Psychoneuroendocrinology (2015) 54, 115—123

Available online at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/psyneuen

Stress pulls us apart: Anxiety leads to differences in competitive confidence under stress

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Received 11 November 2014; received in revised form 30 December 2014; accepted 21 January 2015

KEYWORDS
Stress;
Cortisol;
Anxiety;
Self-confidence;
Competition;
Economic inequality

Summary Social competition is a fundamental mechanism of evolution and plays a central role in structuring individual interactions and communities. Little is known about the factors that affect individuals' competitive success, particularly in humans. Key factors might include stress, a major evolutionary pressure that can affect the establishment of social hierarchies in animals, and individuals' trait anxiety, which largely determines susceptibility to stress and constitutes an important determinant of differences in competitive outcomes. Using an economic-choice experiment to assess competitive self-confidence in 229 human subjects we found that, whereas competitive self-confidence is unaffected by an individual's anxiety level in control conditions, exposure to the Trier social stress test for groups drives the behavior of individuals apart: low-anxiety individuals become overconfident, and high-anxiety individuals become underconfident. Cortisol responses to stress were found to relate to self-confidence, with the direction of the effects depending on trait anxiety. Our findings identify stress as a major regulator of individuals' competitiveness, affecting self-confidence in opposite directions in high and low anxious individuals. Therefore, our findings imply that stress may provide a new channel for generating social and economic inequality and, thus, not only be a consequence, but also a cause of inequality through its impact on competitive self-confidence and decision making in financially-relevant situations.

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http://dx.doi.org/10.1016/j.psyneuen.2015.01.019

1. Introduction

Social competition is a major driving force in evolution and an essential organizing principle for the interactions between individuals and societies. In most social species, the outcome of competitive encounters with conspecifics determines individuals' social rank along with access to resources, and greatly influences physiology and health (Sapolsky, 2005). Despite the important consequences of contest competition on social organization and health, the factors that affect individuals' competitiveness beyond physical traits (such as size, age or gender) or previous social experience (e.g., winner and loser effects) are largely unknown.

In humans, an important attribute that strongly affects competitive decisions is the degree of confidence in one's abilities (Taylor and Brown, 1988). Biases in self-confidence (i.e. over- and underconfidence) can greatly affect individuals' well-being and position in society (Taylor and Brown, 1988) as well as eventually impacting society at different levels, from financial markets to international politics. Given its pervasiveness (Bernardo and Welch, 2001; Johnson, 2004), most studies have so far focused on the phenomenon of overconfidence—the belief that one is better than others in excess of what is justified by the data (Hoffrage, 2004). Although overconfidence can lead to suboptimal decisions with potential negative consequences in the short-run [e.g., losing contests (Camerer and Lovallo, 1999), engaging in costly wars (Johnson and Fowler, 2011), making audacious economic decisions (Barber and Odean, 2001; Malmendier and Tate, 2005, 2008) or providing inaccurate and potentially catastrophic expert judgments (Plous, 1993)], it can also bring important advantages to the individual in the long-run. Overconfidence can convey psychological benefits, such as increasing task motivation and persistence, or increasing utility from having a positive self-image (Bénabou and Tirole, 2002; Köszegi, 2006; Pajares, 1996) and self esteem (Alicke, 1985). Moreover, at the interpersonal level, overconfident individuals are perceived by others as more competent and are, in turn, conferred higher status (Anderson et al., 2012; Burks et al., 2013). Despite evidence that confidence levels in individuals and societies can vary under changing circumstances (Moore and Cain, 2007), little is known about the factors—both environmental and individual—that explain the variation in self-confidence in competitive settings. Evolutionary models have emphasized a critical role for environmental constraints, with overconfidence prevailing when the ratio between the benefits from contested resources and the cost of competition is high and underconfidence prevailing when this ratio is low (Johnson and Fowler, 2011).

Recently, acute stress was shown to facilitate the development of social subordination during competitive encounters in animals (Cordero and Sandi, 2007) and to affect decision-making in both animals (Graham et al., 2010; Shafiei et al., 2012) and humans (Buchanan and Preston, 2014; Pabst et al., 2013). A role for stress might be particularly relevant in humans, as social and economic life is marked by increasing inequality and rising stress (Atkinson and Piketty, 2007). However, although a great deal of research has identified the negative impact of social and economic inequality in stress and health, and highlighted stress as mediator of a wide range of health problems derived from social inequality (Wilkinson and Pickett, 2006), there is no information as to whether stress may itself cause systematic differences in social and economic outcomes. Such situations may arise, for example, if stress would differentially affect financially relevant decision-making in different subpopulations. Attempts to ascertain the contribution of personality in individuals' self-confidence have documented a lack of predictive power for some personality traits (e.g., openness, agreeableness and conscientiousness; Burks et al., 2013; Schaefer et al., 2004) but suggested that trait anxiety might play a role depending on the context (Schaefer et al., 2004). We thus hypothesized that *acute* stress exposure would impact competitive self-confidence in humans, with the outcome depending on the individuals' trait anxiety.

