drugs before the experiments and three of them presented severe depressive symptomatology according to the SRQ. Therefore, the data of 60 participants (30 men; mean age 22.02, SD = 4.3 and 30 women; mean age 22.3, SD = 4.1) were finally considered for analysis.

Questionnaires.

The Self-report questionnaire (SRQ; Harding et al, 1980) was used to assessed depressive symptomatology. It consists of 25 Yes and No questions. The SRQ has been validated for Chilean population (Vielma et al, 1984). Subjects scoring higher than 11 points or answering affirmatively questions 21 to 25 (elevated probability of depressive symptomatology) were not included in the study sample.

The State-Trait anxiety inventory (STAI; Spielberger et al, 1970) was used to assess anxiety symptoms. It consists of 40 questions divided in two subscales: the state anxiety (SA) and the trait anxiety (TA) scales. The STAI has been validated for Chilean population (Vera-Villarroel et al, 2007). We assessed this variable because higher TA scores are related with impairments in decision-making and could potentially affect our results (Miu, Heilman, & Houser, 2008).

Humorous and neutral videos.

To induce humor, a selection of 200 videos (100 humorous and 100 non-humorous) was made from 240 public access videos (120 humorous and 120 non-humorous) available at *www.youtube.com*. The initial 240 videos were selected by the researcher. The criteria were the presence or absence of humor in ecological situations and an adequate duration of stimuli which must be suitable for EEG uses (mean duration = 12.84 secs; *SD* = 5.81 secs). The initial 240 videos selected by the researcher were presented in a randomized order to 50 subjects (25 men and 25 women) who were not part of the sample of the present research. These subjects were asked to rate the videos using a humor scale ranging from 0 to 10 points (0 "not humorous at all"; 10 "the most humorous thing ever"). To identify how each video was rated, participant´s ratings were plotted. We eliminated all individual videos that were less than three standard deviation away from the mean of the opposite condition, which result in the elimination of 40 videos (20 humorous and 20 non- humorous). The final video selection consisted in 100 humorous and 100 non-humorous videos. To examine whether there were statistically significant differences in the rating scores between both types of videos, we conducted a two-way factorial ANOVA (Sex x Video type [humor/non-humor]). Results showed a main effect of video type ($F_{1,198}$ = 220, p<.00, η^2 = .917), indicating that humorous videos were rated as significantly more humorous than non-humorous videos. Neither the main effect of sex nor the interaction (Sex x Video Type) were statistically significant. Humorous videos were assigned to the experimental group while non-humorous to the control group. The mean duration of the humorous videos was 12.84 (*SD* = 5.81) and the non-humorous videos mean was 11.91 sec (*SD* = 4.62).

The IGT.

It was designed as a life-like decision-making task (IGT; Bechara et al., 1994). Participants must choose a card out of any of four card decks (A, B, C, and D). After each choice, participants can be rewarded with virtual money (reward) or punished with a loss of virtual money (punishment). Participants must learn as they play which are the monetarily efficient and inefficient decks to solve the task. Participants can change decks at will during the whole task; however, they're warned that some decks are worse than others in terms of payment and that decks positions are fixed during the whole task. Likewise, they are informed that the goal is to win as much money as possible, or to avoid losing money as much as possible.

Concerning outcomes, card decks A and B are monetarily risky/inefficient, and C and D are monetarily safe/efficient. Card decks A and B are associated with higher sums of immediate rewards (e.g, $100) but maintaining these card decks choices means accumulating less or no profit at all, because of occasional large monetary punishments. As a matter of fact, this strategy leads to a net loss from $250 during the 10 first trials, while card decks C and D could offer an immediate lower reward (e.g $50) but with small monetary punishments, allowing to accumulate profit and leading to a net winning from

$250 during the first 10 trials. Consistent C and/or D choices allow participants to earn virtual money at the end of the task, while A and/or B consistent choices leads to owing money at the end of the task. We modified the original number of trials from 100 to 500 to make statistically valid ERP inferences and we also modified the feedback shown to participants, following Cui et al (2013) guidelines in which the presentation of win and losses observed in the original task is replaced by net scores of either wining or losses (Cui et al., 2013).

IGT performance is calculated by computing the difference between monetarily efficient and monetarily inefficient choices [(C+D) - (A+B)]. This computation is made in twenty-five sets of twenty choices each called blocks. As participants learn IGT, there is an increase in the net score magnitudes, which is an increase in monetarily efficient choices.

