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Emotional stress & decision-making: an emotional stressor significantly reduces loss aversion

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ABSTRACT

Stress influences loss aversion, the principle that losses loom larger than gains, although the nature of this relationship is unclear. Studies show that stress reduces loss aversion; however, stress response has been only studied by means of physiological measures, but the stressor emotional impact remained unclear. Since emotions can modify stress response and increase the activity of the loss aversion neural substrates, it could be expected that an emotional stressor may produce the opposite effect, i.e. loss aversion increase. 69 participants were divided into experimental and control group. The first one was exposed to emotional stress through a 5-minutes video, and control group viewed a match-length distractor video. Physiological stress response was assessed by means of electrodermal activity (EDA), and both perceived stress, and negative affect (i.e. psychological stress response) were registered through questionnaires. Both groups performed a mixed gamble task, which allowed the extraction of loss aversion through a Bayesian-computational model. During and after video, experimental group had higher electrodermal activity, perceived stress, and negative affect than controls, suggesting that emotional stress induction was effective. However, rather than increasing, loss aversion of stressed participants was lower. These results constitute a new evidence of emotional stress influencing loss aversion and highlight that stress, regardless of its emotional impact, can reduce this phenomenon. These results should be considered when predicting risky decisions.

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Stress; decision-making; loss aversion; emotion; emotional stress computational model

Introduction

One of the most accepted phenomena in the social sciences is loss aversion (Gal & Rucker, 2018), the principle that losses loom larger than gains (Kahneman & Tversky, 1979); in other words, "losses are experienced with greater psychological impact" (Gal & Rucker, 2018, p. 497) in comparison to proportional gains, and our judgments and decisions are highly shaped by them. Loss aversion is often considered a fundamental and generalizable principle (Gal & Rucker, 2018), or even a stable behavioral trait (Hadlaczky et al., 2018). However, the current position is that a more contextualized view of this phenomenon would be advisable (Gal & Rucker, 2018; Mrkva et al., 2020). In last years, efforts have been made to identify which factors modulate loss aversion expression, and with it, our decisions. Since many decisions are made under stress, this is one of the most studied factors and the focus of our study.

Stress can significantly influence decision-making (Starcke & Brand, 2012), and specifically loss aversion (Margittai et al., 2018), although the directionality remains unclear. In fact, currently two opposing hypotheses coexist. The "salience-of-losses" hypothesis proposes that acute stress reallocates resources in the brain, favoring the activation of the salience-network (Metz et al., 2020). This network contains regions such as the amygdala, which also constitutes one of the main neural bases of loss aversion (Molins & Serrano, 2019). Hence, it is obvious to expect that stress would enhance loss aversion (Metz et al., 2020). However, the most accepted is the "alignment" hypothesis (Metz et al., 2020), supported by the STARS model (Stress Triggers Additional Reward Salience) (Mather & Lighthall, 2012). It is derived by the findings that in rats, acute stress increases nucleus accumbens extracellular levels of dopamine and firing rates in their midbrain dopamine neurons (Anstrom & Woodward, 2005; Kalivas & Duffy, 1995). In addition, positron emission tomography (PET) studies suggested similar results in humans, where stress enhances striatal dopamine (Scott et al., 2006; Wood et al., 2007), pointing toward thatthese regions may play a key role in representing reward value (Mather & Lighthall, 2012; Rangel et al., 2008). So, with their STARS model, Mather and Lighthall (2012, p. 2) proposed that "stress enhances reward salience via modulation of the dopamine system, resulting in reward-biased learning"; i.e. stress could bias in weighing positive over negative aspects during the decision-making process. Therefore, the alignment hypothesis suggests that stress would balance the susceptibility to gains and losses, the former seeming more attractive, thereby reducing loss aversion (Metz et al., 2020).

