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Dispositional mindfulness attenuates the emotional attentional blink

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ABSTRACT

Emotional stimuli have been shown to automatically hijack attention, hindering the detection of forthcoming targets. Mindfulness is defined as a present moment non-judgemental attentional stance that can be cultivated by meditation practices, but that may present interindividual variability in the general population. The mechanisms underlying modification in emotional reactivity linked to mindfulness are still a matter of debate. In particular, it is not clear whether mindfulness is associated with a diminished emotional response, or with faster recovery. We presented participants with target pictures embedded in a rapid visual presentation stream. The targets could be preceded by negative, neutral or scrambled critical distractors. We showed that dispositional mindfulness, in particular the Non-reacting facet, was related to faster disengagement of attention from emotional stimuli. These results could have implications for mood disorders characterised by an exaggerated attentional bias toward emotional stimuli, such as anxiety and post-traumatic stress disorders.

1. Introduction

Efficiently detecting salient environmental information certainly had an adaptive value for our ancestors, since rapidly processing a possible threat or a source of forage presents obvious survival benefits. Emotionally laden stimuli are a paradigmatic example of biologically salient information. Nevertheless, in some cases, the automatic capture of cognitive resources by emotional stimuli is counterproductive. If attention is hijacked by events that are not relevant to the task at hand, execution of the task could be compromised. This phenomenon is exemplified by the Emotional Attentional Blink effect, consisting in a reduced ability to detect an imperative stimulus when it is closely preceded by an irrelevant emotional distractor (*e.g.*, McHugo, Olatunji, & Zald, 2013). A flexible management of emotional information appears, therefore, to be a key feature of healthy cognitive functioning. Indeed, aberrant attentional bias toward emotional stimuli has been repeatedly reported in different psychiatric conditions (Cisler & Koster, 2010; Williams, Mathews, & MacLeod, 1996).

Mindfulness is thought to foster flexible and adaptive emotional responses, even if the mechanisms producing this effect are still controversial. Expert mindfulness meditators have been reported to show less neural anticipatory activity and faster habituation to aversive events (pain), compared to novices (Lutz, McFarlin, Perlman, Salomons, & Davidson, 2013). Interestingly, this pattern was

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accompanied by a stronger activation in pain related brain regions (*e.g.*, insula) during painful stimulation. Another study, comparing expert and novice meditators, reported that when viewing negative pictures in a mindful state, both groups subjectively reported a decreased emotional response. Nonetheless, neuroimaging findings showed that this was achieved by two different neural pathways. Novices showed decreased activity in an emotion-related brain structure – the amygdala – that was not observed in experts, whereas the latter only showed a deactivation of default mode regions (Taylor et al., 2011). These findings suggest, in line with the proposition of a recent review (Chiesa, Serretti, & Jakobsen, 2013), that the emotional dynamic in novices is characterised by top-down control mechanisms, while in experts it is linked to a reduced cognitive reactivity to emotional stimuli.

Non-reacting and non-judgement are key constructs of different psychological models of mindfulness, defined both as a quality of awareness developed through the practice of meditation, but also as a personality trait, presenting interindividual variations among the general population (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). Although the tools assessing dispositional mindfulness have been criticised (*e.g.*, Grossman, 2011), recent studies have shown that self-reported dispositional mindfulness is linked to structural and functional variability in brain structures related to attentional (*e.g.*, fronto-parietal and salience networks) and emotional (*e.g.*, amygdala and medial frontal regions) processes (Kong, Wang, Song, & Liu, 2016; Lu et al., 2014; Murakami et al., 2012; Taren, Creswell, & Gianaros, 2013; Zhuang et al., 2017). These results suggest that the construct validity of self-reported dispositional mindfulness scales is satisfactory.

Surprisingly, few studies have directly investigated the link between dispositional mindfulness and emotional processing. Two studies reported that trait mindfulness was associated with an increased neural signature of implicit (Creswell, Way, Eisenberger, & Lieberman, 2007) and explicit emotion regulation (Modinos, Ormel, & Aleman, 2010). An EEG study showed that a higher mindfulness trait was related to a weaker neural marker of emotional response (Late Positive Potential – LPP), for both pleasant and unpleasant stimuli (Brown, Goodman, & Inzlicht, 2012). Nevertheless, a more recent study failed to replicate the association between trait mindfulness, LPP amplitude and other physiological markers of emotional arousal (Cosme & Wiens, 2015). While the reason for this inconsistency is unclear, the absence of emotion modulation in its generative phase is coherent with the aforementioned results (Lutz et al., 2013; Taylor et al., 2011), as well as with the core definition of mindfulness. Indeed, mindfulness is not conceptualised as a dampening of emotional reaction, but rather as a stance of open awareness and acceptance to experiences of all kinds. Moreover, while the LPP is usually understood as a marker of automatic attention toward emotional stimuli, it can be modulated by motivational or voluntary control processes (Hajcak, Dunning, & Foti, 2009). Thus, these studies might not be well suited to directly investigate how early automatic emotion-directed attentional mechanisms are modulated by dispositional mindfulness.

