Trait-Anxiety and Belief Updating: Exploring the predictions of the negativity bias and contrast avoidance model.

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Abstract.

Beliefs play a crucial role in shaping our behaviors and mental-health outcomes. Asymmetric belief updating refers to the phenomenon where desirable information is updated more readily than undesirable information. An essential feature of anxiety is threat-overestimation and a tendency to focus on the negative aspects of experience while avoiding sharp negative emotional contrasts. These two characteristics lead to different predictions concerning belief updating. One scenario would suggest a reduction in asymmetric update behavior, indicating negativity bias, while the other would indicate an increase in asymmetric update, indicating contrast avoidance. To test these two rival predictions, participants (n = 44) first completed trait-measures and then performed a belief update task. Moreover, memory for the information presented was assessed in the short-term and long-term. Skin conductance response was measured to assess arousal levels during the task. Overall, our findings revealed that higher levels of trait-anxiety predicted a greater integration of desirable information but not undesirable information. In contrast, trait-intolerance of uncertainty did not exhibit an association with update behavior. Skin conductance and memory were not associated with trait-measures. We discuss these results in line with the Contrast Avoidance Model of anxiety, in terms of avoidance of unexpected negative contrast and positive contrast induced by relief during belief updating.

"The man who has anticipated the coming of troubles takes away their power when they arrive." **Seneca, Consolation to Marcia**

1. Introduction

Beliefs are "propositional attitudes" that shape our internal worlds and serve decision-making and general well-being (Carver et al., 2010; Carver & Scheier, 2014; Craig et al., 2021). However, our beliefs are not a pure reflection of the world. Rather, our cognitive system biases information processing (Gershman, 2019; Kahneman, 2003).

Positive beliefs about the future or ourselves are associated with better health outcomes (Carver et al., 2010; Sweeny et al., 2006). Conversely, intense negative beliefs are a hallmark of mental disorders characterized by suboptimal reward-seeking and punishment avoidance (Borkovec et al., 1999; Moutoussis et al., 2015; Watkins & Moulds, 2005). In general, people tend to overestimate the likelihood of positive future events across a variety of domains, such as finance, intelligence, or accidents (Carver et al., 2010; Sweeny et al., 2006; Weinstein, 1980). Besides their epistemic (truthful) aspect, beliefs possess instrumental and hedonic value (Bromberg-Martin & Sharot, 2020; Loewenstein & Molnar, 2018; Sharot et al., 2023). In other words, the value of beliefs could be derived from their ability to predict the environment and guide action selection (instrumental value), as well from the affective experience that certain beliefs provide (hedonic value).

Holding positive beliefs can be rewarding by itself (i.e., being competent, nice, etc.) while holding negative beliefs can produce distress and are often preferred to be avoided. In this sense, beliefs are more readily integrated in response to desirable information ("good news") than undesirable information ("bad news"; Sharot et al., 2011; Sharot & Garrett, 2016). This asymmetric belief updating, known as the "optimism bias" suggests that when individuals estimate their risk of experiencing negative outcomes, such as a cardiovascular accident, they tend to update "better than expected" information at a higher rate than "worse than expected" information.

These findings have been replicated and consistently show a positive association between optimism and asymmetrical belief updating (Kuzmanovic et al., 2015; Sharot & Garrett, 2016). As dysfunctional beliefs are critical in mental disorders and are explicitly targeted during treatment (i.e., cognitive restructuring in Cognitive Behavioral Therapy; Beck & Dozois, 2011), belief updating processes have gained clinical relevance. Previous research has demonstrated that asymmetrical belief updating is influenced by information valence and the specific psychiatric population being studied (Garrett et al., 2014; Korn et al., 2014; Ossola et al., 2020; Schönfelder et al., 2017).

Fear and anxiety are two related human emotions that primarily differ in their relative imminence and uncertainty about threat (Hamm, 2020; Mobbs et al., 2020). While fear corresponds to a defensive response of the organism (fight or flight) in the face of a detectable imminent threat, anxiety is a more persistent negative state in response to distal, uncertain, or potential threats (Barlow, 2004; LeDoux & Pine, 2016).

Much work has been conducted to understand cognitive and behavioral features as well as biases toward threats that initiate and maintain anxiety (Cisler & Koster, 2010; Coles & Heimberg, 2002; Grupe & Nitschke, 2013; Hartley & Phelps, 2012). First, anxiety is associated with threat overestimation (also known as "pessimistic expectations"). Individuals with high anxiety levels tend to exhibit skewed estimates about the probability of rare or uncommon events, perceiving their consequences as more severe (Beck & Dozois, 2011; Grupe & Nitschke, 2013). Second, anxiety implies high levels of intolerance to uncertainty (IU) and increased reactivity to threats. In other words, individuals with high levels of anxiety find uncertain outcomes distressing and tend to respond more negatively (Buhr & Dugas, 2012; Carleton, Sharpe, et al., 2007). Third, anxiety is associated with biases toward negative information (negativity bias; Cisler & Koster, 2010; Coles & Heimberg, 2002; MacLeod & Mathews, 2012). This implies that anxious individuals have faster threat detection (attentional bias), infer negative scenarios in ambiguous contexts (interpretative bias), and remember more negative information (memory bias). Finally, anxiety is associated with persistent behavioral and cognitive avoidance of threats. Anxious individuals avoid confronting threatening internal or external experiences or escape from them before their occurrence (Bouton et al., 2001; Buhr & Dugas, 2012; Llera & Newman, 2014). Overall, these anxiety features are thought to maintain symptoms and hinder learning from experience by maintaining skewed negative predictions that are rarely confirmed (Fernández et al., 2017; Grupe & Nitschke, 2013).