We tested this hypothesis with an economic choice experiment that involves a decision based on a self-confidence judgment of participants regarding their cognitive abilities. Participants, who had been characterized for trait anxiety and performance in a timed cognitive ability (CA) test one week before the experimental session, were asked to make economic decisions either under control conditions or under acute stress elicited using the Trier Social Stress Test for groups (TSST-G; von Dawans et al., 2011, 2012). Given that uncertainty has been postulated to be essential for under- and overconfidence biases (Johnson and Fowler, 2011), the experimental sessions involved two successive choice-experiments, to investigate participants' performance under high and low levels of uncertainty.

2. Materials and methods

2.1. Participants

Healthy male and female participants were recruited at the University of Lausanne and Ecole Polytechnique Fédérale de Lausanne (EPFL). They were screened for several exclusion criteria, including current medication usage, pregnancy, or breastfeeding; experiencing a major life change or an unusual amount of stress; smoking more than five cigarettes per day; or having a history of medical or psychiatric illness, insomnia, night shift work, or a history of drug or alcohol abuse. Two separate experimental cohorts were scheduled for data collection. Participants completed the sessions in groups of five or six. The final sample size was 229 participants, randomly assigned to either the stress ($n = 109$: 41 females, 68 males) or control ($n = 120$: 48 females, 72 males) conditions.

Participant demographics are listed in Tables 1 and S1. An additional group of 55 participants was recruited separately to play the role of second movers in some of the economic games. The second movers, who did not have to take any decisions, received a cash payment depending on whom they were paired with (mean payment = CHF 21.80). This study was approved by the Hautes Etudes Commerciales (HEC) Ethics Committee of the University of Lausanne.

2.2. Experimental procedures

The procedure is outlined in Fig. 1A. One week before the experimental session, participants completed an

Table 1 Participant demographics and baseline anxiety and physiological measurements.

	Control group $N = 120$		Stress group $N = 109$		*p*-value (*t*-test)
	Mean	S.D	Mean	S.D.	
Gender (% males)	60%		62%		.71, n.s.
Age	19.78	4.35	19.35	6.03	.54, n.s.
Trait anxiety (STAI-T)	34.34	10.18	32.44	8.07	.12, n.s.
CA test percentile	54.51	29.14	55.62	28.83	.72, n.s.
Cortisol (1st measurement)	5.45	3.72	5	4.56	.42, n.s.
Subjective stress (1st measurement)	21.73	18.46	19.9	16.41	.43, n.s.

Notes: Baseline characteristics of subjects are reported. Participants completed the STAI-T (State-Trait Anxiety Inventory, Trait scale) and CA (cognitive ability) tests approximately one week before the experiment was carried out. Cortisol (nmol/L) and subjective stress measurements were acquired shortly after participants arrived in the laboratory (T1, see Fig. 1), before receiving any experimental manipulation. N.s.: not significant.

