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Can decision-making skills affect responses to psychological stress in healthy women?

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Summary In recent studies showing how stress can affect an individual's decision-making process, the cognitive component of decision-making could also be considered a coping resource available to individuals when faced with a stressful situation. The Iowa Gambling Task (IGT) constitutes the standard test for the assessment of decision-making skills under conditions of uncertainty. Responses of the hypothalamic—pituitary—adrenal (HPA) axis to psychosocial stress, in turn, have been estimated by means of cortisol measurements. Our main objective in this study was to test if good and bad IGT performers show distinct HPA axis responses, when challenged in a classic psychosocial stress test. Because women have been shown to outperform men on the IGT under the influence of psychosocial stress, we chose a sample of 40 women to take the IGT before they were exposed to a public speaking task in a virtual environment. The activation of the HPA axis, involved in the stress response, was assessed by examining the levels of cortisol in the subjects' saliva at the following four stages: before the challenge, after the challenge, and 10 and 20 min after the task. Participants were divided into two groups according to their level of performance, good or poor, on the IGT. Results showed statistically significant differences between the groups for pre-exposure cortisol levels and for cortisol levels 20 min after exposure. Overall cortisol levels were significantly higher in the group with poor performance on the IGT. It appears that good decision-making, which may be an important resource for coping with stress, is associated with a lower HPA axis response to a psychosocial stressor.

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1. Introduction

Executive function is one of the most important cognitive components for an optimal personal development across many areas of our lives. The definition of executive function has been widely debated, with some claiming that it is a unitary process and others asserting that it constitutes a set of interdependent cognitive processes. Many authors have defended the latter position (Baddeley, 1998, Roberts et al., 1998; Bechara et al., 2000; Stuss and Alexander, 2000; Davidson, 2002; Stuss and Knight, 2002) and defined executive function as an integration of processes, including behavior production, working memory, planning, inhibition, flexibility, and decision-making (Verdejo-Garcia and Perez-Garcia, 2007). One of the most important components of executive function is decision-making, which has been characterized as an organism's ability to select the most adaptive course of action from all possible alternatives (Bechara et al., 2000). Perhaps the most common instrument to measure decision-making is the *Iowa Gambling Task* (IGT) (Bechara et al., 1994; Bechara, 2004).

Recently, several studies have suggested that decision-making processes are affected by stress and the hormone cortisol (Van Honk et al., 2003; Preston et al., 2007; Starcke et al., 2008; van den Bos et al., 2009; Putman et al., 2010; Starcke et al., 2011). Of these studies, those by Preston et al. (2007) and van den Bos et al. (2009) have been the ones to test whether psychosocial stress may affect performance on the IGT. On the one hand, Preston et al. (2007) found that, when individuals performed the IGT and believed that they would subsequently have to make a speech (stress condition), they learned the contingencies of the test more slowly than individuals who had not been informed of the need to make a speech (stress-free condition). They also found gender differences, with stressed women making more advantageous decisions than stressed males. On the other hand, van den Bos et al. (2009) found that higher levels of salivary cortisol after the *Trier Social Stress Test* (TSST; Kirschbaum et al., 1993) were associated with worse subsequent performance on the IGT in both men and women. However, moderate cortisol levels in women after the TSST were associated with better IGT performance, a relationship that was not present among male participants. Supporting previous results (Preston et al., 2007), the authors of this study suggest that the effect of high stress reactivity on IGT performance could be mediated by the relationship between high cortisol levels and increases in risk-taking behaviors, with men being more prone to this type of behaviors and women more inclined toward risk-aversive behaviors. In an earlier study, Van Honk et al. (2003) had suggested that baseline levels of cortisol and decision-making performance are related as a result of a shift in reward and punishment sensitivity. Their findings showed an inverse relationship between basal cortisol levels and the selection of risky decks, indicating that subjects with lower levels of cortisol showed more disadvantageous patterns of decision-making on the IGT. IGT performance has also been associated with other psychological variables, anxiety being one of them. Thus, de Visser et al. (2010) found that males with low and high trait-anxiety showed worse performance on the IGT than males with medium trait-anxiety. Also, females with high levels of trait-anxiety chose the advantageous decks less often than women with medium and low trait-anxiety. These data, however, were not related to the level of salivary cortisol collected before and after the task.

Although decision-making in stressful situations has been widely studied, little is known about the way in which an individual with good decision-making skills copes with stress. We hypothesized that good decision making could constitute a helpful capacity in coping with stress.