To our knowledge, no previous study directly investigated the process of belief updating about future negative events considering individual differences in trait-anxiety and trait-intolerance of uncertainty (trait-IU). Following this hypothesis on the negativity bias of anxiety, it could be hypothesized that when estimating future negative events, high trait-anxious individuals would exhibit a reduced asymmetrical belief updating (unbiased) compared to low trait-anxious individuals. Hence, highly anxious individuals may update to the same extent desirable and undesirable information as information may provide more instrumental value: the opportunity to learn more about threats (risks) regardless of valence, implement control strategies, and avoid those threats in the future. For example, recent work by Garret et. al. (Garrett et al., 2018) indicated that in the face of an acute threat (Trier Social Stress Test), individuals showed balanced belief updating, in the sense that desirable and undesirable information was integrated to an equal extent. However, as previously mentioned, acute and potential threats as imminent or distal threats may involve different processes (Hamm, 2020; Mobbs et al., 2020)

On the other hand, a complementary anxiety model predicts a different pattern. The Contrast Avoidance model (Kim & Newman, 2023; Llera & Newman, 2014; Newman & Llera, 2011; Rashtbari & Saed, 2020) posits that anxious individuals assume a "worst-case scenario" strategy toward threats, to avoid an increase in negative affect when expectations are "worse than expected" ("*more threatening than expected*"). This strategy implies that there is a higher likelihood for anxious individuals to experience relief from "better than expected" ("less threatening than expected") experiences. Previous work indicated that anxious individuals experience higher relief during avoidance tasks (San Martín et al., 2020; Vervliet et al., 2017). Thus, an alternative hypothesis is that high trait-anxious individuals would display an increased asymmetrical belief updating as it provides more hedonic value. Specifically, there would be an increased relief derived from desirable information and avoidance of a negative affective contrast from undesirable information.

To test these two rival hypotheses, we focused on individual differences in trait-anxiety and trait-IU during a belief update task (Fig. 1) and compared it to trait-optimism which is proposed to be consistently associated with update behavior (Kuzmanovic et al., 2015; Sharot et al., 2011). After completing psychometric measures, participants were exposed to descriptions of negative events and were asked to estimate (First estimate - P1) the probability that these events would occur it would occur to them in the future, taking into account the actual base rate (Actual base rate - PT). Then, participants were provided with the actual population base rate and instructed to re-estimate the probability of occurrence (Second estimate - P2). As arousal levels and prediction error responses differ according to trait-anxiety levels (Duits et al., 2015; Xiao et al., 2011), we measure skin conductance response during the updating task to assess its association with valenced-information integration. We predicted that: if the instrumental value of the information carries more weight during the update process, individuals with higher trait-anxiety would exhibit a reduced asymmetric belief update (balanced), aligning with the negativity hypothesis. Conversely, if the hedonic value carries more weight, individuals with high trait-anxiety would exhibit an increase in the asymmetry (unbalanced), in line with the Contrast Avoidance Model. Finally, we expected that memory for the actual base rate would differ according to valence and trait-anxiety levels.

Methods

1.1. Participants.

A total of 44 undergraduates and graduate young participants (25 females and 19 males) from Buenos Aires University (Argentina) with a mean age of 23.2 ± 2.1 years participated in the study. Our exclusion criteria were a history of psychiatric disorders. Before the experiment, participants completed self-reported trait-measures: the trait subscale of the State-Trait Anxiety Inventory (Spielberger et al., 1970), the Intolerance of Uncertainty Scale-12 (Carleton, Norton, et al., 2007), and the Life Orientation Test-Revised (Scheier et al., 1994). All participants signed a written informed consent form approved by the Ethics Committee of the Review Board of the Instituto de Investigaciones Médicas Alfredo Lanari in accordance with the Declaration of Helsinki. Sample size was based on previous studies using similar update tasks and psychometric measures (Garrett et al., 2014, 2018; Kuzmanovic et al., 2015; Ossola et al., 2020; Sharot et al., 2011).

1.2. Stimuli

Participants were presented with 40 short descriptions of adverse life events (i.e. having a stroke, being assaulted, etc). The average probability of each event occurring to someone from Argentina within the same age range and socio-economic status was estimated from public national sources (https://www.argentina.gob.ar/, https://servicios.registrocivil.gob.ec/cdd/, https://www.indec.gob.ar/). The probabilities of the events ranged between 8% and 70%.

1.3. Measures

1.3.1. Self-report measures

Spielberger State and Trait Anxiety Inventory (STAI; Spielberger et al., 1970). We used the Trait subscale to measure Trait anxiety. The STAI consists of a 20-item scale that assesses the level of anxiety as a general stable trait. Our sample scored M = 26.6 +/- SEM = 0.14, range = 16 – 41.

The Intolerance of Uncertainty Scale - 12 (IUS-12: Carleton, Norton, et al., 2007) consists of 12 items (short version) that individuals rate on a 5-point Likert scale, ranging from "Not at all characteristic of me" to "Entirely characteristic of me.". This scale assesses the dispositional capacity of individuals to cope with uncertain or unknown outcomes. The mean score was M = 31.9 +/- SEM = 0.19, range = 18 – 50.