Procedure

Each trial began with an image announcing the video presentation in which the word "*video*" appeared on the screen during 1500ms. Then the video itself appeared. Each video was followed by five decision-making trials. During these trials, participants saw four deck options (A, B, C, and D) and chose one of the available options by clicking on the deck with a USB mouse. When participants selected a card, its perimeter lit up in red. After that, the screen changed to black during 300ms, which allowed for a clean baseline for Electrophysiological measurement. Immediately after the black screen, the feedback appeared. Feedback corresponds to "0" time to evaluate electrophysiological measures. Feedback was shown during 2000ms. Feedback could be a net winning (e.g +100) or a net loss (e.g, -50). Each card's feedback depended on the probabilities according with Bechara IGT manual (Bechara et al., 1994), using modifications for an electrophysiological adaptation (Cui et al., 2013). During the screen showing the four deck options, on the central superior area of the screen, two bars appeared. A green bar showed participant accumulated winnings and losses and a red bar, representing the lent money. After feedback, bars automatically updated with either won or lost values throughout the task. We emphasized to participants that positions and decks contingencies were fixed during the whole task, that they could change decks at will and that there was no association whatsoever between videos and decks. Participants had no specific information about how to solve the task, nor did they know how long it took. Participants completed 100 videos and 500 trials (divided in 25 blocks of 20 trials each). We programmed two breaks (after 40% and 70% of total trials).

EEG data acquisition and preprocessing.

EEG data was obtained using 64 sintered Ag/AgCI electrodes arranged (Biosemi® Active two) according to the international 10/20 extended system. Two additional external electrodes were placed on the right and left mastoid to be used for later re-referencing. Data pre-processing was performed using Matlab 8.3.0.532 (The Mathworks, Inc.) with

EEGLAB v13.6.5b toolbox. (Swartz Center for Computational Neuroscience; http://sccn.ucsd.edu/eeglab/)

The signal was down-sampled off-line at 1024 Hz following Cohen (2014) guidelines, all electrodes were referenced to averaged mastoids. A 2nd order infinite impulse response (IIR) Butterworth filter was used for band-pass filtering continuous EEG data, with a half amplitude cut-off frequency of 0.1 Hz and 100 Hz. For channels and artifact rejection we segmented data in 500 epochs from -1000 to 2000 milliseconds. This was done in a manner that was blind to experimental condition. We performed a semi-automated channel rejection coupled with visual inspection applying EEGLAB trim outlier function. We set a high upper bound rejection threshold of 200 μ V and a lower bound rejection threshold of 10 μ V. The total average of rejected channels was 0.6 channels per subject. Commonly recorded artefactual potentials (Crap: Luck, 2014) detection was performed setting a high rejection criterion (100 μ V) threshold for the moving window peak-to-peak algorithm. This procedure allowed rejecting extremely noisy data which never exceeded 15% of total trials (75 of 500 trials). We also performed manual inspection to detect muscle like activity. Then we performed independent component analysis (ICA). Through this method we eliminated an average of two ocular stereotypical artefactual components per EEG recording. Then we performed channel spherical interpolation function, being P2 the most frequently interpolated channel (12% of the subjects)

Spectral power analysis.

EEG signal was segmented into 500 trials. For each trial, we selected 200ms previous to feedback up to 1000ms after feedback. We conducted spectral power for each condition (i.e., men under Humor, men under non-humor, women under humor and, women under non-humor) which was obtained by means of the Fourier transform algorithm using a continuous and overlapping Hanning taper of 250 ms, in steps of 10 ms, through the multitaper convolution method between 1 and 80 Hz (MTTCONV from Fieldtrip software). Previous to the fourier transformation the evoked potential was subtracted to all trials in order to calculate the induced time-frequency chart. The resulted spectral power was normalized by means of a decibel normalization using the 200 ms before the stimulus onset (Cohen, 2014). Finally, data was visualized as time-frequency charts using a central (Cz, Cpz and Pz) electrodes. All these analyzes were computed using Fieldtrip software (Oostenveld, Fries, Maris, & Schoffelen, 2011)

The obtained spectral power was analyzed averaging the time window between 380 and 430 ms, for the theta (4-8 Hz) and the beta (13-30 Hz) band of the central electrodes Cz, Cpz and Pz. A unique value of power was obtained per condition.

Correlations between oscillations and IGT performance

Frequency band oscillations are obtained from electrophysiological data from all trials and cumulative IGT performance are obtained from decisional behavioral data from all trials. For that reason, we use IGT cumulative performance instead of blocks by blocks data to measure the relationship between IGT performance and frequency bands oscillations.

IGT cumulative performance correspond to the addition of the results of each consecutive Bechara's net-scores from block 1 to block 25. Therefore, through this procedure, we obtained a unique value of the cumulative IGT performance of each participant across the whole task. Cumulative IGT performances range from -500 to 500 (being "0" random cumulative performance). Following [(C+D) - (A+B)] the minimum net-score possible in a 20 trials block is: -20 = [(C+D = 0) - (A+B = 20)]. Obtaining that result through the 25 blocks is: -500 = (-20 x 25). On the other hand, the maximum net-score possible by each block is: 20 = [(C+D = 20) - (A+B = 0)]. Therefore, a perfect positive cumulative IGT performance through the 25 blocks is 500.