While different stress-reducing variables, such as social support, self-esteem, and coping styles have been widely studied (Cohen and Wills, 1985; McEwen, 2007; Taylor and Stanton, 2007), little is known about how a person's decision-making skills can affect their responses in threatening or overwhelming situations. The IGT may be a good task to study the role of decision making as a coping strategy, since it has been extensively used as a decision-making task in situations of uncertainty (Bechara et al., 1994; Bechara, 2004), but it may also be influenced by context variables. Therefore, failing the IGT does not mean that the person is bad at making decisions in general. In this study, however, our main objective was to test if good and bad IGT performers show distinct HPA axis responses, when challenged by means of a classic psychosocial stress test. For our study, we hypothesized that good performance on the IGT, a marker of decision-making ability, would predict the response to the TSST presented in a virtual environment, a measure of psychosocial stress. Hypothetically, appropriate decision-making would be one of the coping resources that help people experience a psychosocial stress situation less aversively, thereby decreasing their perception of threat. In addition, previous studies (Preston et al., 2007; van den Bos et al., 2009) have shown that the relationship between decision-making and psychological stress differs in men and women. Specifically, stressed women perform better than stressed men on the IGT under similar circumstances. In their review, Kajantie and Phillips (2006) reported on the differences in stress responses that set men and women apart. Their review suggests that sex-specific stress responses depend on the type of stressor, on hormonal differences between the sexes, and on various other modulating variables, such as social support, a behavior that predominates in women, or risk-seeking behaviors, most commonly observed in men. Furthermore, research has shown that women are at a higher risk of experiencing psychological problems derived from stress, such as anxiety disorders and depression (Kessler, 2003; Leach et al., 2008), or autoimmune diseases (Beeson, 1994) and overall stress vulnerability (Kudielka and Kirschbaum, 2005; Kajantie and Phillips, 2006). Because of sex differences in handling stress, women's greater vulnerability to develop stress-related disorders, and sex distinctions in IGT performance, we considered it would be valuable to determine whether decision-making worked as a mitigating factor in the female stress response. Therefore, we conducted this study only on female subjects so that we could more precisely determine how decision-making ability and the response to psychosocial stress are related in educated Western women. Our goal was to verify the aforementioned inverse relationship, that is, to examine whether women with better decision-making skills experience less stress than less able decision-makers, when faced with the task of speaking in public.

2. Method

2.1. Participants

Forty Spanish women participated in this study. They had an average age of 28 years (SD = 11.08) and 14 years of schooling (SD = 1.74). Participants belonged to the local university community and were students, professors, or administrative personnel. They were recruited via posters, emails, and information provided in university classrooms. All subjects signed informed consent forms to participate in the study, which was approved by the ethics committee of our university and carried out according to the recommendations of the Declaration of Helsinki.

After providing information about the study, we conducted semi-structured interviews, obtained socio-demographic data, and evaluated participants according to the inclusion criteria. To be admitted to the study, women had to have at least basic education and be free of hypertension, heart disease, neurological damage, obesity, or any other type of clinical disease. We also controlled for the following variables: consumption of controlled drugs or recreational substances (alcohol, nicotine, amphetamines, barbiturates, methadone, muscle relaxants, or lithium) and the use of contraceptives. Although we did not control for the participant's menstrual phase during the experimental session, we did gather information about the date and duration of last menses during the semi-structured interview, so as to control this variable as a possible confounding factor. It has been found that levels of salivary cortisol are higher in the luteal phase than in the follicular phase of the cycle (Kirschbaum et al., 1999; Kudielka and Kirschbaum, 2005). However, it has also been shown that the menstrual cycle does not affect decision-making (Reavis and Overman, 2001; van den Bos et al., 2007). Finally, in order to rule out psychopathology (i.e., clinical depression and anxiety), we excluded those subjects who scored two standard deviations above the mean on the *Symptom Checklist SCL-90-R* (Derogatis, 1994).

2.2. Instruments

The following are the instruments used in the first phase of mood and decision-making assessment, as well as in the second phase of exposure to psychosocial stress:

2.2.1. Phase 1: Assessment of mood and decision-making skills

A number of instruments were applied in the initial evaluation, including the following: a semi-structured interview, the *Symptom Checklist SCL-90-R* (Derogatis, 1994), the *Positive and Negative Affect Schedule* (PANAS; Watson et al., 1988; Sandín et al., 1999) and the *Iowa Gambling Task* (Bechara et al., 1994). Through the semi-structured interview, we collected socio-demographic data and evaluated all participants according to the inclusion criteria outlined in the previous section.

Psychopathological screening: The *Symptom Checklist SCL-90-R* was used to rule out possible psychopathology. The Checklist is a self-report Likert scale consisting of 90 items with five response choices each (from 0 = none to 4 = much). The person must respond to questions about how they have felt over the past seven days, including the day in which the questionnaire is administered. Answers are evaluated and interpreted in terms of nine primary dimensions (somatization, obsessions and compulsions, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoia and psychoticism) and three global indices of psychological distress (Global Severity Index (GSI), Total Positive Symptoms (PS) and Positive Symptom Distress Index (PSDI)). The *SCL-90-R* showed adequate reliability in terms of Internal Consistency Analysis and Test Retest, which indicated good internal consistency (from 0.73 to 0.88) and temporal stability (from 0.40 to 0.82), in a population sample with ages over 19 (M = 43.5; SD = 23.8), and with 41% females and 59% males (Derogatis, 1994). Scores around 50 were considered normal scores and scores that were two standard deviations above the mean (i.e., over 70) were considered clinical scores.