The Life Orientation Test-Revised (LOT-R; Scheier et al., 1994) was used to assess trait-optimism and expectation regarding positive outcomes in life. It consists of 10 items and respondents rate their level of agreement or disagreement using a Likert scale. Our sample scored M = 18.6 +/- SEM = 0.1, range = 12 – 29.

1.3.2. Electrodermal Activity

We used Skin Conductance Response (SCR) as measure that reflects physiological arousal in response to prediction error (PT - P1). To measure electrodermal activity, we used an input device (Psychlab Precision Contact Instruments) with a sine excitation voltage (±0.5 V) of 50 Hz derived from the main frequency. The device was connected to two Ag/AgCl electrodes of 20 mm and 16 mm located in the intermediate phalanges of the non-dominant hand. Raw SCR scores were square-root transformed to normalize distributions using MatLab Software. We then used an average moving filter of 5 points (smooth command in Matlab Software) to smooth the raw signal. The time window for signal extraction was set to 0.5 s to 4 s between the subject's first estimate and the presentation of the actual base rate. We used a minimum response criterion of 0.002 micro-Siemens (mS), and all other responses were scored as zero.

1.4. Belief update task

Participants performed a belief update task in two sessions (Fig. 1). In the first session, each trial involved a negative life event and participants were instructed to estimate (First estimate - P1) the likelihood of the event happening to them in the future (i.e. ”*What is the probability that you will be mugged?*”). Participants had 5 seconds to respond, after which the actual population base rate of the event (actual base rate - PT) was presented for 2 seconds. If participants had previously experienced a specific event, they were instructed to estimate the likelihood of experiencing the same event again in the future. Once the 40 trials were completed the second session began. Participants were presented again with the same adverse life events and asked to re-estimate (Second estimate - P2) their own risk. In this session, no population base rate was presented to avoid learning or re-learning.

1.5. Memory testing at short and long-delay

At the end of the experiment participants' memory (Short-term) of the actual base rate was assessed. Each of the 40 negative life events was presented again and participants were instructed to report the actual probability previously seen. Previous studies evaluated memory to test their effects on belief updating and reported no differences between desirable and undesirable information retention (Garrett et al., 2018; Sharot et al., 2011). However, as high anxiety levels were reported to be associated with better memory retention of negative information (Coles & Heimberg, 2002; Fernández et al., 2017), we also tested the memory of the 40 negative life events 3 months after the experiment (Long-term). Memory testing at long-delay was conducted online in *Google Forms*. Experimental tasks were designed and presented using MATLAB 2016 (Mathworks Inc., Sherborn, MA, USA) with the Psychtoolbox toolkit.

1.6. Data analysis

To model subjects' responses, we performed generalized hierarchical Bayesian regression models. Update was defined as the difference between the subjects first estimate (P1) and second estimate (P2), resulting in a bounded interval of (-1,1). Prediction error was defined as the absolute difference between P1 and the true value for that stimulus (PT). The valence the base rates of negative life events relied on the initial estimate provided by the participants (P1). If the base rate for an adverse event was lower than the participant's initial estimate (P1 > PT), it was considered as desirable information “good news”). Conversely, if the base rate was higher, it was seen as undesirable information ("bad news", P1 < PT). We employed a normal hierarchical model to capture subjects' update responses. Although the response variable is bounded, we can use the identity link function from the normal model to provide an adequate approximation.

We modeled the updated responses as follows:

$$
\begin{aligned}
update \ = \ & \alpha + \beta_1(News_{desirable}) + \beta_2(Prediction\ Error) + \beta_3(True\ Value) + \beta_4(Anxiety) \\
& + \beta_5(Optimism) + \beta_6(Uncertainty) \\
& + \beta_7(Prediction\ Error\ \times News_{desirable}) + \beta_8(Anxiety\ \times News_{desirable}) \\
& + \beta_9(Optimism\ \times News_{desirable}) + \beta_{10}(Uncertainty\ \times News_{desirable})\ + \\
& + \beta_{11}(True\ Value\ \times News_{desirable}) + \beta_{12}(Anxiety\ \times Prediction\ Error) \\
& + \beta_{13}(Optimism\ \times Prediction\ Error) + \beta_{14}\ (Uncertainty\ \times Prediction\ Error)\ + \\
& + \beta_{15}(Prediction\ Error\ \times News_{desirable} \times Anxiety) \\
& + \beta_{16}\left(Prediction\ Error\ \times News_{s_{desirable}} \times Optimism\right) +\ \beta_{17}(Prediction\ Error \\
& \times News\ _{desirable} \times Uncertainty)
\end{aligned}
$$

That is, the subject's update was explained by the news valence (desirable / undesirable information), the prediction error, the true value of the stimuli and the levels of trait-anxiety, trait-IU and trait-optimism. We included a triple interaction between prediction error and news with both trait-anxiety, trait-IU and trait-optimism. Therefore, the effect of prediction error, news valence and trait-level measures were dependent on the values of each other. We also included an interaction between the true value (PT) and the news valence. Due to the bounded nature of the response variable, we established weakly informed priors for all coefficients following a Normal (0,5) distribution and employed default priors for all other parameters.