To calculate the relationships between oscillations and cumulative IGT performances, we computed bivariate correlations through Pearson's correlation coefficient analyses.

Statistical analysis plan.

Trait anxiety has shown to affect IGT performance and women seem to present higher trait anxiety than men (Miu et al, 2008); thus, to examine whether there were differences between the groups in this variable, we first conducted a two-way factorial ANOVA [Sex x Condition (Humor/Non-humor)] in which the dependent variable was trait anxiety. The main effect of sex, the main effect of condition, and the interaction were not statistically significant, indicating that there were no significant differences in trait anxiety among the groups. Therefore, this variable was not considered in further analyses.

To test whether women under humor exhibit both lower theta and beta activity than women under non-humor (Hypothesis 1), we conducted a MANOVA with the total sample of women and performed ANOVA contrasts for each frequency band activity when needed. To test whether men under humor exhibit both lower theta and beta activity than men under non-humor (Hypothesis 2), we conducted a MANOVA with the total sample of men and performed ANOVA contrasts for each frequency band activity when needed. To test whether under non-humor women exhibit lower theta and beta activity than men (Hypothesis 3), we conducted a MANOVA with the total sample under NHc and performed ANOVA contrasts for each frequency band activity when needed. To test whether under humor women exhibit lower theta and beta activity than men (Hypothesis 4), we conducted a MANOVA with the total sample under Hc and performed ANOVA contrasts for each frequency band activity when needed.

To test whether women under humor show no relationship between theta activity and IGT performance, but a negative relationship between beta activity and IGT performance (Hypothesis 5), we conducted a bivariate Pearson's correlation between women under humor theta activity and their IGT Bechara's cumulative performance and a second bivariate Pearson's correlation between women under humor beta activity and their IGT Bechara's cumulative performance. To test whether women under non-humor show a positive relationship between theta activity and IGT performance and a positive relationship between beta activity and IGT performance (Hypothesis 6), we conducted a bivariate Pearson's correlation between women under non-humor theta activity and their IGT Bechara's cumulative performance and a second bivariate Pearson's correlation between women under non-humor beta activity and their IGT Bechara's cumulative performance. To test whether men under humor show a positive relationship between theta activity and IGT performance, but a negative relationship between beta activity and IGT performance (Hypothesis 7), we conducted a bivariate Pearson's correlation between men under humor theta activity and their IGT Bechara's cumulative performance and a second bivariate Pearson's correlation between men under humor beta activity and their IGT Bechara's cumulative performance. To test whether men under non-humor show no relationship between theta activity and IGT performance but a negative relationship between beta activity and IGT performance (Hypothesis 8), we conducted a bivariate Pearson's correlation between men under non-humor theta activity and their IGT Bechara's cumulative performance and a second bivariate Pearson's correlation between men under non-humor beta activity and their IGT Bechara's cumulative performance.

We checked and correct sources of bias (e.g., linearity and normality) when necessary. Outliers were replaced using the mean plus two standard deviations method recommended by Field (2009).

Results

Differences in theta and beta oscillatory activity by condition and sex.

The results of the MANOVA examining the effect of condition (Humor/Non-humor) performed on the women sample revealed no statistical differences neither for theta nor for beta activity. The result of the MANOVA examining the effect of condition on the men sample, showed statistical differences using Pillai's Trace, $V = 0.23$, $F\ (2,27) = 4.02$, $p = .03$. Separate univariate ANOVAs on the outcome variables showed statistical differences for beta power $F\ (1,28) = 7.29$, $p = .01$ indicating that the men under Hc exhibit higher beta power than the men under NHc ($t\ (1) = 2.7$, $p = .01$, $\eta^2 = .21$; $M_{\text{men Hc}} = 3.69$, $SD_{\text{men Hc}} = 2.02$; $M_{\text{men NHc}} = 2.12$, $SD_{\text{men NHc}} = 1.0$).

The result of the MANOVA examining the effect of no-humor on theta and beta activity conducted with the sample of women and men, showed no statistical differences. Finally, the result of the MANOVA examining the effect of humor on theta and beta activity conducted with the sample of women and men, showed statistical differences using Pillai's Trace, $V = 0.23$, $F\ (2,27) = 3.91$, $p = .03$. Separate univariate ANOVAs on the outcome variables showed differences for theta power $F\ (1,28) = 7.34$, $p = .01$, indicating that men under Hc exhibit less theta activity than women under Hc ($t\ (1) = -2.71$, $p = .01$, $\eta^2 = .21$; $M_{\text{men Hc}} = 25.49$, $SD_{\text{men Hc}} = 9.72$; $M_{\text{women Hc}} = 34.5$, $SD_{\text{women Hc}} = 8.45$)

Theta and beta oscillatory activity and its relationship with IGT performance.