Although seemingly contradictory, both hypotheses may not be mutually exclusive and may reflect responses to

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different stressors. Depending on their nature, stressors can vary in the expression and magnitude of their physiological and psychological responses (Hidalgo et al., 2019). For example, it is known that physical or systemic stressors produce a robust Sympathetic Nervous System (SNS) response, whereas psychosocial stressors elicit the activation of both the SNS and the Hypothalamic-Pituitary-Adrenal (HPA) axis (Hidalgo et al., 2019). Thus, it is important not to study stress in the singular, but how different stressors impact loss aversion. When studying stress and loss aversion, the direct manipulation of catecholamines or cortisol is the most common practice (e.g. Margittai et al., 2018; Metz et al., 2020). However, only a few systemic or physical stressors, such as oxygen-depleted environment (hypoxia) (Pighin et al., 2014) or vigorous physical exercise (Molins & Serrano, 2020) have also been tested. When using these types of stressors, a reduction in loss aversion was observed. However, although these stressors produced physiological responses, they did not have an impact on an emotional level. Neither physical exercise nor hypoxia changed the emotional state (Molins & Serrano, 2020; Pighin et al., 2014). In fact, hypoxia acted unconsciously, without the participants being aware of this context (Pighin et al., 2014). Some studies even ignored measuring whether the stressor had an impact beyond on our physiology (e.g. Sokol-Hessner et al., 2016). Yet, an stressor can produce different biological and behavioral responses depending on its emotional impact (Compton et al., 2013; Goldfarb et al., 2019). Thus, the increase of the negative affect during an emotional stressor exposure was positively associated with the salience-network interconnectivity and the noradrenergic activity (Hermans et al., 2011). In parallel, both norepinephrine brain levels (Sokol-Hessner & Rutledge, 2019), and the activity of the regions that compose the salience-network (Molins & Serrano, 2019) have been closely linked to behavioral loss aversion.

Therefore, we hypothesized that an emotional stressor would produce the opposite effect to that found with other non-emotional stressors, leading to increased loss aversion. In fact, as Pabst et al. (2013) found, an stressor that increased negative affect also led to less risk-taking during decision-making. Nevertheless, to our knowledge, it has never been directly explored whether emotional stress could increase loss aversion. Thus, by exposing an experimental group to an emotional stressor, it is expected that this group would show greater physiological activation and more negative emotional state than the control group. Moreover, after the stressor, both groups would differ in loss aversion. This work aimed to shed light on the question of whether emotional stress would support the salience-of-losses hypothesis or, on the contrary, it will reduce loss aversion regardless of its emotional impact.

Material and methods

Participants

Based on the effect size found in a previous work on stress and loss aversion (Molins & Serrano, 2020), an a priori power analysis using G*Power indicated a requisite of 48 participants ($\eta^2_p = .18$, power = 80%, $\alpha = .05$) to perform an ANOVA and compare loss aversion between groups (emotional stress vs control group). We oversampled 22 participants to account for possible exclusions. 70 participants were recruited. One was eliminated for drug consumption. A total of 69 participants (age: $M = 22.33$, $SD = 2.29$; women: $N = 52$, 75.4%) were finally included. They met the following inclusion criteria: not having cardiovascular, endocrine, neurological or psychiatric diseases; not consuming more than 5 cigarettes a day; not consuming drugs habitually; not doing more than 10 hours of exercise per week and not having experienced a highly stressful event in the last month. In addition, participants were asked to not perform extenuating exercise or to take drugs or alcohol in the last 24 h, and to not smoke or take stimulant drinks in the 2 h before the experimental session. Participants were randomly distributed into two groups, experimental ($N = 37$) and control ($N = 32$).