To model the impact of skin conductance response (SCR) we used again the identity link function for the generalized hierarchical Bayesian regression model using Normal (0,2) priors for all parameters. We employed a modified version of the original model for update response and included the SCR value as a predictor variable alongside a triple interaction with the prediction error and the news valence.

Finally, subject's short-term memory was defined as the absolute difference between the true value (PT) and the subject's response at the end of the experiment (short-term memory) for each event. Therefore, it was naturally bounded between the (0,1) interval. To model the subject's memory of the actual base rate (PT) we employed a zero-inflated beta hierarchical Bayesian model due to the bounded nature of the response variable and the presence of a (relatively) small amount of 0 values forcing us to include the zero-generating component. In this model, we employed Normal (0,2) priors for all fixed coefficients including the intercept. We also defined a Normal (0,1) prior for the random effects and a Gamma (1,0.01) prior for the Φ component of the regression. Lastly, we defined a Normal (-3,1) prior for the zero-generating component to accommodate the small number of zero cases. We employed the same model as in the case of the update response and included a time-interval (Short / Long) parameter which is a categorical variable defining whether the response variable came from an immediate test or delayed test. In addition, we included the triple interaction between this parameter, the prediction error, and the news valence.

We computed posterior estimates for all models using 4 chains of Markov chain Monte Carlo (MCMC) of 10,000 iterations each (5,000 were used as warm-up). We performed a visual inspection of trace plots, density plots of the posterior, and autocorrelation plots for each parameter. We also assessed, for each parameter, adequate convergence using R-hat values and examined the effective sample size (ESS) to determine the posterior estimation stability. Lastly, we checked the model adequacy using prior posterior predictive checks and posterior predictive checks.

Due to the presence of nonlinearities, arising from interactions or non-linear link functions, we computed average marginal effects to examine the impact of specific covariates. In this report, we present the coefficients (β) extracted from the model and the average marginal effects (*M*) to test the effects of interest. All posterior reports use the mean as the posterior point estimate and the 95% Highest Density Interval (HDI) as a measure of uncertainty. The HDI conveys the range of most probable values in the posterior. Parameter estimates can be interpreted as statistically meaningful (akin to statistical significance in the frequentist approach) if zero is outside the HDI. All analyses were performed in R version 4.3.0. The *brms* package was used for model fitting and estimation of generalized hierarchical Bayesian models. The *tidybayes* package was employed for general posterior manipulation and plotting and *marginaleffects* package to compute all types of marginal effects.

2. Results

2.1. Belief Update Task

Overall the hierarchical bayesian analysis showed the expected asymmetry in belief updating (Fig. 2, News Valence β = -0.37 [-0.71, -0.03]). Subjects updated to a greater extent while receiving desirable information (M = 0.152 [0.13, 0.17]) compared to undesirable information (M = 0.085 [0.06, 0.09], $M_{\text{difference}}$ = 0.069 [0.052, 0.81]). In addition, we found an association between Prediction Error level, the True Value (PT) and subsequent update (Prediction Error β = 1.35 [0.51, 2.47], True Value (PT) β = -0.19 [-0.28, -0.09]). There was also a noticeable difference in the slope of the

Prediction Error ($M_{difference}$ = 0.332 [0.193, 0.465]) between undesirable information (M = 0.396 [0.278, 0.513]), and desirable information (M = 0.729 [0.662, 0.795]), suggesting that although both were in the same direction, the latter showed a higher prediction error-dependent update than the former.

A core feature of trait-anxiety and trait-optimism is the type of predictions made when confronted with potential negative events (overestimation vs underestimation of threat/rewards). Trait-anxiety and trait-optimism showed a significant negative correlation (rho = 0.43, $p < 0.001$) and a small association with the initial estimates (P1) of the likelihood of negative events (rho = 0.080, $p = 0.02$; rho = -0.18, $p < 0.001$, respectively). Moreover, trait-IU was also associated with trait-anxiety (rho = 0.44, $p < 0.001$) and trait-optimism (rho = -0.25, $p < 0.001$) but not with initial risk estimate (rho = -0.04, $p = 0.12$). Notably, in accordance with the Contrast Avoidance model of anxiety, we found that higher levels of trait-anxiety were associated with increased asymmetry in the integration of information (Fig. 3 A, Main effect of trait-anxiety β = -0.001 [-0.006, 0.004], trait-anxiety x News Valence x Prediction Error interaction β = 0.04 [0.01, 0.06], desirable and undesirable information $M_{\text{difference}}$ = 0.011 [0.007, 0.016]). Moreover, higher scores of trait-anxiety exhibited an increase in update behavior for desirable information (M = 0.009 [0.004, 0.013]), but not for undesirable information (M = -0.003 [-0.007, 0.001]). In contrast, we did not find evidence that trait-IU was associated with the integration of information (Fig. 3 B, Main effect of trait-IU β = 0.001 [-0.001,0.001], trait-IU x News Valence x Prediction Error interaction β = 0.001 [-0.02, 0.02]). Regarding trait-optimism, marginal effect analysis revealed a difference in update behavior while receiving desirable compared to undesirable information (Fig. 3 C, Main effect of trait-optimism β = -0.001 [-0.01, 0.007], trait-optimism x News Valence x Prediction Error interaction β = 0.02 [0.01, 0.06], $M_{\text{difference}}$ = 0.012, HDI

[0.005, 0.019]). Finally, undesirable information showed a negative slope of *M* = -0.010 [-0.016, -0.003] indicating that higher levels of trait-optimism lead to lower levels of update, while the slope for good news wasn't different from 0 (*M* = 0.001 [-0.004, 0.008]).