Evaluation of mood: We measured state variables (i.e., temporary fluctuations in mood) of positive and negative affect by means of the PANAS. We used the *state* measure from the Spanish version of Sandín et al. (1999) before and after the stressful task (*PANAS state pre-* and *PANAS state post*). This instrument contains 20 items (10 for positive affect and 10 for negative affect) with responses ranging between 1 and 5, where 1 = never, 2 = almost never, 3 = sometimes, 4 = often, and 5 = almost always. The PANAS has adequate internal consistency in university women both for the positive affect scale (α = 0.87) and the negative affect scale (α = 0.89). Mean scores in females were 30.37 (SD = 6.08) for positive affect and 22.69 (SD = 6.83) for negative affect (Sandín et al., 1999).

Decision-making assessment: In evaluating decision-making skills, we used the Iowa Gambling Task (IGT). This computerized task has been used to assess decision-making in a wide variety of studies (Bechara, 2004). It simulates essential components of decision-making common to everyday life, and the assessment of rewarding and punishing events under conditions of uncertainty and risk. In the task, subjects must choose among four decks of cards. Two of them provide a high and immediate gain but great future losses (long-term loss), while the other two decks provide lower immediate gains but a smaller future loss (long-term gain). Initially, participants do not know these deck characteristics. The program provides feedback about the consequences of each choice the participant makes. The purpose of the task is to try to earn as much money as possible and to incur minimal losses when it is impossible to win. Therefore, in order to win money in the task, the appropriate strategy is to consistently select more cards from the advantageous (long-term gain) decks than from the disadvantageous (long-term loss) decks. The primary dependent variable is the difference between the number of advantageous and disadvantageous choices in each of the five blocks of 20 trials that comprise the task.

If we consider results from the control group in the study by van den Bos et al. (2007), we can appreciate that there are no changes in cortisol levels as a function of IGT performance. Similarly, de Visser et al. (2010) failed to obtain any changes in cortisol levels when subjects were administered the STAI, IGT, or Wisconsin Card Sorting Test (WCST). Therefore, we consider that Phase 1 of our pre-evaluation should have not affected the first cortisol measurement conducted during the period of stress exposure.

2.2.2. Phase 2: Stress exposure

During this portion of the experiment, participants were exposed to the Trier Social Stress Test in a virtual reality environment. Afterwards, their emotional status was assessed by means of the PANAS, and the feeling of immersion in the virtual environment was evaluated by means of the *Igroup Presence Questionnaire* (IPQ; Schubert et al., 2001).

Trier Social Stress Test, adapted for a Virtual Reality Environment — TSST (VR): This task is based on the traditional *Trier Social Stress Test* (TSST; Kirschbaum et al., 1993) and has been adapted into a virtual environment by Santos-Ruiz et al. (2010). It consists of the presentation of a virtual audience in a 3D display, with the sounds of the virtual environment being conveyed to the subjects through headphones and a microphone that is used to simulate the recording of the speech (at the end of the study, it is revealed to the participants that their speech was not recorded). The virtual reality task contains the same phases as the traditional TSST. The first phase (*anticipatory stress period*) consists of the initiation of the virtual environment where subjects face a curtain and hear the sound of the virtual room. For 5 min, participants must prepare a speech about their own qualities in which they expose their strengths and flaws, and explain why they identify with them. The second phase (*exposure period*) begins as the curtain rises and the audience appears (Fig. 1). The subject must begin the speech, having been informed earlier that it should last 5 min and that they should be careful about both the content and form of the information they convey, as the audience would react according to the quality of the presentation. Special emphasis is placed on the requirement to speak continuously for the entire 5 min. After the second minute of the speech, a change takes place in the attitude of the virtual audiences, which changes from being an "interested audience" into a "restless audience". This change occurs independently of the participant's performance and continues until the end of the speech. Once the speech ends, the last stage (*the arithmetic task*) begins. This task consists of serially subtracting the number 13 from the number 1022 as quickly as possible for 5 min. Subjects must restart from 1022 whenever they make an error.

Evaluation of the hypothalamic—pituitary—adrenal (HPA) axis: The collection of salivary cortisol samples was performed using Salivette® Cortisol (*Sarstedt*, Numbrecht, Germany, Ref.51.1534), which consists of two small tubes and a small piece of cotton in one of them. Participants chewed the cotton for about 60 s, after which it was introduced into the *salivette* for analysis. Samples were analyzed at the San Cecilio University Hospital, using the electrochemiluminescence immunoassay "ECLIA" method. This method is designed for use in Roche Elecsys 1010/2010 automated analyzers and in the Elecsys MODULAR NALYTICS E170 module. Salivary cortisol samples were obtained at four collection times in the study. The first sample was collected after the explanation of the TSST (VR) (*cortisol pre-exposure*). Subsequently, the second sample (*cortisol post-exposure*) was collected upon completion of the three tasks (anticipatory stress, exposure, and arithmetic task). The third sample was obtained 10 min after the completion of the task (*cortisol post+10 min*), and the last sample was obtained 20 min after the end of the TSST (RV) (*cortisol post+20 min*).