Procedure

This study was approved by the Ethics Research Committee of the University of Valencia in accordance with the ethical standards of the 1969 Declaration of Helsinki. Experimental session was carried out between 15:00 pm and 20:00 pm and lasted approximately an hour. Participants were asked to wait in the University hall and were accompanied in an elevator to the laboratory, avoiding the use of stairs, to prevent any disruption in their physiological state. The general procedure was explained, and informed consent was signed. Participants were connected to the electrodermal activity (EDA) sensor and had 10 minutes of rest as habituation. Then, experimental group was exposed to emotional stress (stressful video), while the control group was submitted to a distractor (non-stressful video). Before and after the emotional stressor/distractor, participants were evaluated for positive and negative mood with the Positive and Negative Affect registry, PANAS (Watson et al., 1988) and were asked about the subjective stress they felt. After that, both groups performed an economical decision-making task to measure loss aversion.

Emotional stressor

Following Shields et al. (2016), emotional stress was induced through a video with unpleasant content: a 2-day-old crying infant being circumcised. This video had a length of 5 minutes. In contrast, participants in the control condition watched a length-matched, non-emotional video about how marbles are made. Both groups watched the video with headphones to avoid any possible distraction. To prove that the emotional stress manipulation was effective, we also obtained EDA of each group before and during the video, as well as during the economical task. In addition, before and after the emotional stressor/distractor, participants were asked about the stress they felt (perceived stress), and positive and negative mood was assessed with PANAS.

Electrodermal activity (EDA)

EDA is one of the most used physiological signals for detecting stress (Liu & Du, 2018). It has been consistently demonstrated that when the stress induction is effective, it is accompanied by the pronounced increase in EDA (Reinhardt et al., 2012). EDA was recorded and analyzed following recommendations for electrodermal measurements (Boucsein et al., 2012). Two electrodes were placed on non-dominant hand (index and middle finger distal phalanges), using isotonic gel to amplify the signal. BIOPAC, with EDA-100C transducer, 1000 Hz sampling frequency and AcqKnowledge software were also used. The electrodermal registry was resampled with the linear interpolation method at 250 Hz and filtered by smoothing factor with a median value of 5. The average of skin conductance level (SCL) in microsiemens (μS) was extracted from three different periods of 5 minute: (1) baseline (last five minutes of the habituation period), (2) stressor/distractor and (3) economical task.

Perceived stress

Before and after the video (stressor/distractor), participants were asked about the subjective stress they felt. This question, designed *ad hoc* for the study, asked: "How much stress do you feel right now?" The answer was given on a Likert scale where 0 is "no stress," and 10 is "a lot of stress."

Positive and negative affect registry (PANAS)

PANAS (Watson et al., 1988) is a 20 Likert-type items scale (from 1, more than usual, to 4, much less than usual) that evaluates positive and negative mood. Each dimension contains 10 items that must be added. The higher the score, the more positive or negative the mood. PANAS was evaluated before and after the stressor/distractor.

Mixed gamble task (MGT)

Both groups performed a short version of MGT (Chandrasekhar Pammi et al., 2015). Each trial entailed a bet with one of the combinations randomly extracted from an 8×8 losses and gains matrix, until the 64 combinations were completed (see Figure 1). Following gamble ranges used by Chandrasekhar Pammi et al. (2015), as well as by Tom et al. (2007) in the original task, gains could range from €100 to €380 in €40 increments, and losses from €50 to €190 in €20 increments. In each trial there was a 50% chance of gaining and 50% chance of losing. Participants had to decide whether to accept or reject the bet. They were instructed that €200 was their initial amount and each bet had to be encountered with that reference. Betting results were not presented immediately, however, they had to choose carefully in each trial since, at the end, four bets would be randomly picked and played heads or tails, affecting the initial amount. Loss aversion parameter was extracted through the Prospect-Theory computational model (Sokol-Hessner et al., 2009).