2.2. Skin Conductance Response (SCR) and update behavior

When replicating the original statistical model including SCR as a predictor, we did not find evidence for an association between SCR and update behavior (Main effect β = 0.034 [-0.016, 0.088], SCR x News Valence x Prediction Error, β = 0.36 [-0.52, 1.04]). However, model comparison based on Pareto Smoothed importance sampling Leave-One-Out Cross-Validation indicated that a simpler model without trait-measures interactions provided a better model fit (Winning model: *News x SCR x Prediction Error + News x True Value + Trait Measures*; Supplementary material). Overall, we found results similar to those of the original model (Supplementary material). Interaction analysis of the winning model provided evidence that SCR levels in the time interval between subjects first estimate (P1) and the presentation of the actual base rate (PT), predicted subsequent update behavior (Fig. 4 A, Main effect SCR, β = -0.03 [-0.15, 0.09], SCR x News Valence x Prediction Error (β = 0.75 [0.16, 1.35]). Moreover, SCR levels were higher during the presentation of desirable information (*M* = 0.15 [0.13, 0.178] compared to undesirable information (*M* = 0.09 [0.07, 0.12], $M_{\text{difference}}$ = - 0.06 [-0.08, - 0.03].

2.3. Short-term and long-term memory of the presented base rate (PT)

As depicted in Fig. 4 B memory errors were higher at long-term testing compared to short-term testing (Interval β = -0.23 [-0.34, -0.12], short-term *M* = 0.02 [-0.02, 0.07], long-term *M* = 0.2 [0.14, 0.25], $M_{\text{difference}}$ = -0.06 [-0.07, -0.05]). Moreover, Prediction Error (β = 0.022 [0.13, 0.31] during the belief update task and the actual base rate (PT, β = 0.15 [0.09, 0.21]) predicted memory performance. Notably, we found no effect of news valence on memory retention (β = 0.01 [-0.29, 0.31]. Finally, trait-anxiety (β = -0.001 [-00002, 0.00001]), trait-IU (β = 0.001 [-00001, 0.00001]), and trait-optimism (β = 0.001 [-00001, 0.00001]) were not associated with memory errors at testing (see Supplementary material for details).

3. Discussion

The formation and updating of our belief system do not accurately or impartially represent the external world or even our inner world. Belief changes involve biased motivations, preferences, values, expectations, and other cognitive processes that alter our “objective rationality”(Kahneman, 2003; Loewenstein & Molnar, 2018). Thus, a robust finding is that individuals are more prone to update their beliefs when confronted with desirable information (“good news”) rather than undesirable information (“bad news”) regarding potential negative life-events (Sharot et al., 2011; Sharot & Garrett, 2016). Given this scenario, it is expected that differences in individual traits are associated with different information integration (updating) patterns. Our results provide evidence that trait-anxiety is strongly associated with the level of information integration of possible future negative events. More specifically, we found that the higher the levels of trait-anxiety, the greater the updating of desirable information but not undesirable information. On the other hand, the trait-intolerance of uncertainty (IU) was not associated with the update behavior. These results are aligned with the idea that the Intolerance of Uncertainty Scale (IUS) overlaps with more cognitive aspects of anxiety such as the need for controllability and fear of the unknown, while the State-Trait Anxiety Inventory (STAI) captures more affective aspects of dispositional anxiety such as the tendency to experience negative affect (Chen et al., 2018; Llera & Newman, 2023; Wroblewski et al., 2022). While anxiety is characterized by overestimating the probability of threats, optimism is characterized by underestimating them (Sweeny et al., 2006; Sweeny & Dooley, 2017). Accordingly, trait-optimism was also associated with asymmetrical belief updating. However, we found an interesting dissociation in how trait-anxiety and trait-optimism contribute to biased belief updating. Our results suggest that trait-anxiety mainly affects desirable information integration, whereas trait-optimism alters the way undesirable information is incorporated.

Consistent with previous findings (Garrett et al., 2018; Kuzmanovic et al., 2015; Sharot et al., 2011), update behavior was not explained by memory, as short-term and long-term retention of the actual base rate of negative events were similar for desirable and undesirable information and not associated with trait-measures. Thus, our results did not support the memory bias hypothesis for negative information in highly anxious individuals. On the other hand, electrodermal data indicated that changes in skin conductance between the first estimation (P1) and the presentation of the actual base rate (PT), predicted subsequent update behavior. However, this effect was not found to be associated with trait-measures. As a result, further investigation is required to explore the potential application of electrodermal activity as a marker of update behavior.