The result of the bivariate Pearson's correlation analysis of theta activity and IGT Bechara's cumulative performance of the women under humor, revealed that theta activity was not significantly related to IGT cumulative performance. The result of the bivariate Pearson's correlation analysis of theta activity and IGT Bechara's cumulative performance of the women under non-humor, revealed that theta activity was positively and significantly related to IGT cumulative performance, $r = .533$, 95% BCa CI [.018, .836], $p = .04$. (See Figure 1 A).

Additionally, the result of the bivariate Pearson's correlation analysis between beta activity and IGT Bechara's cumulative performance of women under humor, revealed no statistically significant relationship. The result of the bivariate Pearson's correlation analysis between beta activity and IGT Bechara's cumulative performance of women under non-humor revealed no statistically significant relationship either. (See Figure 1 B).

The result of the bivariate Pearson's correlation analysis of theta activity and IGT Bechara's cumulative performance of the men under humor, revealed that theta activity was not significantly related to IGT cumulative performance. The bivariate Pearson's correlation analysis of theta activity and IGT Bechara's cumulative performance of the men under non-humor, revealed that theta activity was not significantly related to IGT cumulative performance either (See Figure 1 C)

Nevertheless, the result of the bivariate Pearson's correlation analysis between beta activity and IGT Bechara's cumulative performance of men under humor revealed a negative and significant relationship, $r = -.515$, 95% BCa CI [-.824, -.128], $p = .04$. And finally, the result of the Pearson's correlation analysis between men under non-humor beta activity and IGT Bechara's cumulative performance of men under non-humor, revealed no statistically significant relationship too (See Figure 1 D).

[Please, insert figure 1 here]

[Please, insert figure 2 here]

Discussion

Our results did not support the expected decrement in theta and beta activity in women under Hc. As a matter of fact, humor did not change significantly women's theta nor beta activity when compared to the group of women under NHc. Regarding men, as expected, we found evidence indicating that humor increases men's beta activity when compared to men under NHc, nevertheless, we found no effect for theta activity. Contrary to our expectations, we found that men and women participants under NHc showed no difference in theta nor beta activity. And finally, contrary to our expectations, we found that under Hc men actually exhibited less theta activity than women, we found no effect for beta activity.

Our results confirmed our expectation about finding no correlation between theta activity and IGT performance in women under Hc, nevertheless, we couldn't find any significant correlation between beta activity and IGT performance. Our results confirmed our first expectation regarding women under NHc, they exhibited a positive correlation between theta activity and IGT performance, but we couldn't find any significant correlation between beta activity and IGT performance. Regarding men, our results didn't support our expectation about theta, thus no correlation between theta activity and IGT performance was found, but we confirmed our expectation about finding a negative correlation between beta activity and IGT performance. Finally, our results confirmed that among men under NHc they show no correlation between theta activity and IGT performance. No significant correlation between beta activity and IGT performance was found.

The relationship between sex, humor, and brain oscillations in IGT decision-making

Little is known about the relationship between these variables altogether. Nevertheless, it is of common agreement that theta activity is considered as a neural correlate of cognitive effort (Sederberg et al, 2003; Gevins, 1997) and beta activity is considered as a neural correlate of top-down control (Buschman and Miller, 2007; Wang, 2010; Fries, 2015). Our results indicate that a higher IGT performance is achieved in conditions of either low cognitive effort or low top-down control. For instance, women obtained lower performances under NHc, conversely, men obtained lower performances under Hc. Correlation analyses indicated that women under NHc exhibited a positive correlation between theta activity and IGT performance; implying that women under NHc had to concentrate longer or use more cognitive effort in order to achieve better IGT performances. On the other hand, men under Hc exhibited a negative correlation between beta activity and IGT performance; implying that men under Hc need to decrease their top-down control in order to obtain higher performances during the IGT.

We also observed that women obtained higher performances under Hc and men obtained higher performances under NHc. Correlation analyses indicate that women under humor condition showed no correlation between theta activity and IGT performance nor between beta activity and IGT performance. Conversely, men under NHc showed no correlation between theta activity and IGT performance, nor between beta activity and IGT performance. We interpreted these results as men's higher IGT performance seem to emerge possibly automatically under NHc, but when humor is involved, this additional processing seems to impair men's performance, requiring top-down control to focus on performance. Conversely, for women humor seem to facilitate a decrement in cognitive effort, probably requiring less monitoring of the task, which is behaviorally expressed as better IGT performance.