Prospect-Theory computational model

The Prospect-Theory model (Sokol-Hessner et al., 2009) follows the classical approach of the Prospect Theory (Kahneman & Tversky, 1979) where a bet would be accepted or rejected as a function of its expected utility. Following the original paper of Sokol-Hessner et al. (2009), the utility for gains was estimated through the equation $u(x^{gain}) = x^{\rho}$, and the utility for losses through the equation $u(x^{loss}) = -\lambda \times (-x)^{\rho}$. Finally, the probability of accepting a gamble was estimated through the SoftMax function, $P_{(Accept)} = 1/(1 + e^{-\mu(U(Accept)-U(Reject))})$. As can be seen, three parameters are derived from this model: λ (loss aversion coefficient), ρ (the curvature of the utility function or risk aversion), and μ (the logit parameter). However, as we were interested in specifically addressing loss aversion, following Ahn et al. (2017), we set the risk aversion parameter to 1 and using the Maximum likelihood estimation method, λ and μ were obtained. $\lambda = 1$ indicates that gains and losses were valued equally, however, when $\lambda > 1$, losses were overvalued relative to gains (loss aversion). The logit parameter (μ) represents the amount of "randomness" in the subject's choices or, in other words, consistency over choices. Higher levels of the parameter would represent that participants rely more on "rule-based" decision-making (Sokol-Hessner et al., 2009).

These parameters were estimated for each participant through Hierarchical Bayesian Analyses (HBA; see Anh, 2008 for more details), performed with the hBayesDM package (Ahn et al., 2017) for the R software. The hBayesDM uses Stan 2.1.1 (Stan Development Team, 2017) with the Hamiltonian Monte Carlo (HMC) algorithm as MCMC for sampling the posterior distributions. Following Alacreu-Crespo et al. (2020), we drawn 40.000 samples, after burn-in of 23.333 samples, in three different chains (in sum, a total of 120.000 samples and 70.000 burn-in). The Gelman-Rubin test (Gelman & Rubin, 1992) was used to study if the chains converged ($\hat{R}$) to the target distribution. $\hat{R}$ values were 1, which means that convergence was achieved. In addition, to confirm this convergence, the MCMC chains were visually inspected.

Statistical analyses

Outliers were detected with the 2.5 standard deviations method and Mahalanobis distance for repeatedly measured variables (e.g. electrodermal activity). Kolmogorov-Smirnoff with Lilliefors correction was used to check normality. Post-video negative affect had to be normalized with log10. The pre-video measure was also transformed to allow the comparison. Analyses included repeated-measures ANOVAs, with the group (experimental vs control) as a between-participants factor, to test the emotional stress induction effectiveness, both at the physiological (EDA) and at the subjective level (stress level, positive affect and negative affect). In addition, loss aversion and the logit parameter were compared between groups through one-way ANOVA. The α significance level was set at .05. Partial eta square (η^2_p) symbolizes the effect size and β-1 (power) represents power. All analyses

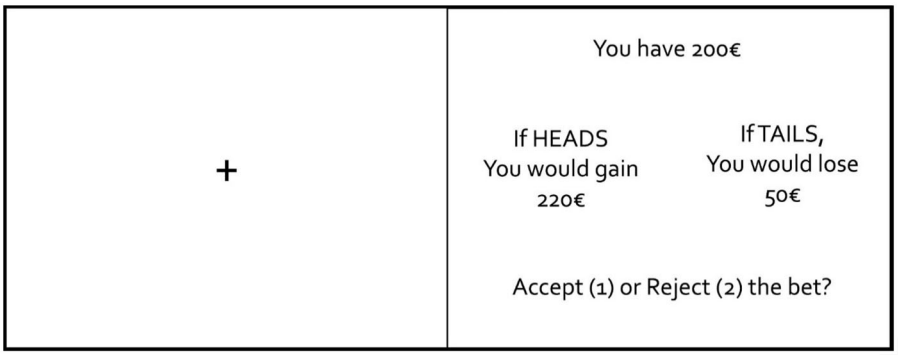

Figure 1. A Mixed gamble task trial. Each of the 64 trials in the task consists of (A) 5 seconds of fixation point and (B) a bet. The bet offers a possible gain and a possible loss, both with a probability of 50% (heads or tails). The participant must decide whether to play or reject that bet.

were performed with IBM SPSS Statistics 25, except for the extraction of λ which was done with R.