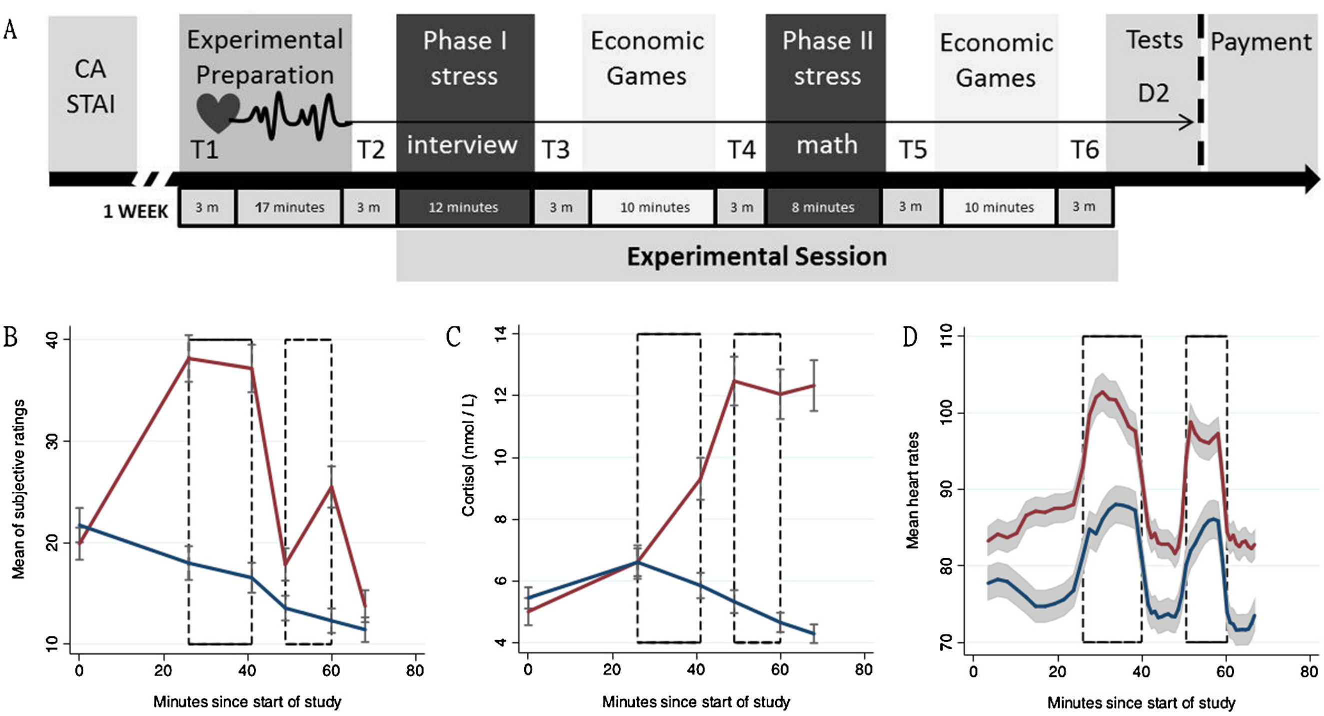

Figure 1 (A) The timeline of the experimental session. *Lower pane*: The impact of the stress condition on psychological and physiological responses expressed in (B) subjective stress ratings, (C) salivary cortisol and (D) heart rate. T1—T6: Time points at which physiological samples and subjective ratings of stress were collected. CA, cognitive ability test; STAI, State-Trait Anxiety Inventory. Red lines indicate stress condition, blue lines indicate control condition. Dashed boxes indicate the time during which the TSST-G stressors were administered. $N = 224$—229 (for five individuals, the cortisol data was incomplete and, therefore, omitted from the graph; for one participant there was no heart rate data available). Results are the means ± SEM. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

online behavioral characterization containing demographic questionnaires, the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983), as well as a custom-made Cognitive Ability (CA) test: a 10-minute timed version of the Bochumer Matrizen-test (Hossiep et al., 1999). As we evaluated the impact of trait anxiety (measured with the STAI-T scale) on economic choices, for statistical purposes, STAI-T values were normalized to the minimum value in this test (i.e., 20). Experimental sessions were performed in groups of five or six individuals. Sessions took place daily either between 14:00 and 16:00 or between 16:00 and 18:00. Each day included a stress and a control session, with order counterbalanced across days for each experimental condition.

We followed the procedures outlined in von Dawans et al. (2012). Upon arrival to the laboratory, participants received general information, completed consent forms, and were fitted a heart rate monitor (POLAR CSX800; Polar Electro, Kempele, Finland). Saliva samples were obtained using Salivette sampling devices (Sarstedt, Nümbrecht, Germany), and visual analog scales were used to assess perceived levels of stress at different times throughout the experimental session (see T1—T6 in Fig. 1A). Economic games were fully explained and examples were completed by the participants to ensure their full understanding before the stress or control manipulation. Participants were then told which experimental group they were assigned to and were given 10 min to prepare for the sessions. Participants in the stress group were exposed to the TSST-G, which involved the preparation and delivery of an oral presentation simulating a job interview, as well as performing a mental arithmetic task before an unresponsive jury and video cameras. Participants in the control group were given a text to read simultaneously in a low voice, followed by an easy counting task. These measures have been shown to control for the different factors of the TSST procedure excluding the psychosocial stress component (von Dawans et al., 2011). Following each of the speaking and arithmetic tasks (and amid saliva and questionnaire sampling), both groups played a series of economic games, including the overconfidence game explained below. At the end of the experimental session, all participants completed an attention test (d2; Brickenkamp and Zillmer, 1998) to check for potential differences in participants' attention due to cognitive load. The credibility of the experiments was verified by asking participants at the end whether they doubted that they were truly matched against another person, on a scale between 0 (no doubt at all) and 100 (highly doubtful). A large majority of the participants had little or no doubt ($M = 27.05$, $SD = 33.24$). At the end of the experimental session, decisions were entered and monetary pay-outs calculated based on their CA scores and random parameters. Participants were paid a lump sum of 45 Swiss Francs (CHF 45; CHF 1 = 1.03 USD) plus an additional amount based on the results of their participation in a series of economic games, which could vary between CHF 0 and CHF 35.