The main aim of the present work was to study the relationship between dispositional mindfulness and early attentional capture by emotional stimuli in a population naive to meditation practice. We took advantage of the Emotional Attentional Blink (EAB) effect. This phenomenon arises when, in a rapid serial visual presentation stream, the presence of an emotionally irrelevant arousing stimulus transiently hinders the detection of a subsequent target. The duration of this emotion-induced blindness could be considered as a measure of the attentional efficiency in disengaging from the emotional distractor and refocusing on the task (*e.g.*, McHugo et al., 2013). We measured the detection threshold for target pictures that were preceded by three types of critical distractors: negative, neutral, and scrambled images. Our main hypothesis was that a higher dispositional mindfulness would be related to a faster attentional recovery in the emotional (*i.e.,* negative) condition. To further investigate the underlying mechanism, we added a surprise recognition task for the critical distractors. We hypothesized that if the reduction of the delay needed to detect the target in participants with higher mindfulness traits was due to a lower attentional capture, we should expect poorer memory performances compared to participants with low mindfulness traits. On the contrary, if this effect is supported by a faster attentional disengagement, no differences should be observed in the recognition rate. These results would make it possible to clarify whether mindfulness is linked to emotional dampening (lower attentional capture) or to an acceptance stance toward emotional stimuli (faster attentional disengagement).

2. Material and methods

2.1. Participants

Participants were 34 French native volunteers recruited through advertisement. Exclusion criteria were any neurological or psychiatric disease, and the practice of any form of meditation. Two participants were excluded due to technical problems, and three were removed for having outlying discrimination scores (see Section 3). The final sample was composed of 29 participants (Age: 29.55 ± 12.99, 62% female). All participants were informed of the academic nature of the study and accepted that their responses would be processed anonymously. The local ethics committee approved the study.

2.2. Questionnaires

The mindfulness trait was assessed using the Five Facets Mindfulness Questionnaire (FFMQ; Baer et al., 2008; French version, Heeren, Douilliez, Peschard, Debrauwere, & Philippot, 2011). The FFMQ contains 39 items measuring 5 different components: *Observing, Describing, Acting with Awareness, Non-judging* and *Non-reacting*. *Observing* refers to the ability of attending to internal and external events; *Describing* refers to the tendency and the ability to verbally label internal experiences; *Acting with Awareness* is linked to attending to one's present activities; *Non-judging* is related to a non-evaluative stance of one's own feelings and thoughts; *Non-reacting* describes the tendency to allow one's own feelings and thoughts to pass by without getting caught up in them.