Results

Preliminary analyses

Experimental and control groups were homogeneously distributed with no significant differences in age (experimental: $M = 22.27$, $SD = 2.21$; control: $M = 22.41$, $SD = 2.42$), $p = .80$; nor in BMI (experimental: $M = 23.72$, $SD = 3.42$; control: $M = 23.88$, $SD = 2.44$), $p = .92$. Moreover, there were more women than men, but the chi-square test revealed that both women (experimental: 73%; control: 78.1%), $p = .78$; and men (experimental: 27%; control: 21.9%), $p = .47$; maintained similar proportions in both groups.

Emotional stress induction

Physiological stress

A repeated-measures ANOVA including group (experimental vs control) as a between-factor was performed to test whether the emotional stress induction was effective at the physiological level. Analyses revealed a significant main effect of the moment (EDA-baseline vs. EDA-video vs. EDA-MGT), $F(2, 66) = 12.44$, $p < .001$, $\eta^2_p = .29$; and a significant group-$\times$moment interaction, $F(2, 66) = 7.39$, $p < .001$, $\eta^2_p = .19$, which indicates that EDA evolution was different for both groups (see Figure 2). We explored this effect further.

When contrasting by groups, the experimental group's EDA was significantly higher during the video than during the baseline, $F(1, 36) = 24.38$, $p < .001$, $\eta^2_p = .43$. This level was significantly reduced during MGT, $F(1, 36) = 10.09$, $p = .003$, $\eta^2_p = .23$; but even so this level remained higher than the baseline, $F(1, 36) = 14.08$, $p = .001$, $\eta^2_p = .31$. On the other hand, the control group did not show differences between any of the EDA measurement levels (p's $> .05$). All means can be consulted in Table 1. Finally, intergroup analysis controlling for basal levels (see Table 1) revealed that, although both groups did not differ in their EDA at the baseline, the experimental group showed significantly higher activity than the control group during video and MGT.

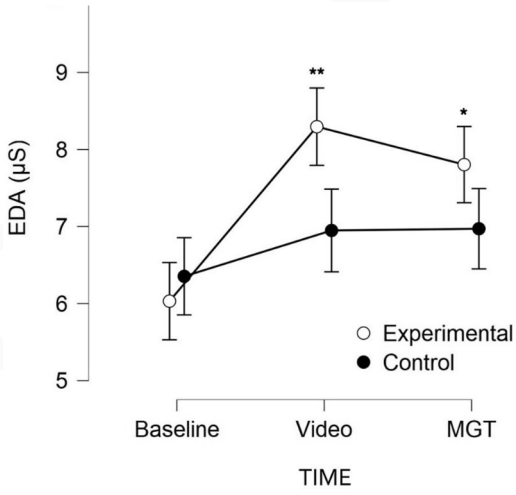

Figure 2. Electrodermal activity during baseline, video, and Mixed Gamble Task (MGT) by group. Experimental and control group significantly differed in their EDA level during the video and the MGT. *Significant contrast at the .05 level; **Significant contrast at the .01 level; $M \pm SE$.

Emotional stress

Regarding the emotional impact of the stress, repeated measures ANOVAs (including group as between-factor) were carried out to study differences pre- and post-video in the subjective-perceived stress and both the positive and the negative affect. Focusing on the perceived stress, it was found a significant group $\times$ moment interaction, $F(1, 67) = 70.06$, $p < .001$, $\eta^2_p = .52$. So, while the control group did not show differences between pre- ($M = 4.28$, $SD = 2.05$) and post-video ($M = 4.45$, $SD = 2.39$) levels, $F(1, 31) = 1.87$, $p = .12$, $\eta^2_p = .02$; the experimental group experienced an increase in perceived stress after being submitted to emotional stress ($M = 5.87$, $SD = 2.20$), compared to their pre-video level ($M = 3.41$, $SD = 2.31$), $F(1, 36) = 45.66$, $p < .001$, $\eta^2_p = .58$. In addition, both groups did not differ at their basal level, $F(1, 67) = 2.60$, $p = .112$, $\eta^2_p = .03$; but the perceived stress level of the experimental group was significantly higher than the level reported by the control group after video, $F(1, 67) = 39.29$, $p < .001$, $\eta^2_p = .38$.