2.3. Cortisol assessment

Following each session, saliva samples were stored at −20 °C until processed. Samples were then centrifuged at 3000 rpm for 15 min at room temperature and salivary cortisol concentrations measured by enzyme immunoassay (Salimetrics, Suffolk, United Kingdom) according to the manufacturer's instructions. The analytical sensitivity for the cortisol assay is 0.007 μg/dL with standard curve ranging from 0.012 to 3.00 μg/dL. Coefficients of variation for low and high commercial controls were 4.75% for intra-assay and 8.2% for inter-assay.

2.4. The competitive confidence game

After the experimental manipulation, participants were told that they would be matched with a randomly selected opponent also participating in the study. They were then given the choice between playing a lottery game, in which they could win 20 Swiss Francs (CHF 1 = USD 1.03) with a probability p, or competing with their opponent on the basis of their respective CA scores such that they would be paid CHF 20 if their score in the CA test (that they had taken the week before) was higher than their opponent's and CHF 0 if not. Therefore, payoffs for winning (CHF 20) and losing (CHF 0) were identical for both the lottery and the competition. Responses were collected from participants using the strategy method: participants were asked from which probability p of winning the lottery they would choose the lottery over the CA competition, but were not informed of their performance in the CA test. Therefore, this first experiment was performed under high uncertainty. Rational individuals should switch to the lottery at the probability p that they believe is the probability that they have outperformed a randomly selected participant (henceforth switching probability). A higher switching probability indicates higher confidence in one's skill, as the individual will switch to the lottery only when the probability of winning is higher. Rational individuals with common priors should produce uniformly-distributed switching probabilities with a mean of 50%.

In the second choice experiment and in order to reduce uncertainty levels, participants were given a signal of their performance and asked again to indicate the probability p at which they would favor the lottery over the competition. Specifically, we told participants whether their score in the CA test was above or below the median score of all participants and asked them to estimate their switching probability on the same choice experiment.

2.5. Descriptive statistics and randomization checks

Table 1 provides descriptive statistics on participant demographics and baseline anxiety (STAI-T) and physiological measurements (i.e., saliva cortisol and subjective stress levels) before the experimental session started, for the control and stress groups separately. The groups did not differ *a priori* in any of the considered variables (all $p > .1$). Table S1 shows correlations among demographics variables. No significant correlation was found for any of the considered variables (i.e., gender, age, trait anxiety and CA test percentile), except for a trend towards a negative correlation between trait anxiety and the performance in the CA test. Therefore, these checks confirm that the randomization of subjects within the experimental groups worked with respect to various important variables that could be related to subsequent experimental measures.

3. Results

3.1. Subjective and physiological impact of the stress manipulation

The stress group exhibited higher subjective stress ratings (Fig. 1B), as well as higher cortisol (Fig. 1C) and heart rate levels (Fig. 1D) than the control group throughout the session. For subjective stress ratings, there was no significant difference between control and stress groups at the beginning, [$F(1, 226) = 0.63$, $p = .43$], nor at the end of the session [$F(1, 226) = 1.35$, $p = .25$]. For subsequent measurements (time points T1—T4 in Fig. 1A), there was a difference between the two groups (respectively $F_{1,226} = 50.5$, 55.65, 4.58, 31.21; $p < .001$, $p < .001$, $p = .033$, $p < .001$). Physiological measures also validated the stress manipulation: whilst there was no difference in salivary cortisol levels between groups in the two samples taken before