Contrary to the hypothesis that could be derived from the negativity bias in anxiety (Cisler & Koster, 2010; Coles & Heimberg, 2002; Grupe & Nitschke, 2013; MacLeod & Mathews, 2012), which suggests, that highly anxious individuals would exhibit unbiased belief updating, our findings indicate that individuals with high trait-anxiety tend to update desirable information to a greater extent than undesirable information. These findings are consistent with the Contrast Avoidance Model, which aims to explain the etiology and maintenance of anxiety and worry (Llera & Newman, 2014; Newman & Llera, 2011; Rashtbari & Saed, 2020). More specifically, the model proposes that individuals with generalized anxiety mainly avoid unexpected negative changes (contrasts) in their emotional state. Therefore, by generating sustained mild negative emotional states such as worry (expecting the worst-case scenario), highly anxious individuals prevent strong negative emotional contrasts. Consequently, as the worst-case scenario rarely occurs, highly anxious individuals experience relief and an increase in the likelihood of positive emotional contrast. Thus, threat-overestimation and worry are reinforced and maintained. For example, Kim & Newman (Kim & Newman, 2023) found that participants with Generalized Anxiety Disorder who engaged in worrying before watching a positive film clip experienced a greater increase in positive affect compared to those who had relaxed before the clip. A recent finding supported this result using momentary assessment and worry induction (Newman et al., 2019). In other paradigms, it was also found that the emotional impact of individuals receiving bad grades or discovering that they had tested positive for a fictitious disease was better when they had predicted the worst scenario than the best one (Sweeny & Dooley, 2017). These ideas resemble the ancient Stoic practice of "negative visualization" which suggests exercising our imagination to envision the worst-case scenario in order to prepare ourselves to face it and subsequently experience gratitude.

In our experiment, it could be considered that anxious individuals experience relief and a positive emotional contrast when they overestimate the threat of a negative event (first estimate) and receive desirable information (actual base rate < subjective estimate). This implies a greater integration of "better than expected" information which may function as a reassurance-seeking strategy. On the other hand, when anxious individuals underestimate the probability of a negative event (undesirable information), they would experience an aversive negative contrast, leading to decreased belief updating to avoid a greater negative emotional state. This suggests that in individuals with higher trait-anxiety levels, the hedonic value of a belief, namely, the expected relief, carries greater weight than its instrumental value in accurately predicting events (Bromberg-Martin & Sharot, 2020; Sharot et al., 2023). This perspective also clarifies the robust association between update behavior trait-anxiety but not trait-IU, as the former is more closely related to the affective experience of anxiety while the latter to the cognitive one. Future experiments on belief updating could incorporate trial-by-trial online measures of positive and negative affect after presenting the actual base rate (PT) to clarify the Contrast Avoidance model's hypothesis of anxiety.

Previous research has provided important insights into the ways that individuals update their beliefs in response to new information, and how these processes might differ among individuals with certain psychiatric conditions or traits. For example, studies have shown that patients with mood disorders tend to update their beliefs in an unbiased manner (Garrett et al., 2014; Korn et al., 2014), while individuals at risk of mania show an exaggerated integration of positive information (Schönfelder et al., 2017), and surprisingly that performance on this task could predict future relapse in bipolar patients (Ossola et al., 2020). Our study focused on individuals with different levels of trait-anxiety, and found that highly anxious individuals tend to integrate desirable information more strongly than undesirable information about negative future events. In line with the Contrast Avoidance Model, we propose that this phenomenon could occur due to the avoidance of unexpected negative emotional contrast, as well as positive contrast induced by relief. Our beliefs have a significant impact on our lives, public policy, and mental health. The study of beliefs holds promise for better understanding psychiatric disorders and developing new interventions in the field of psychotherapy.

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Conflict of interest

All authors declare to have no conflict of interest related to the presented work.

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Figure Captions.