We can also appreciate that under Hc women IGT performance is more packed and above random (above “0”) conversely, women under NHc IGT performance is more scattered and some of the participants are actually below random (below “0”) indicating difficulties in changing an inferior monetarily strategy into something more efficient. Yang-Gui et al (2018) found in a decision-making paradigm of intertemporal choice that there was an increment in theta oscillations during impulsive decisions and an increment of beta oscillations during non-impulsive ones. According to this interpretation, our results would indicate that women participants under NHc are more impulsive in their decisions than those under Hc, which could negatively affect their performance, and that men participants under Hc need to deliberately control the task requiring additional cognitive resources. Nevertheless, to prove this alternative interpretation (impulsive vs. non-impulsive behavior) more research is needed.

Humor and the power of competition in men and the power of emotion regulation facilitation in women

One can wonder why women perform better than men under Hc? this question is very interesting because participants under Hc are focusing in several things at the same time (humor processing + IGT decision strategy). Cognitive control literature suggests that when participants are doing several things at the same time, their attention suffer because it is forced to split and switch from one task to the other, resulting in an inferior performance (Treisman and Davies, 1973). However, recent research indicates that men and women process emotions differently, and these differences may indicate how sex mediate the neural mechanisms responsible for emotion regulation and cognition (Mitchell, 2011; McRae, 2008). It seems that in order to improve performance in decision-making tasks, we must take into consideration the use of different cognitive and emotion regulation strategies when used by women or men, because the way each sex processes information and regulate their emotions is mirrored in how well different strategies of cognitive control are implemented. In our case, the use of positive emotions in women may facilitate their emotion regulation and positively affect their decision-making performance. Conversely in men, the use of positive emotion may affect them negatively, because their attention competes between the different things that draw their attention. An example of the latter comes from Preston et al (2007) This research indicates that inducing stress by a situation non-directly related with IGT (i.e., to know in advance that participants have to give a public speech after performing IGT) impairs men’s performance more than women’s. The authors indicate that this occur because in men, but not in women, the first task (controlling stress) competes for cognitive resources with the second one (solving IGT). They suggested that these results reflect the consequences of the men’s focus on cognitive processing, which could be more negatively affected by competition than for women.

Therefore, the existing literature regarding sex differences in emotional regulation and cognitive control suggest that positive emotions, such as humor, could help to regulate women's negative emotions and may, in consequence, positively affect women's decision-making on tasks such as the IGT. Conversely the men's advantage in regulating emotions and deploying cognitive control depends on the possibility of allocating cognitive resources to a single task at a time. Therefore, unlike women, when men are exposed to a cognitively and emotionally complex task in which attention has to be divided, (e.g., observing humorous videos and at the same time paying attention to IGT performance), their cognitive control is impaired. Which is precisely what we observe in our current research.

Future Directions

Our results suggest that men and women make decisions differently because of a different way of processing both emotions and decisional information, thus opening the possibility to explore this phenomenon in terms of brain mechanisms involved and possibly exploring whether these mechanisms may affect other areas of cognitive performance or is it a particular domain of emotion and decision-making. Future research may focus in the specific circuitry involved in the emotional control during the decision-making through fMRI exploration or minimally invasive techniques such as Transcranial magnetic stimulation (TMS) or Direct current stimulation (DCS). Additionally, different emotional regulation techniques such as cognitive reappraisal could be explored in order to evaluate whether our current results are replicated and confirmed if our results still remain valid.