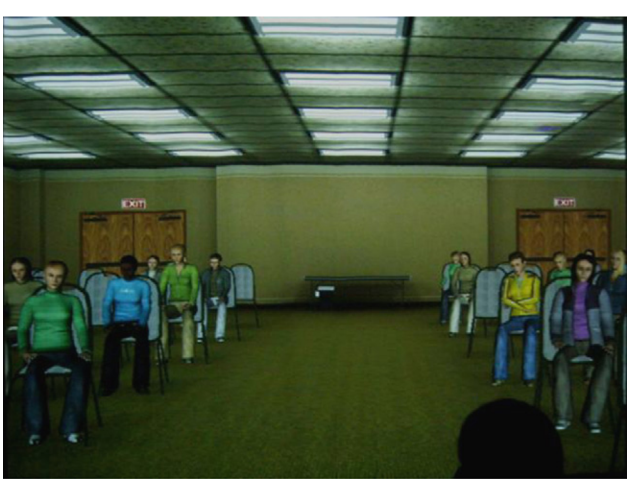

Figure 1 Virtual audience displayed during the speech.

The study by Kirschbaum et al. (1993) showed that, on average, cortisol levels went from 5.3 to 8.2 nmol/L between the time immediately preceding the TSST with a real audience to the time immediately following it. In a virtual environment, Kelly et al. (2007) demonstrated that this type of stressor (i.e., a public speech plus a test of arithmetic) also produces a significant increase in salivary cortisol from the time prior to the test to the time following it, although the increase is not as sizeable as with a real audience. In this latter study, the magnitude of the increase in cortisol level was not reported, but the graphs in the study showed a cortisol increase from 0.38 μg/dL to 0.45 μg/dL as a function of the exposure to the stressors.

Sense of presence: We used the *Igroup Presence Questionnaire* (*IPQ*; Schubert et al., 2001). The IPQ is a scale used to measure the sense of presence experienced in a virtual environment. The questionnaire was used to rule out the possibility that potential differences between good and poor decision makers could be attributable to variations in the sense of presence experienced by participants within the virtual environment. IPQ responses range from -3 (=totally disagree) to +3 (=totally agree). The IPQ consists of a global scale and the following three subscales: spatial presence (i.e., the sense of being physically present in the virtual environment), involvement (i.e., the attention devoted to the virtual environment and the degree of involvement experienced), and experienced realism (i.e., the subjective experience of realism in the virtual environment). Reliability data are not yet available for the Spanish population.

2.3. Procedure

The study was scheduled around the diurnal cortisol curve, which shows that levels of salivary cortisol are more stable between 1500 and 1800 h in the Spanish population (Santos-Ruiz et al., 2010).

The study was carried out in two phases:

1. Phase 1: Assessment of emotional status and decision-making skills.
2. Phase 2: Exposure to the stressing situation.

2.3.1. Phase 1: Assessment of emotional status and decision-making skills

We provided general information about the study to the participants at the beginning of the study. Subsequently,

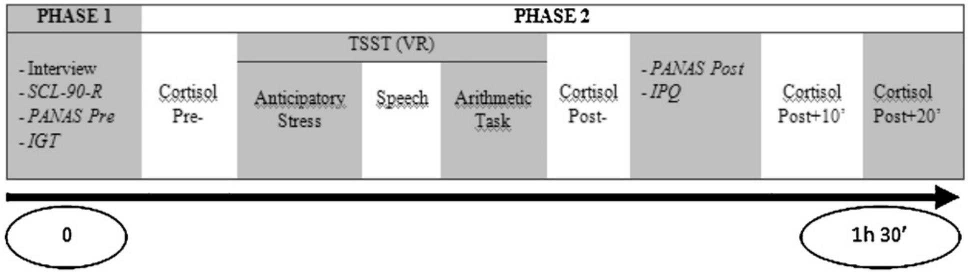

Figure 2 Procedure used in the study: *Trier Social Stress Test* adapted for Virtual Reality. *Note*: Phase 1: Assessment of mood and decision-making skills; phase 2: Stress exposure; *SCL-90-R = Symptom Checklist SCL-90-R; IGT = Iowa Gambling Task; IPQ = Presence Questionnaire*; TSST (VR) = *Trier Social Stress Test adapted to Virtual Reality*; Cortisol Pre = cortisol pre-exposure; Cortisol Post = -cortisol post-exposure; Cortisol Post+10 min = cortisol at 10 min after exposure; Cortisol Post+20 min = cortisol at 20 min after exposure.

they signed informed consent forms. We then conducted an assessment, where the following instruments were consecutively applied: a semi-structured interview, the *Symptom Checklist SCL-90-R*, the *PANAS-State-Pre* and the *Iowa Gambling Task*.