On the other side, regarding positive affect assessed with PANAS, no pre-post changes or differences between groups were found (p's $> .05$). However, regarding negative affect, analyses also revealed a significant group $\times$ moment interaction, $F(1, 67) = 39.91$, $p < .001$, $\eta^2_p = .37$. Experimental

Table 1. Intergroup differences in electrodermal activity (EDA) during baseline, video, and Mixed Gamble Task (MGT).

	Experimental (N = 37)	Control (N = 32)	F	gl between	gl intra	p-value	η^2_p
EDA							
Baseline	M = 5.95 ± 2.81	M = 6.35 ± 2.78	0.34	1	67	.56	.005
Video	M = 8.29 ± 2.88	M = 6.94 ± 2.99	6.41	1	66	.01**	.09
MGT	M = 7.70 ± 2.79	M = 6.91 ± 2.87	4.80	1	66	.03*	.07

M: mean; ± SD; *Significant contrast at the .05 level; **Significant contrast at the .01 level.

(M = 21.68, SD = 4.32) and control (M = 21.59, SD = 2.78) group did not present differences pre-video, $F(1, 67) = .008$, $p = .93$, $\eta^2_p = .00$. Yet, the experimental group suffered a significant increase in negative affect after video (M = 25.11, SD = 6.24), $F(1, 36) = 21.34$, $p < .001$, $\eta^2_p = .37$; while the control group kept a similar level (M = 20.94, SD = 3.17), $F(1, 31) = .007$, $p = .97$, $\eta^2_p = .00$. Levels post-video significantly differed between groups, $F(1, 67) = 26.29$, $p < .001$, $\eta^2_p = .28$.

Loss aversion

First, it was checked if our sample was loss averse. Both control (M = 2.11, SD = .41) and experimental (M = 1.43, SD = .31) groups showed an average λ (loss aversion) value higher than 1, indicating that both groups expressed loss aversion during MGT. However, the group submitted to emotional stress (experimental group) manifested a significantly lower level of loss aversion than the control group, $F(1, 67) = 60.09$, $p < .001$, $\eta^2_p = .47$.

As we saw, applying the computational model also yielded a second parameter, the logit parameter (μ), which informs us about the consistency of participants' choices. Experimental group showed a higher logit parameter or consistency (M = 2.62, SD = .16) than the control group (M = 0.17, SD = .02), $F(1, 67) = 69.86$, $p < .001$, $\eta^2_p = .99$.

Discussion

The present study examined the impact of an emotional stressor on loss aversion (Kahneman & Tversky, 1979). Both physiological and psychological measures suggest that our manipulation worked: compared to the control group, participants exposed to emotional stress exhibited significant increase in electrodermal activity, but also in their perceived stress and negative affect. As expected, both groups differed in their loss aversion level post-stressor, which suggests that the emotional stress was influencing decision-making. However, despite its emotional impact, stressor was followed by a reduction in loss aversion rather than its increase. These results do not support the salience-of-losses hypothesis that was supposed to produce the emotional stress.

Loss aversion values usually described in the literature are between 2 and 2.5 (Duke et al., 2018; Kahneman & Tversky, 1979; Tom et al., 2007). This means that participants accepted gambles if gains were at least 2 times as large as losses. In this study, control participants exhibited loss aversion values compatible with previous evidence. Yet, participants submitted to emotional stress accepted gambles when gains were just 1.43 times as large as losses, which indicates that this group was less loss averse. In addition, the logit parameter of the experimental group indicates that they made more consistent choices. This would be in line with the lower loss aversion as this bias is an emotional phenomenon which, when manifested, tends to lead to more impulsive and less rule-driven decisions. According to the salience-of-losses hypothesis (Metz et al., 2020), since emotional stress enhances the salience-network activity (Hermans et al., 2011), it should exacerbate the impact of losses on our perception and, therefore, behavioral loss aversion should increase. Our results do not support this.