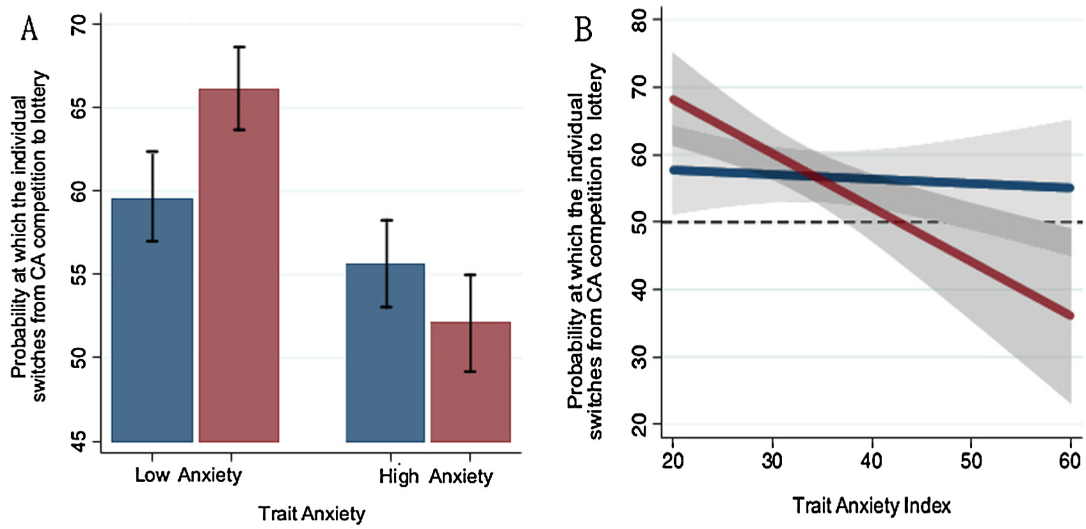

Figure 2 The impact of stress on the relationship between anxiety and switching probability visualized using (A) median split and (B) linear regressions including cognitive ability. Red boxes and lines denote stress condition; blue boxes and lines denote control condition. $N = 229$ for all analyses. (A) All groups exhibited overconfidence (Wilcoxon signed rank test, $p < .001$ for both stress and control conditions), but stress differentially affected self-confidence in low and high anxious individuals. Error bars indicate the standard error of the mean. (B) The linear regression accounts for both cognitive ability (CA) and continuous trait anxiety and also shows no effect of anxiety on confidence levels in the control condition, but a strong interaction with anxiety in the stress condition. Shaded regions indicate 95% confidence bands around the respective values. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the stress manipulation (both F's < 0.64, both p's > .42), stress participants had higher salivary cortisol levels than control participants in all measurements taken after the manipulation (all F's > 19.75, all p's < .001). The heart rate differed between the control and stress groups from the minute after the start of the measurement [$F(1, 221) = 4.07$, $p = .044$], again confirming that the TSST-G procedure was effective in producing a strong physiological stress response.

We also performed a further series of manipulation checks that allowed us to verify that the stress manipulation was successful and the experiment was well-balanced in terms of allocation of individuals to different treatments (Fig. 1B—D; Tables S2 and S3). We also verified that the stress condition did not affect participants' attention levels as measured in the *d*2 attention test [Ordinary Least Squares (OLS) regression estimate on experimental condition = −0.095, $SD = 10.782$, $R^2 < .001$].

3.2. Main results

We then examined the results from the first choice experiment, in which participants indicated at what probability they would switch to the lottery from the CA contest without having received information regarding theirs or their opponent's CA score (i.e., under high uncertainty). On a first assessment, we observed that the distribution of switching probabilities has a mean of 58 and is clearly skewed toward overconfidence (see SI Figure S1). A Wilcoxon signed rank test rejected that the mean is equal to 50 (its theoretical expectation in the rational benchmark) for both the stress and control groups separately (control: $M = 57.5$, $SD = 20.2$, $p < .001$; stress: $M = 59.2$, $SD = 21.2$, $p < .001$). Thus, on average, behavior in our study is overconfident.

Importantly, we found strong support for our hypothesis that the response to stress depends on trait anxiety. We demonstrate this in two steps. In a first step, we used a median split of the trait anxiety score, dividing participants into high-anxiety (Control, $n = 60$; Stress, $n = 55$) and low-anxiety (Control, $n = 60$; Stress, $n = 54$) groups and found differential effects of stress [Fig. 2A; ($F(3,225) = 3.06$, $p = .03$)]. While self-confidence did not significantly differ between low-anxiety and high-anxiety individuals in the control condition [$t(120) = 1.43$, $p = .15$], differences in behavior between these groups emerged in the stress condition [$t(109) = 2.52$, $p = .01$]. Specifically, low-anxiety individuals became more self-confident, but stress had the opposite effect in high-anxiety individuals, who became less confident. In a second step, we used the full range of variation in trait anxiety to test for the hypothesis that trait anxiety modulates stress effects with more precision in a series of linear regressions (Fig. 2B and Table 2; note that, as stated in Section 2, trait anxiety was normalized to its minimum value of 20, such that the main effect of stress from the regression analyses can be directly interpreted as the effect on an individual with the lowest possible anxiety score). These regressions allowed us to control for gender and performance on the CA. Since CA was held constant, any effect of our experiment on performance can directly be interpreted as an effect on self-confidence. The main results are displayed in column (1) of Table 2. As can be seen, the interaction of the stress manipulation with trait anxiety has a significant and quantitatively important effect on self-confidence ($p = .01$). Individuals scoring at the

Table 2 Regression models of self-confidence on stress, trait anxiety and covariates.