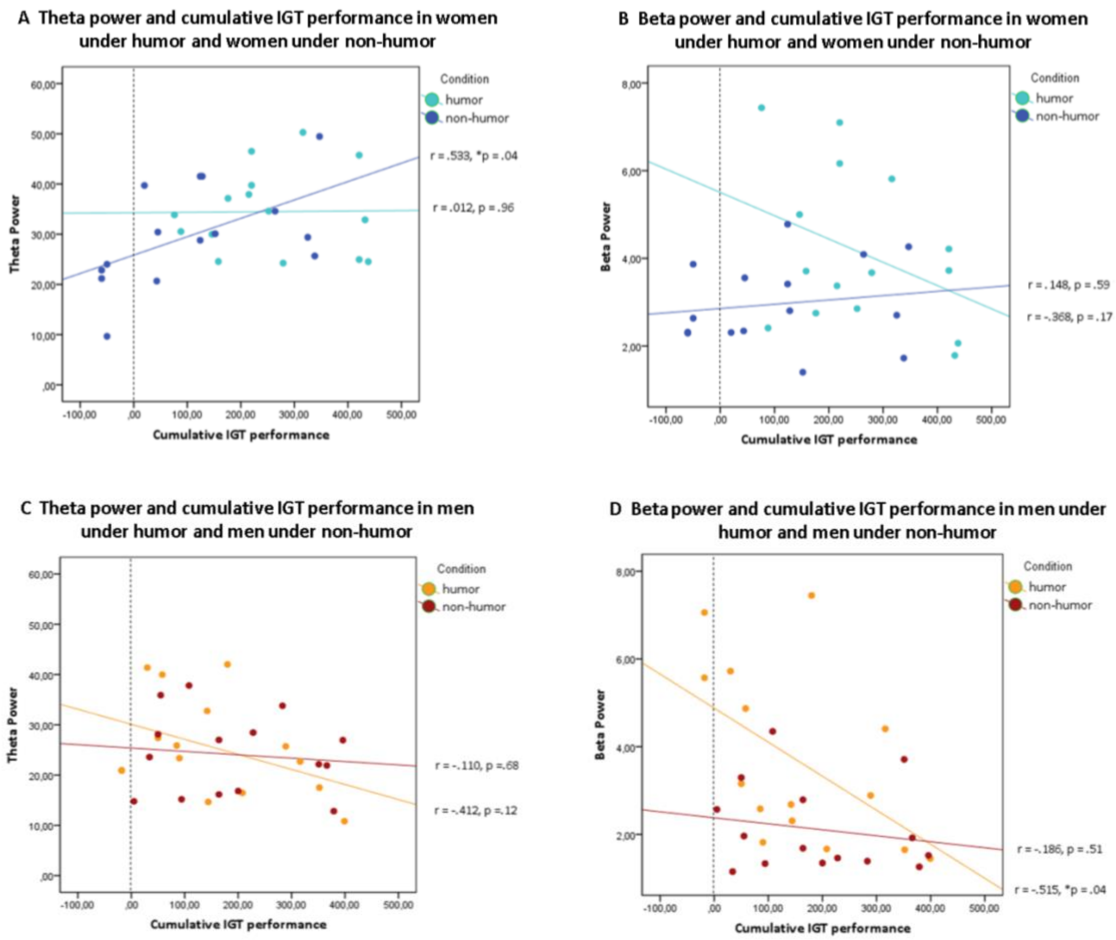

Figure 1: Results for the correlations between theta power activity and cumulative IGT performance and beta power activity and cumulative IGT performance by condition (30 men: 15 under the NHc and 15 under the Hc, and 30 women: 15 under the NHc and 15 under the Hc). Cumulative IGT performances and theta power activity are computed using the total 500-trials. **(A)** A non-significant correlation between theta power and IGT cumulative performance for women under Hc, and a positive and statistically significant correlation between theta power and IGT cumulative performance for women under NHc **(B)** Non-significant correlation between beta power and IGT cumulative performance for women under Hc, and a non-significant correlation between beta power and IGT cumulative performance for women under NHc. **(C)** Non-significant correlation between theta power and IGT cumulative performance for men under Hc, and a non-significant correlation between theta power and IGT cumulative performance for men under NHc. **(D)** Statistically significant correlation between beta power and IGT cumulative performance for men under Hc, and a non-significant correlation between beta power and IGT cumulative performance for men under NHc.