2.3.2. Phase 2: Exposure to a stressful situation

Following the end of Phase 1, participants were exposed to a stressful situation. First, we collected the first salivary cortisol sample (*cortisol pre-exposure*) and, after that, explained the TSST (VR), and began the stress tasks (i.e., anticipatory stress, a situation of public speaking, and arithmetic task). Once we collected the post-exposure cortisol sample, participants completed two questionnaires: the *PANAS-state-Post* and the *Igroup Presence Questionnaire*. The last two salivary cortisol samples were collected 10 and 20 min after the end of the task. Subsequently, participants were told that their talks had not been recorded and that the aim of the study was not to analyze speech and arithmetic performance but to generate a stress response for later analysis. A diagram of the protocol of the TSST (VR) is shown in Fig. 2.

2.4. Statistical analysis

Performance on the IGT was used as the independent variable. Subjects were divided into two groups according to whether their total score on the IGT was positive (good decision-makers) or negative (poor decision-makers). *t*-Tests for independent samples were conducted to measure performance differences between good and poor decision-makers in terms of those psychological variables indexed by the *SCL-90-R*, *PANAS state* (pre and post), and *IPQ*. Step-wise regression analyses (age and years of education), and ANOVAs (tobacco and phase of the menstrual cycle), were carried out to test whether there was a relationship between salivary cortisol (*pre-exposure*, *post-exposure*, *post+10 min*, and *post+20 min cortisol samples*) and any of these potentially confounding variables. Finally, we conducted a two-way ANOVA (time x decision-making performance) to compare reactions of the HPA-axis between groups of poor versus good decision makers, and *t*-tests for independent samples to evaluate differences in HPA axis activation between subjects with good and poor decision-making skills. Bonferroni adjustments were not applied following the recommendations of Schulz and Grimes (2005) about the use of that adjustment in biomedical research. Additionally, for the within-group analysis, we used the general linear model with repeated measures and the Bonferroni correction to test the activation of the HPA axis in each group. We also carried out an analysis of potential outliers with respect to the various cortisol measures, and there were no outliers for pre-exposure cortisol levels. Two outliers were found, one in each of the IGT groups, for post-exposure and post+10 min cortisol levels, and three outliers appeared when post+20 - min cortisol levels were analyzed. Once outliers were removed, differences remained significant for pre-exposure cortisol levels, but they disappeared for post+20 min cortisol levels.

3. Results

3.1. Sample description

First, we separated the sample into two groups: good (n = 24) and poor (n = 16) decision-makers. Subjects whose total IGT score was greater than zero comprised the good decision-making group, as positive scores reflected a predominance of advantageous selections (Bechara, 2004). The poor decision-making group was made up of individuals who received negative total IGT scores.

The socio-demographic, psychological, and decision-making data of both groups are shown in Table 1.

Several *t*-tests for independent samples were performed to determine whether there were significant differences between subjects with good and poor decision-making skills in terms of the psychological variables included in the assessment (i.e., psychopathological symptoms from the *Symptom Checklist SCL-90-R*, positive and negative affect of *PANAS pre- and post-exposure*, and scales form the *Igroup Presence Questionnaire*). Two subjects were excluded, one from each group, because they obtained clinical scores (>70) in depression and anxiety variables of the SCL-90-R.

Results of these analyses were statistically significant only for the *Psychoticism* subscale of the *SCL-90-R* (t = 2.52, $p < 0.02$), with higher scores in the poor decision-making group (57.15) compared to the good decision-making group (47.10). Nevertheless, both scores were within the normal range.

Table 1 Means and standard deviations of socio-demographic data, psychological variables, and performance on the *Iowa Gambling Task* in both groups.

	Good IGT performance, $n = 23$	Poor IGT performance, $n = 15$
Age (years)	29.52 ± 12.03	25.36 ± 7.75
Education (years)	13.89 ± 1.99	14.36 ± 1.57
Symptom Checklist SCL-90-R		
Somatization	51.52 ± 5.36	55.42 ± 8.32
Obsessions and compulsions	57.94 ± 8.51	61.63 ± 8.42
Interpersonal sensitivity	54.57 ± 9.10	61.05 ± 10.67
Depression	49.89 ± 7.80	54.84 ± 10.69
Anxiety	51.52 ± 9.27	54.84 ± 10.69
Hostility	49.63 ± 7.56	51.94 ± 9.88
Phobic anxiety	45.00 ± 11.27	42.57 ± 9.84
Paranoia	54.05 ± 9.98	56.05 ± 10.16
Psychoticism	47.10 ± 12.99	57.15 ± 11.52*
Global severity index	48.57 ± 10.29	56.47 ± 12.13
Total positive symptoms	53.94 ± 9.89	60.89 ± 11.65
Positive symptomatic malaise	46.63 ± 7.53	49.84 ± 6.44
PANAS-State-Pre		
Positive	26.84 ± 5.96	25.84 ± 5.67
Negative	22.00 ± 6.88	21.78 ± 6.97
PANAS-State-Post		
Positive	25.89 ± 5.66	23.05 ± 6.53
Negative	18.21 ± 5.23	17.78 ± 6.83
Igroup Presence Questionnaire		
General	0.47 ± 1.74	−0.52 ± 1.67
Spatial presence	1.31 ± 3.75	−0.15 ± 3.77
Involvement	2.47 ± 4.70	1.00 ± 4.86
Experienced realism	−2.68 ± 3.23	−3.73 ± 2.68
Iowa Gambling Task		
Performance block 1	0.10 ± 3.97	−3.57 ± 2.71*
Performance block 2	1.15 ± 4.07	−2.31 ± 3.41*
Performance block 3	3.78 ± 4.21	−3.47 ± 4.20*
Performance block 4	5.89 ± 6.58	−6.52 ± 4.98*
Performance block 5	7.36 ± 7.86	−3.68 ± 6.36*
Total performance	18.31 ± 18.26	−19.57 ± 12.39*