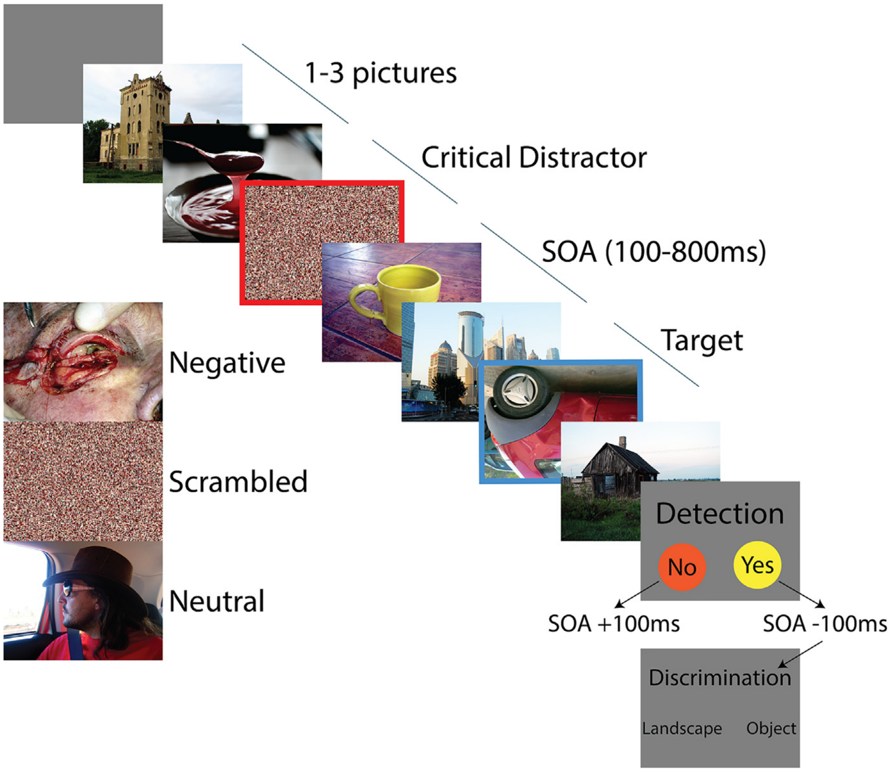

Fig. 1. The EAB procedure. The critical distractor is outlined in red, and the target in blue. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.3. Emotional attentional blink task

2.3.1. Stimuli

We selected 423 pictures from the Affective Picture System (NAPS; Marchewka, Żurawski, Jednoróg, & Grabowska, 2014), a standardized, high-quality, realistic picture database, based on normative data for arousal and valence. Among them, 297 pictures representing landscapes or objects (arousal between 3 and 5, on a scale from 1 = very negative to 9 = very positive, with 5 = neutral; valence between 4.25 and 5.75, on a scale from 1 = relaxed to 9 = aroused, with 5 = neutral/ambivalent) composed the distractor pool. The 126 remaining pictures represented faces or people and were used as critical distractors. Among them, 63 were emotionally neutral (following the same criteria as distractors and targets), and 63 were emotionally negative (arousal > 6.5, Valence < 3). For each participant, 42 negative critical distractors (2/3 of the available items), 42 neutral critical distractors, and 126 pictures from the distractor pool for the target set, with an equal number of landscapes and objects were randomly selected among the total pool. The remaining critical distractors were used as lures in the subsequent recognition task. The software then created a third set of critical distractors by scrambling the selected negative critical distractors. This condition was used as a control for low-level visual features of the stimuli.

2.3.2. Detection

Participants were tested on a 24-inch monitor (1920 × 1080, 60 Hz) at a distance of 80 cm. The experiment was programmed in Python 3.5 using the Neuropsydia module (Makowski & Dutriaux, 2017). The main task consisted of 126 trials equally distributed in 3 conditions: negative, neutral and scrambled. Each condition consisted of 42 trials, including 36 target trials and 6 catch trials (*i.e.*, that did not contain any target). In target trials, the target consisted of a picture flipped upside down. In addition to the target, each trial included one critical distractor (defining the condition) as well as 15 distractor pictures randomly picked with replacement out of the distractor pool. Within each trial sequence (see Fig. 1), the 17 pictures were presented on a neutral grey background in the centre of the computer screen (60 Hz refresh) for 100 ms (6 frames). The critical distractor position in the sequence randomly varied between position 3 and 6. The target was positioned within the 8 subsequent pictures, depending on the SOA (varying between 100 ms, *i.e.,* the target immediately following the critical distractor; and 800 ms, the target being preceded by 7 distractors). Distractor pictures filled the remaining positions. The task of the participants was to carefully attend to the sequence of pictures and detect the picture that was flipped upside down. At the end of each trial, participants were asked whether they had detected the target, with a binary yes/no answer (detection). If the participant answered “yes”, they were asked whether the picture was a landscape or object (discrimination). The SOA varied following a condition wise one-up-one-down staircase procedure. The starting

SOA was always set at 800 ms; it decreased by 100 ms when the participant detected the target, and increased by 100 ms in the contrary case (catch trial responses were not considered for staircase adjustment).

2.3.3. Recognition

After the Detection phase participants were requested to fill in the questionnaire (≈20 min). During the recognition phase the 42 neutral and the 42 negative critical distractors were randomly presented, intermixed with 42 new stimuli (half neutral and half negative). To disentangle the phenomenological level of recollection, we used an RKG procedure (Gardiner, 2001). For each stimulus, the participants could answer No ("The picture was not presented"), Guess ("I suppose that the picture was presented"), Know ("I know that the picture was presented") and Remember ("I remember that the picture was presented, I can re-experience the encoding context"). Finally, participants were thanked and debriefed.