Estimated coefficients	Regression model		
	(1)	(2)	(3)
Stress	10.47*	7.830	10.36
	(4.553)	(6.237)	(7.461)
Trait anxiety (STAI-T)	−0.0625	−0.0702	−0.0628
	(0.181)	(0.182)	(0.183)
STAI-T × Stress	−0.748*	−0.741*	−0.747*
	(0.303)	(0.305)	(0.307)
CA percentile	0.172**	0.170**	0.171**
	(0.0445)	(0.0442)	(0.0594)
Gender	6.766*	4.810	6.764*
	(2.755)	(3.940)	(2.749)
Gender × Stress		4.154	
		(5.488)	
CA percentile × Stress			0.00170
			(0.0896)
Constant	45.03**	46.39**	45.08**
	(4.994)	(5.424)	(5.619)
R^2	0.144	.147	.144

Notes: The dependent variable for all models is the switching probability p at which the participant prefers the lottery to the contest based on performance in the cognitive ability (CA) test. Each column represents a different specification, with the explanatory variables listed in that column. Gender: Female = 0, male = 1; Stress = Experimental condition (Control = 0, Stress = 1). Trait anxiety is normalized such that the coefficient on the stress condition can be directly interpreted as the effect of the stress condition for an individual with a minimal score of trait anxiety. OLS linear regression estimates with robust standard errors (in parenthesis). * $p < .05$; ** $p < .01$; *** $p < .001$. $N = 229$.

minimum of the anxiety scale are significantly overconfident, and more so than the sample average. Conversely, individuals with the highest observed score of trait anxiety, but same performance in the CA test, estimated their probability of winning at only 32%, significantly lower than the rational benchmark of 50%. It is also noteworthy that our results show that males were more confident in assessing their skills. Importantly, although males were significantly more overconfident than females in our sample, the interaction of stress with trait anxiety remains significant when males are analyzed separately [$F(3,135) = 3.81$, $p = 0.01$].

In order to assess the statistical robustness of this result and to rule out alternative interpretations, we performed several robustness checks on this result, reported in regressions indicated in columns (2) and (3) of Table 2. We examined whether other variables typically correlated with trait anxiety, rather than trait anxiety itself, might drive this pattern. Thus, we first focused on the possible moderating effects of gender. Previous studies have suggested the existence of gender differences in response to psychosocial stress (Kirschbaum et al., 1992), suggesting that women tend to be more anxious than men (Wittchen et al., 1994; Kessler et al., 2005). Thus, we added an interaction of the stress condition with gender to the baseline specification of column (1). The estimates of the regression model in column (2) show that the modulation of the stress manipulation effect by anxiety is still significant, and its point estimates and quantitative implications are virtually unchanged. Furthermore, the interaction with gender did not modulate the stress manipulation effects in our study, as this effect was not significant; thus we cannot reject the hypothesis that males and female respond similarly to the stress condition. We next investigated whether the CA score was moderating the effects of stress. In column (3), we added an interaction with the CA score to the baseline regression model. One may argue that differences in ability, rather than differences in anxiety, modulate stress effects. However, our results do not support this interpretation: trait anxiety significantly modulates stress, while the additional interaction with the percentile of the CA performance was not statistically significant.

3.3. Cortisol responses and confidence

We then evaluated whether cortisol responses capture the treatment effects. To this end, we first calculated the area under the curve measure using the cortisol measurements T3—T6 relative to the baseline measures T1 and T2 (see Fig. 1A), when both groups' levels do not differ (Fig. 2C). Then, we estimated a regression model (OLS) using these cortisol responses and an interaction with trait anxiety as our dependent variable while controlling for CA test performance, trait anxiety and gender. The results are displayed in column (1; OLS) of Table 3. We also estimated the same regression model, but using the treatment group assignment and its interaction with trait anxiety as instrumental variables (IV) for cortisol response and its interaction with anxiety. The IV-estimate only uses variation in cortisol induced by the experiment and the interaction with trait anxiety, to identify the impact of cortisol on confidence. The results from this analysis are displayed in column (2;

Table 3 Regression models of self-confidence and its relationship to cortisol responses.