* $p \leq 0.05$ = statistically significant differences between both groups.

Post hoc bivariate correlations revealed a moderate correlation between Psychoticism and total IGT score ($r = -0.575$; $p < 0.01$) but no association with any of the measures of cortisol level.

With respect to the proportion of responders and non-responders to the stress test, Kirschbaum et al. (1993) reported that 70% of subjects responded to the TSST. In our study, responders and non-responders were uniformly distributed across groups of good and poor decision-makers (73% and 68% of responders in each group, respectively).

3.2. Cortisol and confounding variables

Neither use of tobacco [pre-exposure cortisol: $F(1,36) = 3.36$, $p = 0.08$; post-exposure cortisol: $F(1,36) = 0.96$, $p = 0.33$; post+10 min: $F(1,36) = 1.26$, $p = 0.26$; post+20 min: $F(1,36) = 2.01$, $p = 0.16$] nor phase of the menstrual cycle [pre-exposure cortisol: $F(3,34) = 0.97$, $p = 0.41$; post-exposure cortisol: $F(3,34) = 0.95$, $p = 0.42$; post+10 min: $F(3,34) = 0.53$, $p = 0.66$; post+20 min: $F(3,34) = 0.42$, $p = 0.73$] predicted salivary cortisol levels. Similarly, age did not predict salivary cortisol levels, but level of education significantly predicted cortisol pre-exposure levels ($r^2 = 0.081$; $p < 0.05$), such that higher levels of education were correlated with higher levels of cortisol.

3.3. Differences between good and poor IGT performance groups in the activation of the HPA axis

Regarding the between group analysis, no interaction effect was found between good and poor performance in the IGT and collection times ($F(1,36) = 1.06$; $p = 0.34$), although collection time was significant as a main effect ($F(1,36) = 11.49$; $p < 0.01$). Results showed that there were significant differences between the two groups in pre-exposure cortisol levels ($t = -2.18$, $p < 0.04$), with the poor performance group having higher cortisol secretion levels (2.8 nmol/L vs. 4.09 nmol/L, good and poor performance groups, respectively). There were also differences between the two groups in cortisol post+20 min ($t = -2.11$, $p < 0.04$), with the poor performance group once again showing higher cortisol

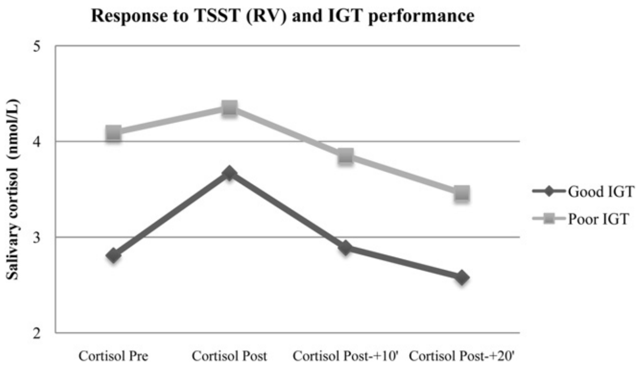

Figure 3 Salivary cortisol levels in response to the TSST (VR) after performance of the *Iowa Gambling Task*.

secretion levels (2.58 nmol/L vs. 3.46 nmol/L, good and poor performance groups, respectively). No differences were found between the two groups at the other two collection times (post-exposure and post+10 min). In general, the group with poor performance on the IGT had higher levels of salivary cortisol than the group with good performance over the four collection times studied. This effect is shown in Fig. 3.

Both good ($F(1,54) = 6.01$.; $p < 0.01$) and poor ($F(1,54) = 6.73$; $p < 0.01$) decision-makers showed differences in cortisol level across experimental time. Good decision-makers differed in cortisol levels between post-exposure and post+10 min ($p = 0.02$), and post+20 ($p = 0.02$). Poor decision-makers, on the other hand, varied in their cortisol levels between pre-exposure and post+20 - min ($p = 0.01$), and between post-exposure and post+20 min ($p < 0.01$) (see Table 2).