2.4. Statistical analysis

Statistical analysis was performed using R (R Development Core Team, 2008) and the *psycho* (Makowski, 2018), the *BayesFactor* (Morey, Rouder, & Jamil, 2015) and the *rstanarm* (Gabry & Goodrich, 2016) packages. The analysis was performed in the Bayesian framework as it appeared more reliable, with better accuracy in noisy or small data samples, a more straightforward interpretation and less prone to type I error (Andrews & Baguley, 2013; Etz and Vandekerckhove, 2016; Kruschke, 2010; Kruschke, Aguinis, & Joo, 2012; Wagenmakers et al., 2018). Bayesian inference was done using Markov Chain Monte Carlo (MCMC) sampling. Bayes factors (*BF*) for t-tests and ANOVAs were interpreted using Jeffreys (1961) heuristics (Jarosz & Wiley, 2014). For the general linear models, all priors were set as mildly informative (normal distributions with mean = 0). For all mixed models, participants were set as the random factor. For all models, we report several characteristics of the posterior distribution of the effects: the median (a robust estimate comparable to the beta from frequentist linear models), MAD (median absolute deviation, a robust equivalent of standard deviation) and the 90% *credible* interval. Moreover, for the mixed models, instead of the *p* value as an index of effect existence, we also computed the maximum probability of effect (MPE), *i.e.*, the maximum probability that the effect is different from 0 in the median's direction. For our analyses, we will consider an effect as probable if its MPE is higher than 90%.

3. Results

3.1. Manipulation check

3.1.1. False detection ratio

For each participant, we computed the ratio of "detected" answers in the catch trials (Mean = 0.20, SD = 0.19). These false detection ratios were half-normally distributed, revealing three outliers (with a ratio exceeding the mean by 1.96 standard deviations) that were removed for the remaining analysis.

3.1.2. Staircase convergence

To check whether the staircase procedure converged, we compared the probability that the actual performance was different (alternative hypothesis) from the expected performance (frequency of detection equal to 0.5, the null hypothesis). There was moderate (for the negative condition) and anecdotal (for neutral and scrambled) evidence against the alternative hypothesis ($M_{negative} = 0.49$, SD = 0.17, BF = 0.20; $M_{neutral} = 0.54$, SD = 0.18, BF = 0.34; $M_{scrambled} = 0.53$, SD = 0.21, BF = 0.34), suggesting an effective staircase convergence. Additionally, the Bayesian one-way ANOVA suggested moderate evidence in favour of the null hypothesis (BF = 0.16).

3.1.3. Correct discrimination

To ensure that participants responded "detected" when they had genuinely detected the target, we verified whether the ratio of correct discrimination was greater than chance (0.5). There is extreme evidence that correct discrimination ratios were different from 0.5 in all conditions ($M_{negative} = 0.65 \pm 0.12$, BF > 100; $M_{neutral} = 0.69 \pm 0.11$, BF > 100; $M_{scrambled} = 0.72 \pm 0.12$, BF > 100). Additionally, the one-way ANOVA comparing the discrimination ratio between the three conditions yielded anecdotal evidence in favour of the null hypothesis (BF = 0.62).

3.2. Emotional attentional blink effect

3.2.1. Detection threshold

The detection threshold (DT) for each participant and each condition was computed as the mean SOA at each inversion point (*i.e.,* items for which the SOA at $n - 1 = n + 1_)$. We fitted a Bayesian linear mixed model with the DT as outcome variable and the condition as fixed factor. The overall model explained about 78% (R2 median) of the outcome's variance. The model's intercept (the neutral condition) was at 478.32 (see Fig. 2A). Within this model, only the negative condition led to a different (higher) threshold (Negative: Median = 75.13, MAD = 29.28, 90% CI [27.41, 126.58], MPE = 99.33%; Scrambled: Median = −18.10, MAD = 29.64, 90% CI [−64.91, 32.79], MPE = 73.20%). Additionally, an estimated marginal means comparison showed that the negative condition also led to a higher threshold compared to the scrambled condition (Median = 93.50, MAD = 29.09, 90% CI [44.65, 140.85], MPE = 99.85%). See Fig. 2B.