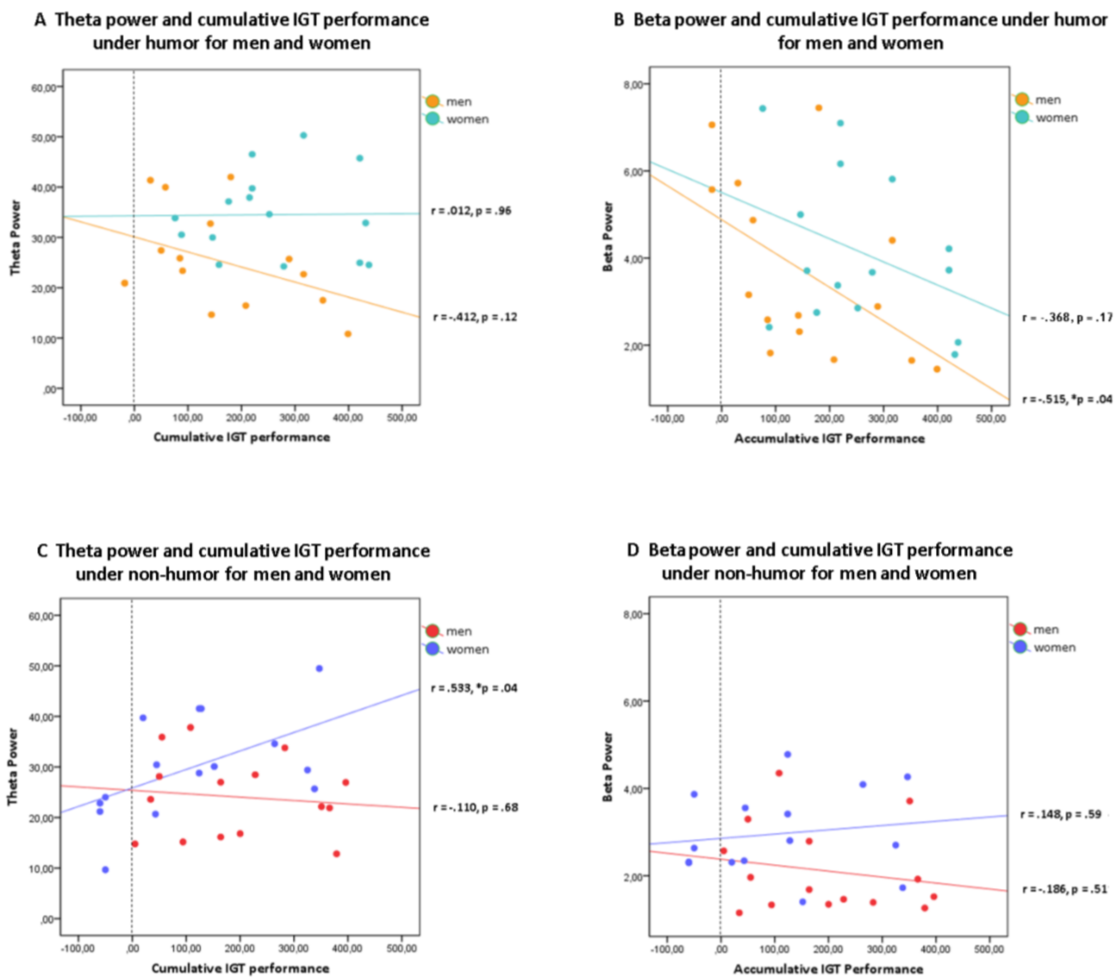

Figure 2: Results for the correlations between theta power activity and cumulative IGT performance and beta power activity and cumulative IGT performance by sex (30 men: 15 under the NHc and 15 under the Hc, and 30 women: 15 under the NHc and 15 under the Hc). Cumulative IGT performances and beta power activity are computed using the total 500-trials. **(A)** Non-significant correlation between theta power and IGT cumulative performance for men under Hc, and non-significant correlation between theta power and IGT cumulative performance for women under Hc. **(B)** Negative and statistically significant correlation between beta power and IGT cumulative performance for men under Hc, and a non-significant correlation between beta power and IGT cumulative performance for women under Hc. **(C)** Non-significant correlation between theta power and IGT cumulative performance for men under NHc, and a positive and statistically significant correlation between theta power and IGT cumulative performance for women under NHc. **(D)** Non-significant correlation between beta power and IGT cumulative performance for men under NHc, and a non-significant correlation between beta power and IGT cumulative performance for women under NHc.

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5.0 *An integrated discussion of the main findings presented in this thesis*

During this work we read and studied a huge amount of research articles about gender differences in decision-making. Often, we could read between the lines – in scientific articles written mainly by men- that women performed worse during the IGT or aren't as good as men while making decisions in general, because there is something wrong in the way they feel or even in the way their brains work. We want to emphasize that during our research we didn't see any evidence supporting the idea that women had something wrong when compared to men while making decisions. As a matter of fact, what our results really showed is that when we must decide and initially we have no information about the available choices, there are different ways to successfully optimize decision-making. Our research strongly suggest that these different strategies depend on sexual differences in the neural mechanisms in charge of emotion regulation and cognitive control, and that correctly using the adequate strategy, becomes an advantage during the execution of predominantly cognitive decisional behavior. That means that we cannot assume that men and women process emotion and information in the same way, therefore we have to be careful when using a particular strategy to regulate emotions or to enhance decision-making, because what it is good for men it is not necessarily good for women and vice versa.

When women have enough trials to learn from, we observed that humor improves slow but constantly their performance. Our electrophysiological results indicate that under humor there is an improvement in their allocation of attentional resources and their cognitive effort is decreased, which allow obtaining better performances when compared to the women participants under non-humor. We suggest that during women's IGT performance, humor allows to decrease the use of cognitive resources used to control negative emotions, re-allocating those resources to the task, therefore, making it easier than under non-humor. Conversely, we observed that humor decreases men's IGT performance affecting negatively their memory and learning. Our electrophysiological results indicate that this impairment could be even pre-attentional. Additionally, we observed that the more top down-control they exert, more negative is the outcome in terms of performance. Implying that when men under humor successfully identify their learning difficulty, and try to revert it by voluntarily controlling their outcome, this action may worsen their IGT performance.

To conclude and as a wider or more general observation, we consider very important that in order for our science to have a wider scope and substantial and meticulous predictions, we need research that consider gender differences. A large amount of studies just assume that it is not important to have equal sample sizes of men and women, leading to incomplete or even poor conclusions. We know that considering gender differences is difficult when doing neuroscience, because it demands a cost in terms of time and effort when completing the sample or applying additional statistical analyses to an already complex study, nevertheless, we cannot tolerate comments such as *"considering females in my experiment it is a bad idea.... everything will be more complex, I don't want to deal with menstrual cycles and or other hormonal complications"* we just wonder, if you are interested in describing neural mechanisms that ultimately impact in every day behavior, how good are your conclusions when you are excluding 50% of the population? Or even worse, how good or ethical are the basis of our knowledge when we are just assuming that women are an imperfect version of what males can do right? We need a joint effort to describe and to predict what is the best way to use our affect and cognition, in order to make the better choices we can. It is an ambitious but fair quest to look what is the finest way for every one of us, but considering our subtle differences at the same time.