Estimated coefficients	Estimation method	
	(1) OLS estimate	(2) IV estimate
Cortisol response	0.584**	0.865*
	(0.196)	(0.362)
Trait anxiety (STAI-T)	−0.0191	0.189
	(0.184)	(0.288)
STAI-T × Cortisol response	−0.0399*	−0.0661*
	(0.0162)	(0.0263)
CA percentile	0.174**	0.172**
	(0.0454)	(0.0449)
Gender	6.527*	6.782*
	(2.868)	(2.849)
Constant	43.85**	41.42**
	(4.662)	(5.704)
F-test: interaction stress and trait anxiety	$p = .003$	$p = .003$
R^2	.161	.147

Notes: The dependent variable for all models is the switching probability p at which the participant prefers the lottery to the contest based on performance in the cognitive ability (CA) test. Gender: Female = 0, male = 1; Cortisol response = area under the curve measure of cortisol response over the entire experimental session relative to baseline measurements T1 and T2. Trait anxiety is normalized such that the coefficient on the stress condition can be directly interpreted as the effect of the cortisol response for an individual with a minimal score of trait anxiety. The first column presents the estimates from the Ordinary Least Square (OLS) regression, the second column the instrumental variables (IV) estimates with the stress condition and the stress condition interacted with trait anxiety as instruments. Robust standard errors. * $p < .05$; ** $p < .01$; *** $p < .001$. $N = 217$, as 12 cortisol measurements failed for technical reasons.

IV) of Table 3. Both sets of results show the same picture. The impact of the cortisol response on confidence strongly depends on trait anxiety: for individuals scoring low on trait anxiety, a higher cortisol response was associated with higher confidence, taking into account their performance in the CA test and their gender. For individuals scoring high in trait anxiety, the sign was reversed and higher cortisol was associated with lower confidence. This implies that, under stress, self-confidence in a very low anxious individual would increase by 11 percentage points, while in a high anxious individual, scoring at the 90th percentile in the STAI-T, it would decrease by 13 percentage points. To put this into perspective, this 24 percentage point difference amounts to almost four times the gender effect on overconfidence.

3.4. Confidence assessments with a signal

We also analyzed the data from the second choice experiment in which the participants were given a rough indication of how they scored in the CA test (whether they were above or below the median) that they had performed around one week before the experimental session. As we hypothesized, in this treatment, we find no association between the stress condition or its interaction with anxiety, or the cortisol response and the behavior (all p's > .1, see SI Table S4). The signal is the only significant predictor of participants' behavior in this case; not even gender plays a significant effect.

4. Discussion

We investigated the impact of acute stress on self-confident behavior to compete for a monetary reward and its modulation by trait anxiety. In the absence of stress, both high-anxiety and low-anxiety individuals exhibited overconfident behavior to a similar extent. This fits with numerous reports indicating that overconfidence is pervasive in our societies, along with recent evolutionary models that propose that natural selection has favored the emergence of overconfident populations (Johnson and Fowler, 2011; Trivers, 2000; von Hippel and Trivers, 2011). Strikingly, however, stress interacted with personality to influence confidence, driving the behavior of individuals differing in trait anxiety in opposite directions; i.e., increasing overconfidence in participants with lower anxiety, while reducing self-confidence in individuals with higher anxiety. These findings reveal that overconfidence is not necessarily a fixed attribute of individuals but instead can be shaped by the interaction of personality and stress.

This result was not due to the effect of other variables correlated with trait anxiety, as CA scores and gender had no significant interactions with stress despite exhibiting significant effects on confidence in our regression model. Although males are significantly more overconfident than females in our sample, consistent with other findings in the literature (Gneezy et al., 2003), the interaction of stress with trait anxiety remains significant when males are analyzed separately. This is particularly relevant, as gender differences in risk-taking behavior have been reported following stress exposure (Lighthall et al., 2009; Van den Bos et al., 2009).

According to emerging literature showing that trait anxiety moderates the impact of stress on brain and behavior (Sandi and Richter-Levin, 2009), the disparate effects found for stress in competitive self-confidence when high- and low-anxiety individuals are challenged under uncertainty are probably embedded in individuals' neurobiological endowment. Indeed, behavioral and cognitive effects of stress are believed to result from alterations on the activity of large-scale brain networks (Drabant et al., 2012; Gathmann et al., 2014; Hermans et al., 2011). Differences in trait anxiety can result in different physiological stress responses (Sandi and Richter-Levin, 2009); however, they do not seem to account for the observed differences in competitive decisions. We found that changes in cortisol levels or heart rate did not relate to trait anxiety, only to the stress manipulation. However, importantly, we found clear evidence for an impact of cortisol on self-confidence that strongly depends on trait anxiety: whereas higher cortisol responses were associated with higher confidence in low-anxious individuals, the opposite association was observed in high anxious subjects. These remarkable findings suggest that glucocorticoids impinge a differential responsiveness in brain function and behavior in individuals that differ in trait anxiety, and fit with the idea that enhanced glucocorticoid levels would facilitate behavioral responses according to existing predispositions.