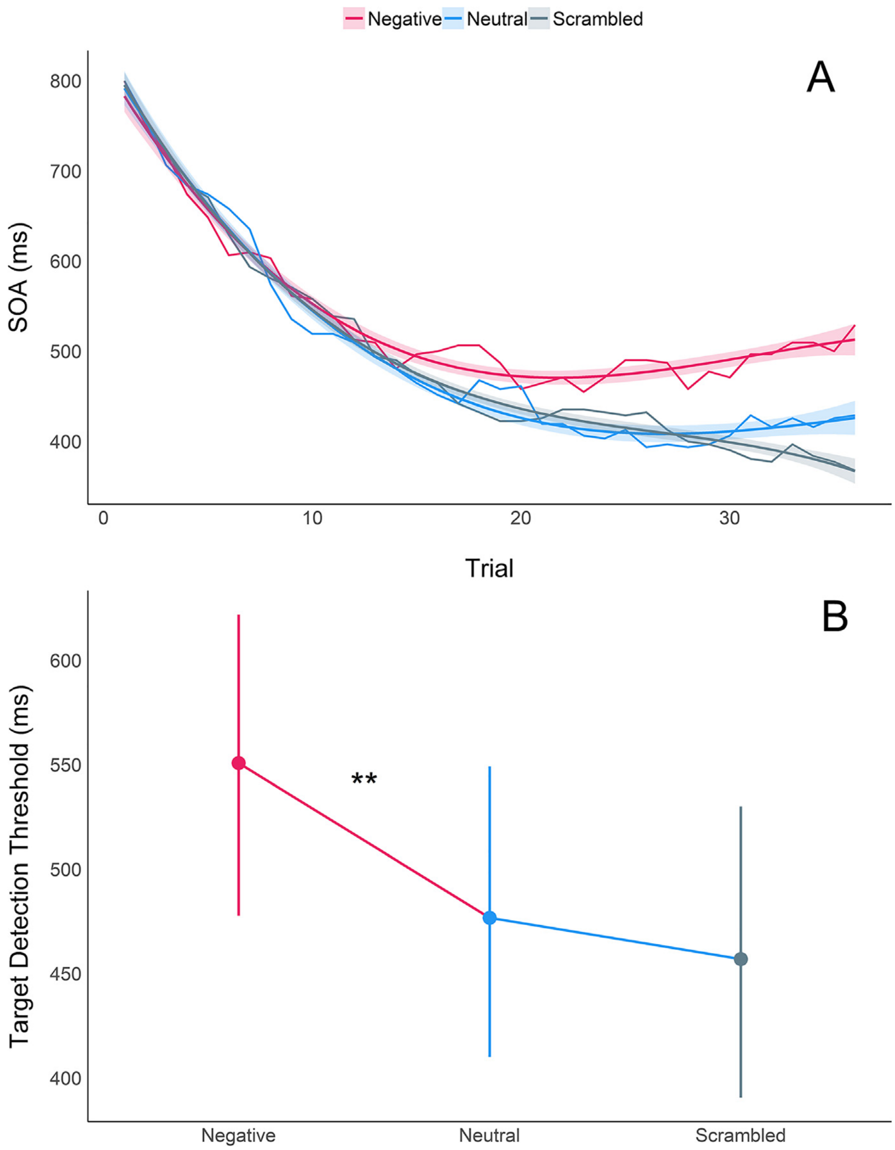

Fig. 2. The effect of condition on the SOA (top) and detection threshold (bottom). Top: The SOA started at 800 ms for the three conditions, then varied (± 100 ms) depending on the participant's detection answer. The bold line represents a 3rd order polynomial fit of the mean evolution (represented by the thin line), and the ribbon represents its 95% confidence level interval. Bottom: The detection threshold (mean SOA at each inversion point) estimated marginal means. The points represent the medians of the posterior distributions and the bars their 90% credible intervals.

3.2.2. Recognition

Due to technical problems, 2 participants did not carry out the recognition task. For the remaining participants, we computed the number of each recognition answer type ("Remember", "Know", "Guess" and "No") for the negative and neutral condition (scrambled pictures were not presented in the recognition task). Moreover, this score was separately computed for critical distractors followed by a detected or a non-detected target. Due to the low number of recognition answers other than "No" (see Fig. 3A), we grouped the other types of responses together and created a binary recognition factor.