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Annexes

Cuestionario de autorreporte *Self reporting questionnaire* (SRQ)

Instrucciones: A continuación encontrará unas frases que se utilizan corrientemente para describirse uno a sí mismo. Lea cada frase y marque la alternativa "SI" o "NO" de acuerdo a si se siente o no representado por ella. No hay respuestas buenas ni malas. No emplee demasiado tiempo en cada frase y conteste señalando la respuesta que describa mejor su situación actual.

(SRQ)

1.- ¿Tiene frecuentes dolores de cabeza?	SI	NO
2.- ¿Tiene mal apetito?	SI	NO
3.- ¿Duerme mal?	SI	NO
4.- ¿Se asusta con facilidad?	SI	NO
5.- ¿Sufre de temblor de manos?	SI	NO
6.- ¿Se siente nervioso, tenso o aburrido?	SI	NO
7.- ¿Sufre de mala digestión?	SI	NO
8.- ¿No puede pensar con claridad?	SI	NO
9.- ¿Se siente triste?	SI	NO
10.- ¿Llora usted con mucha frecuencia?	SI	NO
11.- ¿Tiene dificultad en disfrutar sus actividades diarias?	SI	NO
12.- ¿Tiene dificultad para tomar decisiones?	SI	NO
13.- ¿Tiene dificultad en hacer su trabajo? (¿Sufre usted con su trabajo?	SI	NO
14.- ¿Es incapaz de desempeñar un papel útil en su vida?	SI	NO
15.- ¿Ha perdido interés en las cosas?	SI	NO
16.- ¿Siente que usted es una persona inútil?	SI	NO
17.- ¿Ha tenido la idea de acabar con su vida?	SI	NO
18.- ¿Se siente cansado todo el tiempo?	SI	NO
19.- ¿Tiene sensaciones desagradables en su estómago?	SI	NO
20.- ¿Se cansa con facilidad?	SI	NO
21.- ¿Siente usted que alguien ha tratado de herirlo en alguna forma?	SI	NO
22.- ¿Es usted una persona mucho más importante de lo que piensan los demás?	SI	NO
23.- ¿Ha notado interferencias o algo raro en su pensamiento?	SI	NO
24.- ¿Oye voces sin saber de dónde vienen o que otras personas no pueden oír?	SI	NO
25.- ¿Ha tenido convulsiones, ataques o caídas al suelo, con movimientos de brazos y piernas; con mordedura de la lengua o pérdida del conocimiento?	SI	NO

Inventario de ansiedad Estado-Rasgo

(State-Trait Anxiety inventory, STAI)

Ansiedad Rasgo

Instrucciones: A continuación encontrará unas frases que se utilizan corrientemente para describirse uno a sí mismo. Lea cada frase y señale la puntuación de 0 a 3 que indique mejor como se siente usted en general, en la mayoría de las ocasiones. No hay respuestas buenas ni malas. No emplee demasiado tiempo en cada frase y conteste señalando la respuesta que describa mejor como se siente usted generalmente.

	Casi nunca	A veces	A menudo	Casi siempre
1.- Me siento bien.	1	2	3	4
2.- Me canso rápidamente.	1	2	3	4
3.- Siento ganas de llorar	1	2	3	4
4.- Me gustaría ser tan feliz como otros.	1	2	3	4
5.- Pierdo oportunidades por no decidirme pronto	1	2	3	4
6.- Me siento descansado.	1	2	3	4
7.- Soy una persona tranquila, serena y pacífica.	1	2	3	4
8.- Veo que las dificultades se amontonan y no puedo con ellas	1	2	3	4
9.- Me preocupo demasiado por cosas sin importancia	1	2	3	4
10.- Soy feliz.	1	2	3	4
11.- Suelo tomar las cosas demasiado seriamente	1	2	3	4
12.- Me falta confianza en mí mismo	1	2	3	4
13.- Me siento seguro.	1	2	3	4
14.- No suelo afrontar las crisis o dificultades	1	2	3	4
15.- Me siento triste y melancólico	1	2	3	4
16.- Estoy satisfecho.	1	2	3	4
17.- Me rondan y molestan pensamientos sin importancia2	1	2	3	4
18.- Me afectan tanto los desengaños que no puedo olvidarlos	1	2	3	4
19.- Soy una persona estable.	1	2	3	4
20.- Cuando pienso sobre asuntos y preocupaciones actuales me pongo tenso/a y agitado/a	1	2	3	4