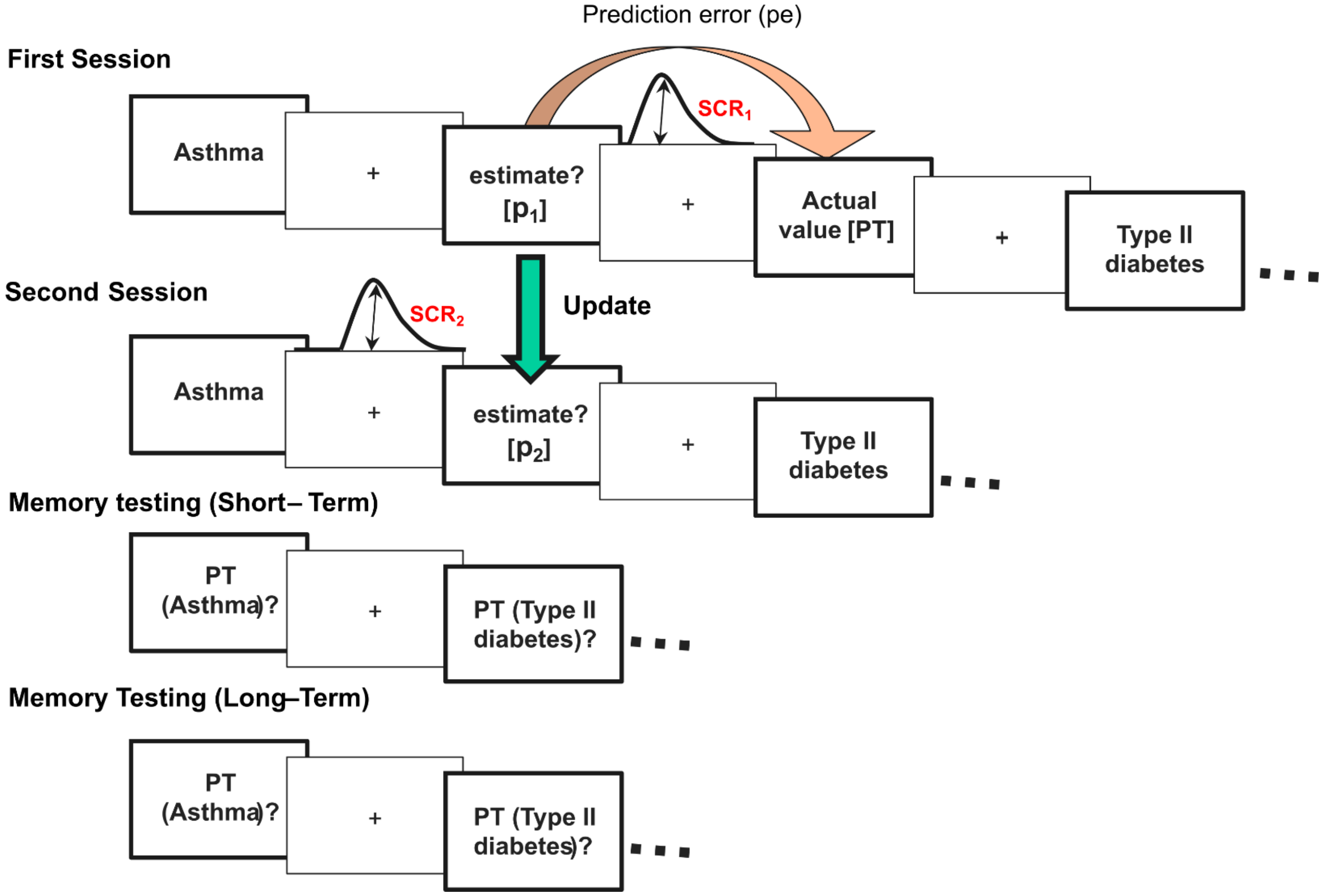

Fig. 1. Belief update Task. On each trial, subjects were presented with varying adverse life events and asked to estimate how likely this event was to occur to them in the future (First estimate – P1, First Session). Then the actual base rate for a person with a similar background (age, gender, and socio-economic status) was presented (True Value – PT). Trials were classified according to their valence. When P1 < PT it was considered that the subject received desirable information ("good news"). On the other hand, when P1 > PT the trial was classified as undesirable information ("bad news"). SCR picture corresponds to the moment in which it was measured in the trial. After finishing the 40 trials (events), participants proceeded to the second session in which they were asked again to re-estimate the likelihood of adverse life events happening

to them (P2). Update parameter is calculated as the absolute difference between the participants' estimates in the two sessions (P2-P1), before and after the information (PT) was given. Memory for the actual base rate (PT) was evaluated after the second session (Short-term) and 3 months later (Long-term).

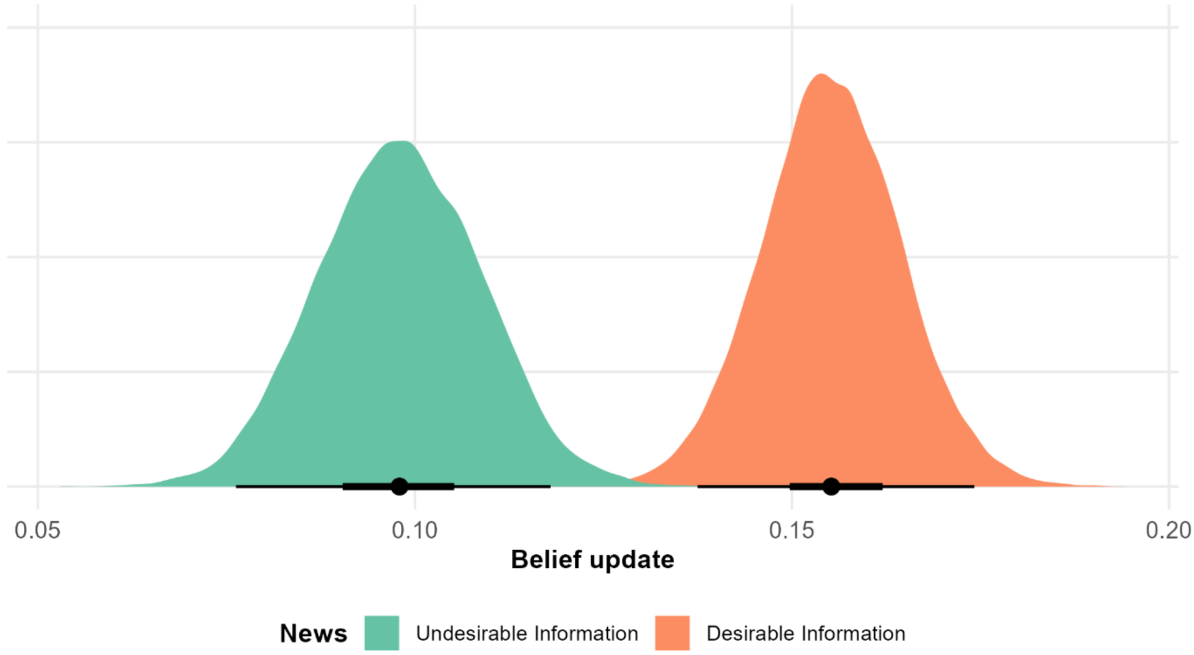

Fig.2. Belief update results. Posterior marginal effect of news valence (desirable / undesirable information). Subjects updated their estimations to a greater extent after receiving desirable information than undesirable information (asymmetrical belief updating).