4. Discussion

The main findings of this study demonstrate significant differences between women with good and poor decision-making skills in their level of salivary cortisol prior to exposure to a psychosocial stressor presented in a virtual environment. Results also showed that the group with poor decision-making skills (i.e., poor IGT performance) presented higher levels of salivary cortisol than the group with good performance at all times of salivary cortisol collection (pre-exposure, post-exposure, post+10 min, and post+20 min), with differences being statistically significant at the beginning of exposure. However, these initial findings need to be considered preliminary, as this is the first study to consider decision-making as a skill in confronting stressful situations.

These results of cortisol levels are in contrast with those obtained by Van Honk et al. (2003), a discrepancy that could be attributed to differences in aims and methodology between the two studies. Van Honk et al. (2003) investigated levels of cortisol in stressed subjects during IGT performance, without differentiating good and poor performance on the IGT before participants were exposed to the stressful situation.

Hypothetically, in the study by Van Honk et al. (2003) could have interfered with IGT performance. de Visser et al. (2010) has also shown that high or low levels of state anxiety hinder IGT performance. In contrast, our findings suggest that individuals that are capable of making good decisions confront stressful situations with lower levels of cortisol.

In a closely related study, van den Bos et al. (2009) demonstrated that moderately increased levels of salivary cortisol in response to a psychosocial stressor improved subsequent performance in the Iowa Gambling Task in women (van den Bos et al., 2009). In this study, we found that, following IGT performance and before the beginning of the stress task, differences were already present between good and poor decision-makers. This difference was sustained throughout the time period tested, with the poor IGT performance group consistently showing higher cortisol levels than the good IGT performance group. Thus, once again it is not possible to make a direct comparison of our results with those of van den Bos et al. (2009), since in this latter study only the third cortisol measurement in the control group is equivalent to our first cortisol measurement (i.e., pre-exposure cortisol). Presumably, in the study by van den Bos et al. (2009), those participants that did not respond to the TSST were not stressed, as they showed the same low cortisol levels as the subjects that did not engage in the TSST. It is not possible, however, to determine whether a lack of response in the TSST could be due to an improved ability to deal with stressful situations. In our case, we were able to show a preliminary relationship between greater ability to solve problems and better stress-management skills, a relationship that appears to be associated with lower cortisol levels in facing the stressful situation.

An alternative explanation for our data incorporates the uncertainty factor as a mediating variable. Coates and Herbert (2008) examined testosterone and cortisol levels in

Table 2 Within-subject analysis of cortisol levels in saliva (nmol/L) in subjects with good and poor performance in the Iowa Gambling Task (IGT).

Group	Cortisol pre-exposure Mean ± SD (range)	Cortisol post-exposure Mean ± SD (range)	T_0 p	Cortisol post+10 min Mean ± SD (range)	T_1 p	Cortisol post+20 min Mean ± SD (range)	T_2 p
Good IGT performance	2.81 ± 1.54	3.67 ± 2.65	0.26	2.89 ± 1.89	1.00	2.58 (1.54)	1.00
	(0.64–5.52)	(0.50–11.04)		(0.50–8.28)		(0.50–5.52)	
Poor IGT performance	4.09 ± 2.00	4.35 ± 2.59	1.00	3.85 ± 2.44	1.00	3.46 ± 1.54	0.17
	(1.19–8.31)	(1.39–11.03)		(1.44–11.03)		(1.27–8.28)	

Note: T_0 = comparison of pre- and post-exposure cortisol; T_1 = comparison of pre- and 10 min post-exposure cortisol; T_2 = comparison of pre- and 20 min post-exposure cortisol.

financial traders while they were making real financial decisions. They found that cortisol levels were more closely related to uncertainty, measured in terms of market volatility, than to losses per se. Drawing a parallel between Coates and Herbert's (2008) data and our own, we could conclude that good decision makers might experience less uncertainty when making decisions and, consequently, show lower levels of salivary cortisol in decision-making tasks. Therefore, we could argue that an individual who is capable of making suitable decisions in uncertain situations would show lower levels of cortisol in stressful situations. After all, stressful situations entail uncertainty in addition to uncontrollability, and could well overwhelm the individual's resources.

An adaptive stress response is characterized by the activation of the HPA axis and an associated initial increase in cortisol level, followed by a subsequent recovery from stress and return to baseline levels of cortisol. Our data show that less able decision-makers did not show a reactivity to stress, despite their consistently higher cortisol levels with respect to the more able decision-making women. In contrast, this latter group had lower levels of cortisol at all collection times, paired with enhanced cortisol reactivity. Group differences in pre-exposure salivary cortisol could be explained by the failure to learn IGT contingencies that was evidenced by poor decision-makers. This is an unlikely explanation, however, since the amount of time required to complete the IGT is too short to produce significant changes in cortisol level. Alternatively, group differences in cortisol level could be attributed to psychological variables measured by the questionnaires. Indeed, de Visser et al. (2010) found that trait anxiety was inversely related to IGT performance. However, neither trait anxiety nor IGT performance were related to cortisol level in female subjects. In our study, the single psychological variable that was related to IGT performance was Psychoticism.