However, the neural bases of loss aversion highlights that this bias does not only depend on the losses processing. Neural loss aversion is composed by two systems: the appetitive and the aversive one (Molins & Serrano, 2019). Faced with a gamble, both systems work together, being activated at different intensities in response to potential gains and losses, respectively. Then, they would send signals to prefrontal regions where a cost-benefit analysis would be carried out, leading to a decision (Canessa et al., 2017; Croxson et al., 2009; Molins & Serrano, 2019).

Attending to the STARS model (Mather & Lighthall, 2012), as was introduced, stress would trigger additional reward salience by enhancing dopamine activity in dopaminergic reward-processing brain regions (Metz et al., 2020; Pighin et al., 2014), which would bias our decisions by weighing positive over negative aspects during the decision-making process; i.e. stress could be also enhancing the loss aversion appetitive-system activity. Therefore, emotional stress may increase the aversive-system activity, but this may not be enough to overcome the greater activity of the appetitive-system. Thus, the balance would shift toward the search for gains, leading to less behavioral loss aversion. This would be in line with our results and multiple previous evidence where stress also reduced loss aversion (Margittai et al., 2018; Molins & Serrano, 2020; Pighin et al., 2014). Moreover, all this seems to support the reward-alignment hypothesis (Metz et al., 2020), whereby stress may lead to a loss aversion decrease due to the reward-system activity increment. Nevertheless, since our study has no measures to explore brain activity, we cannot be sure that this hypothesis is being fulfilled. Our emotional stressor could be increasing the attractiveness of gains, but also reducing the aversion to losses, or both. For all these reasons, our explanation is only speculation and future research addressing complementary physiological and neural data is needed to shed light on these issues.

In fact, the absence of such measures is the main limitation of our work. EDA indicates that participants showed greater physiological arousal, but we did not explore the role of other factors such as catecholamines or cortisol. In addition, PANAS (Watson et al., 1988) was used to measure the

emotional impact. This questionnaire addresses whether the negative affect increased but does not provide information about the specific negative emotion felt. Different negative emotions (e.g. fear or anger) do not affect decision-making in the same way (Lerner et al., 2015). So, it will be necessary to explore whether different stressors that produce different emotions also lead to other results. In fact, because specific stress responses (e.g. an increase in cortisol or proinflammatory cytokines) was not assessed, and because people are bad at distinguishing or reporting stress from other forms of negative affects without training, we cannot confirm that the manipulation is producing a stress response. This may also be another reason why results differ from previous studies using validated experimental paradigms to induce stress, for example using the Trier Social Stress Test (Kirschbaum et al., 1993). Our paradigm is based in Shields et al. (2016) who found that the emotional video produces specific stress responses (i.e. pro-inflammatory cytokine reactivity), but this is not a validated paradigm and we did not include such measures to test this. Finally, previous data have reported age and sex differences when taking risk and facing stress (Hidalgo et al., 2019; van den Bos et al., 2009), but our study was conducted only with young people and the sample was predominantly female (none of them were taking contraceptives, but their ovulatory cycle period was not monitored), preventing a thorough exploration of these issues. Future research should also address the influence of these variables.

Nevertheless, this study constitutes a direct test of an emotional stress influencing loss aversion. Although mechanisms by which this happens need to be further explored, it seems that stress, regardless of its emotional impact, can reduce loss aversion. These results could be relevant and should be considered when predicting risky decisions. Emotional stress may push individuals to take less biased decisions, but also to be less cautious when deciding.

Disclosure statement

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