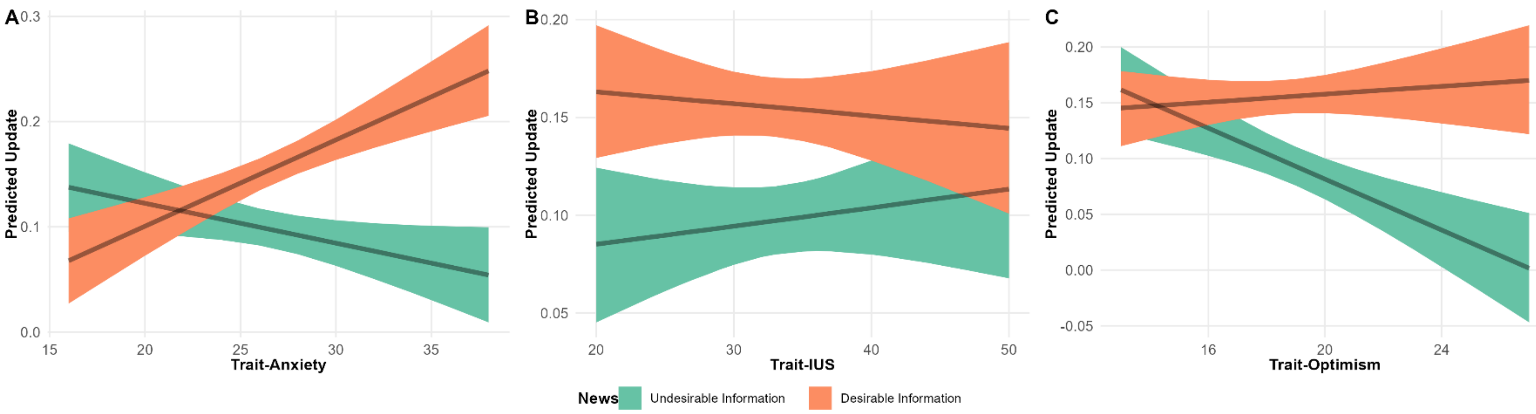

Fig.3. Belief updating as a function of trait-measures and news valence (desirable / undesirable information). Predicted marginal effect of Trait-measures on update behavior. (A) Trait-anxiety, (B) Trait-IU, (C) Trait-Optimism.

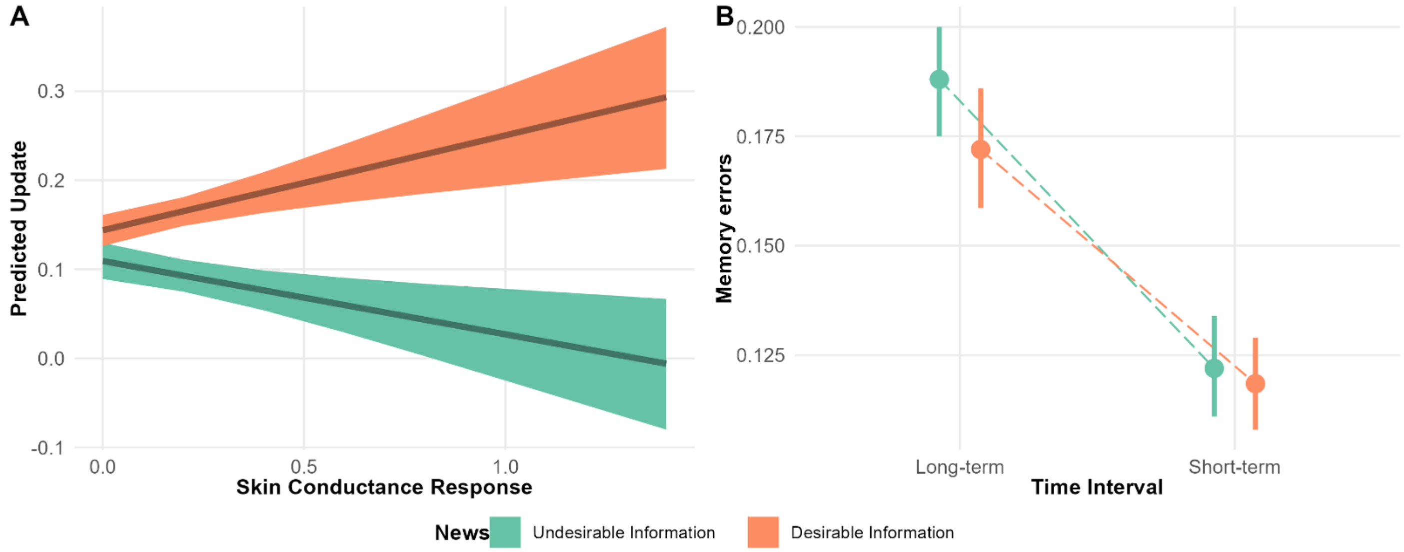

Fig.4. Skin Conductance Response (SCR) and Memory errors results. (A). Predicted marginal effect of SCR during belief update task. (B) Posterior marginal means of Memory errors at short-term (immediate) and long-term interval (3 months).