Then, we fitted a Bayesian logistic mixed model to predict the probability of recognition of the critical distractors with emotion (negative/neutral) conditions and target detection (detected/not-detected) as fixed factors. The model explained about 11% of the outcome's variance. The model's intercept (negative and undetected target) was at −1.61. Within this model, in the negative condition, the target detection was related to a lower probability of distractor recognition (Median = −0.49, MAD = 0.18, 90% CI [−0.79, −0.19], MPE = 99.57%). This relationship interacted with the neutral condition, in which the target detection was related to a higher probability of distractor recognition (Median = 0.94, MAD = 0.26, 90% CI [0.49, 1.36], MPE = 99.97%). Moreover, when the target was not detected, the negative condition, compared to the neutral one, was related to a higher probability of recognition (Median = 0.57, MAD = 0.20, 90% CI [0.26, 0.88], MPE = 99.87%). On the contrary, when the target was detected, the

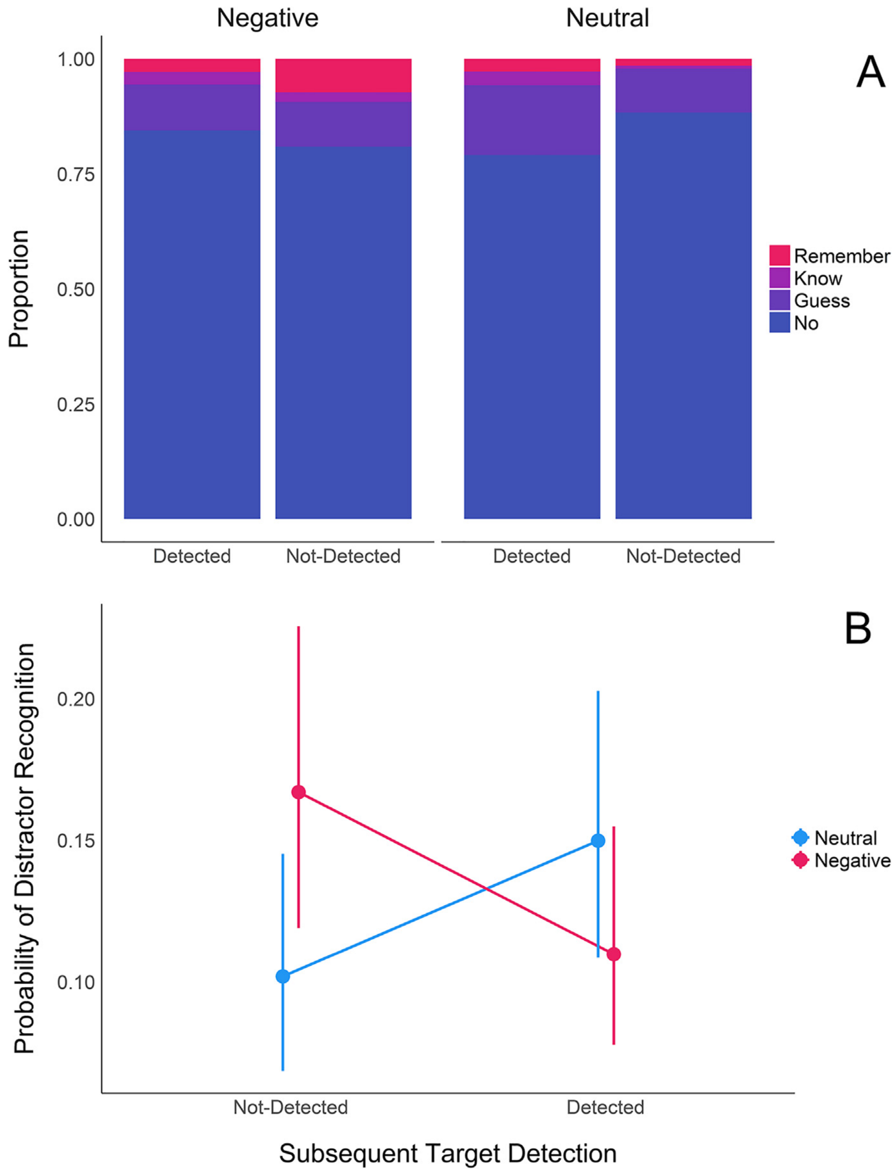

Fig. 3. Answer type proportion (top) and recognition probability for critical distractors (bottom) depending on the condition and the subsequent target detection. The analysis shows that all levels (contrasts) are statistically different.

negative condition, compared to the neutral one, was associated with a lower probability of recognition (Median = −0.57, MAD = 0.20, 90% CI [−0.88, −0.26], MPE = 99.87%). See Fig. 3B.