This idea is in line with rodent studies indicating that acute increases in the stress hormone corticosterone exacerbate context-dependent status, increasing agonistic responses in dominant individuals while submissive responses in subordination [see Timmer and Sandi (2010) for a discussion; note, though, that the link between context and anxiety in those examples remains to be established]. In addition, the implication of cortisol in the performance in the economic game is in line with formerly reported rapid effects of glucocorticoids in behavioral coping (Sandi et al., 1996) and social interactions (Mikics et al., 2004). Future studies are warranted to examine the potential differential impact of cortisol in brain activation and dynamics in high- and low-anxiety individuals.

Our experimental design excludes several possible interpretations, such as a role for changes in the cost/benefit ratio involved in the competition (Johnson and Fowler, 2011), as these were held constant across the two options (i.e. competition or lottery) presented to the participants. Consequently, potential effects of stress in reward responsivity (Ossewaarde et al., 2011) or reward learning (Cavanagh et al., 2011) cannot account for our findings. In addition, our experimental design excludes the possibility that overconfident participants were motivated by the desire to send positive signals to others about their own skills (Burks et al., 2013), as their decision-making process did not involve any direct social interaction. Although we did not find an effect of gender in our main data, a limitation of our study is that we did not collect information regarding the estrous cycle or the use of contraceptives, which precluded us from investigating potential effects depending on these factors. However, it is important to emphasize that our main results remain significant even if analyses are only performed in our male sample. Another limitation of our study is that we did not measure anxiety state with STAI-S during the experimental session and, therefore, we could not asses the relevance of this factor, on its own or in interaction with trait anxiety, in the effect of stress on self-confidence.

Most of the previous research on the role of stress in economic outcomes has emphasized the negative effects of stress in individuals' physical and mental health, as well as the resulting global economic burden (Kalia, 2002). Differences in health are predictive of major socioeconomic outcomes and, therefore, can operate as an important source for social inequalities (Currie, 2011). Our study reveals a new and broader mechanism whereby stress can generate inequality through economic decisions.

Therefore, our results demonstrate for the first time an interaction between a personality trait and stress exposure on competitive self-confidence, implying that decision-makers' personality and the environment within which they act can interact in shaping their choices. Our findings predict that changes in the stressful nature of individuals' environments could have a profound impact on individuals and the organizations within which they interact, depending on their trait anxiety. Although overconfidence is not necessarily beneficial in all possible scenarios (Barber and Odean, 2001; Camerer and Lovallo, 1999; Deaves et al., 2005; Johnson and Fowler, 2011; Malmendier and Tate, 2005, 2008; Plous, 1993), there is a substantial literature showing that overconfident individuals frequently derive both psychological (Bénabou and Tirole, 2002; Burks et al., 2013; Taylor and Brown, 1988) and social advantages (Anderson et al., 2012) from their overconfidence. Accordingly, a prediction from our study is that stressful environments will segregate high- and low-anxiety individuals by their ability to thrive in their respective social environments, with individuals characterized by low anxiety potentially gaining higher social status than those characterized by high anxiety. As a result, stress could eventually place high-anxiety individuals in a disadvantaged position for gaining access to contested resources and exerting control on collective matters.

Conflict of interest statement

The authors declare that they have no conflicts of interest with respect to their authorship or the publication of this article.

Role of the funding source

We gratefully acknowledge support grants from the Swiss National Science Foundation (CR10I3-146431 and 31003AB-135710) and intramural funding from the EPFL und UNIL.

Acknowledgments

The authors would like to thank N. Berchier, D. Brunner, C. Fournier, L. Fuehrer, N. Habbadi, L. Loued-Khenissi, T. Nga, C. Ransome, A. Strasser and K. Trang and O. Zanoletti for excellent experimental help.

Goette, L., Bendahan, S., Thoresen, J. C., Hollis, F., and Sandi, C. Stress pulls us apart: Anxiety leads to differences in competitive confidence under stress.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.psyneuen.2015.01.019.

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