Emotional status also appears to affect performance on the IGT, so that people with high levels of trait anxiety (de Visser et al., 2010) or major depressive disorder (Cella et al., 2010) tend to underperform on the IGT. In the present study, however, there were no significant differences between good and poor decision-makers on any psychological variable with the exception of the Psychoticism subscale of the *SCL-90-R*. Poor decision-makers showed higher levels of Psychoticism, although their scores were still within the normal range of the scale. Psychoticism has been associated with impulsivity, sensation seeking, and disturbances of reward and punishment, all traits that have been related to poor performance on the IGT. Therefore, it is possible that Psychoticism may have acted as a mediating variable for IGT performance in the study's subjects. On the other hand, high cortisol levels have been associated with greater reward dependence (Joyce et al., 1994) and with high scores on the Psychoticism scale of the SCL-90 (Hess et al., 2007), although this last relationship was not found when using the Eysenck Personality Questionnaire (Schommer et al., 1999). These considerations lead us to conclude that Psychoticism could be mediating either IGT performance or pre-exposure cortisol levels. There was, however, a moderate correlation between Psychoticism and total IGT score, while there was no correlation with any of the cortisol measures.

Social support, self-efficacy, and coping style have all been studied as stress reducing variables (Cohen and Wills, 1985; McEwen, 2007; Taylor and Stanton, 2007). However, other variables such as decision-making ability have not been taken into account as determining factors in how people tackle stress. Although preliminary, our results suggest that women who face a stressful situation and have more resources available to them, show an adequate response to stress, perceiving it as a challenge instead of as a threat, and have lower levels of cortisol than women with less resources.

According to Lazarus and Folkman (1984), stress is defined as a particular relationship between individuals and their environment, where the environment is evaluated as being threatening or overwhelming to their resources and thus endangering of their welfare. Along these lines, these authors argue that when individuals assess a situation as threatening (primary appraisal), they then analyze the resources they have available to deal with it (secondary appraisal). Subsequently, people make a reassessment, where changes are introduced based on the new information about the environment or about their own coping resources. These evaluations interact, resulting in the perception of stress and the consequent physical and emotional response to it. Therefore, decision-making would be one of the resources available to the individual in coping with a situation perceived as stressful or overwhelming (secondary assessment); a resource that would lead to perceiving the situation as a challenge rather than as a threat. We argue that in the assessments by Lazarus and Folkman (1984), where individuals make an assessment of both the threatening situation and their own coping resources, one such resource would be decision-making, which is defined as the ability to select the most adaptive course of action for the organism among all possible alternatives (Bechara et al., 2000). Decision-making would thus favor a decreased perception of stress and result in a reduced reaction to it, which would be reflected in lower secretion of salivary cortisol. Our study has some limitations stemming from the nature of the sample. In the group with good IGT performance was observed a higher trend toward significance than the poor IGT performance between the pre-exposure and post-exposure cortisol levels; this trend could have been statistically significant with a large sample. We purposely selected only women for our study, as they had been shown to be good decision-makers under moderate levels of stress. We anticipated that women with high levels of performance on the IGT would face a psychosocial stress task better than less able decision-makers. Still, our data cannot be easily generalized to the population at large, since they only include women. Moreover, our sample is modest and perhaps we could have reached stronger and more general conclusions, had we included a wider range of ages and education levels. Thus, future studies should aim to increase the sample size and to extend the study to both sexes, so as to be able to contrast men and women in their IGT performance and subsequent responses to psychosocial stressors.

With respect to the assessment of the HPA axis, it should be noted that a basal measure of salivary cortisol prior to engaging in the IGT might provide information about whether IGT performance in itself leads to an increase in salivary cortisol. These data are lacking in the extant literature, but we would anticipate no relationship between IGT performance and cortisol level because cortisol starts to increase only 20 min after the introduction of a stressor and the IGT is only 10-min long. Therefore, if cortisol levels were increased after IGT performance, it could not be attributed to the IGT alone. Still, had we acquired a cortisol sample prior to engaging in the IGT, we could have established a more direct comparison with the results from the study by Van Honk et al. (2003).

Here, we investigated decision-making skills as a determining factor in women's ability to face psychosocial stress. Similarly, it would be interesting to explore how other components of executive function, such as updating, cognitive flexibility, and change of criteria relate to perception of psychological stress.

In conclusion, decision-making is related to the stress response as measured by means of cortisol levels in saliva. Several studies have shown that responses to stress affect decision-making on the IGT in women and men, with the latter group being the most affected. Our study shows that women with poor performance on the IGT have higher levels of cortisol than better performing women throughout a psychosocial stress task presented in a virtual environment. Consequently, it would be useful to develop stress-management programs that include cognitive components such as decision-making and that may help reduce the consequences of stress.

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Conflicts of interest statement

All authors state no competing financial interests or potential conflict of interest relevant to this work.

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