3.3. The effect of mindfulness

3.3.1. Detection threshold

To investigate the interaction between the detection threshold and mindfulness, we fitted a Bayesian multiple linear regression model to predict the detection threshold in the negative condition with the 5 mindfulness facets measured by the FFMQ. All variables were standardized, so that the coefficients (expressed in terms of standard deviations) drawn from the different models can be interpreted using Cohen (1988) *d* set of rules of thumb (0.2, 0.5, 0.8 corresponding respectively to small, medium and large effects). The Bayesian framework, returning a distribution of values instead of a single coefficient, reports the probability of each effect size category. The model explained about 39% of the outcome's variance. The model's intercept was at 0.0051. Within this model, only the linear relationship between the detection threshold and the Non-reacting facet was probable (Median = −0.47, MAD = 0.17, 90% CI [−0.76, −0.20], MPE = 99.55%, see Fig. 4A) and can be considered as large, medium, small and very small with respective probabilities of 2.85%, 39.85%, 52.05% and 4.80%. The full model is presented in **Supplementary Statistics**.

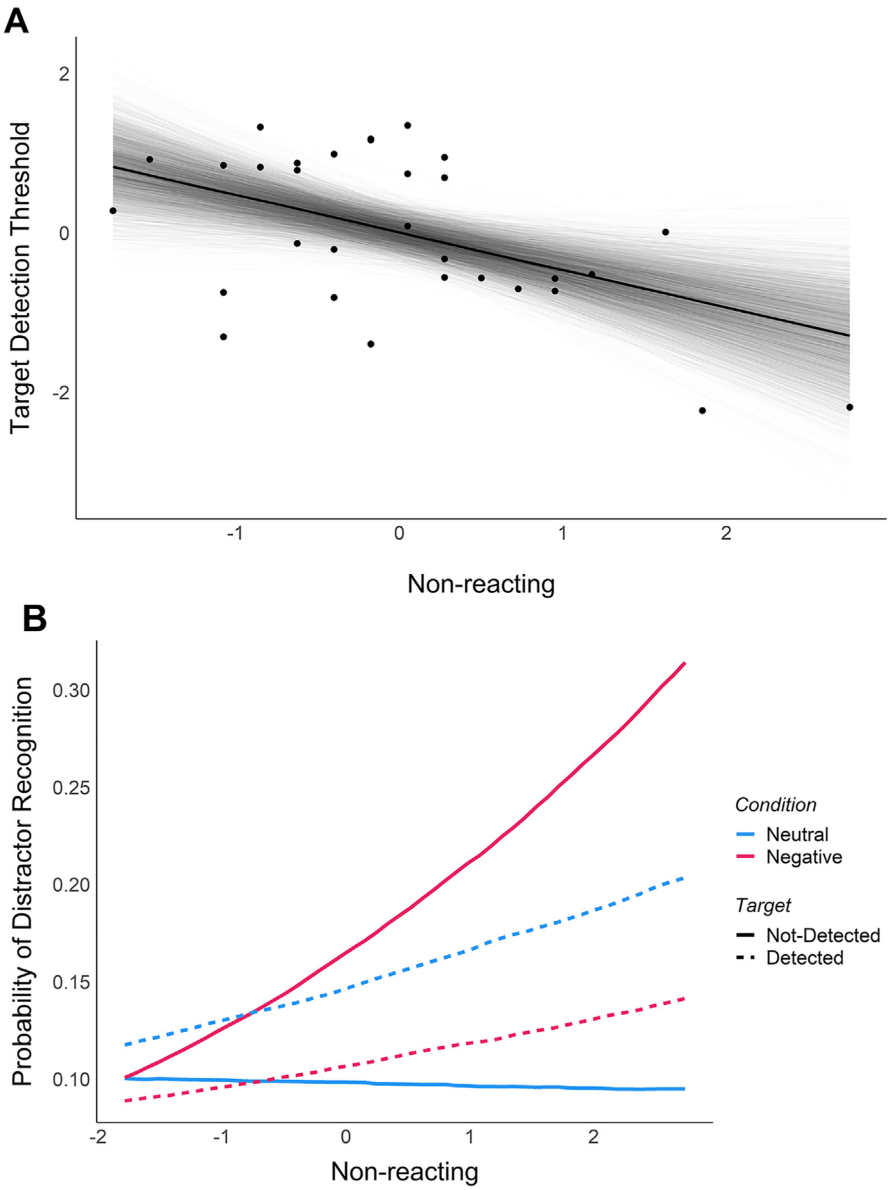

Fig. 4. Relationship between the Non-reacting mindfulness trait and target detection threshold (top) and critical distractor recognition (bottom). Top: the bold line represents the median of the effect (based on the Bayesian linear model), and the thin lines represent all the draws from the posterior distribution (all possible effects compatible with our data). Bottom: The median relationship (based on the Bayesian logistic mixed model) between Non-reacting and the probability of critical distractor recognition for negative and neutral critical distractors, when the subsequent target was detected or not.

3.3.2. Recognition

To test if the same mindfulness facet (Non-reacting) modulating the detection threshold was related to distractor recognition performances, we added it within the logistic model predicting the recognition score. The model predicted about 11% of the outcome's variance. The model's intercept (neutral condition, undetected target, and mean (0) Non-reacting) was at −2.22. Critically for this model, Non-reacting appeared to be unrelated to recognition for the neutral-undetected (Median = −0.019, MAD = 0.26, 90% CI [−0.45, 0.42], MPE = 52.67%), and neutral-detected conditions (Median = 0.16, MAD = 0.20, 90% CI [−0.14, 0.52], MPE = 79.63%). However, in the negative and undetected target condition, higher Non-reacting is linked to higher recognition probability (Median = 0.33, MAD = 0.22, 90% CI [−0.047, 0.67], MPE = 93.53%). Moreover, this positive link is dampened when the target is detected (Median = −0.37, MAD = 0.27, 90% CI [−0.78, 0.11], MPE = 91%). See Fig. 4B. The full model is presented in **Supplementary Statistics**.

4. Discussion

In the present work, we tested the link between dispositional mindfulness and automatic capture of attention by emotional stimuli. The main findings were that higher trait mindfulness, specifically the Non-reacting facet, was associated with a shorter attentional recovery, after emotional critical distractors. This effect was even paired with an increase in the probability of recognising the negative distractors, more pronounced for those distractors that were followed by a detection failure. Taken together, these results suggest that higher Non-reacting is not associated with less attentional engagement toward irrelevant emotional distractors, but rather with a faster disengagement.

We first conducted a series of analyses to ensure that our staircase version of the EAB was effective in capturing the cognitive processes we wished to study. We basically replicated existing results by showing that a negative picture, presented in a rapid visual stream, automatically captured attentional resources, thus hindering, for a longer interval compared to neutral and scrambled pictures, the conscious detection of a subsequent target. This effect was not caused by the content of the pictures (*i.e.,* humans), which was shared by both the neutral and the negative pictures, nor by the low-level perceptual features (*e.g.,* colours, brightness), shared by both the negative and the scrambled pictures, but rather by the emotional nature of the stimuli. The affective nature of the distractors and the successful detection of the target interactively modulated the probability of recognition of critical distractors. Negative distractors that successfully interfered with target detection were associated with higher recognition performance, suggesting a deeper processing of these distractors likely due to higher attentional capture. On the contrary, neutral distractors were better recognized when they were followed by successful target detection. This might be explained by a modification in the attentional capture dynamics: neutral pictures could have played a warning role, fostering attentional preparation. These results corroborate the attentional nature of the emotional attentional blink effect (Mathewson, Arnell, & Mansfield, 2008).

The main finding is that higher Non-reacting scores measured by the FFMQ were associated with a faster attentional recovery in the negative condition, but not with lower recognition performances for the emotional distractors. We interpret these results as a more flexible allocation of attention between irrelevant emotional stimuli and task salient information. These findings are coherent with those reported by Slagter et al. (2007), employing a standard attentional blink task, of better allocation of limited brain resources between stimuli competing for attention, and expand these results to emotional stimuli. Accordingly, this facet of mindfulness refers to the tendency to allow one's own feelings and thoughts to pass by without getting caught up in them. Non-reacting is a core feature of mindfulness, and can be seen as a component of accepting present-moment experience without reacting impulsively (Baer et al., 2006). This definition is, thus, coherent with the faster recovery of attentional resources after the negative images reported here.

Interestingly, Most, Chun, Widders, and Zald (2005) reported that participants with a high score in harm avoidance, a personality trait related to anxiety and negatively associated with mindfulness Non-reacting (Baer et al., 2006), were unable to reduce the EAB effect under instruction meant to facilitate ignoring the emotional stimulus. In a following study, the same authors found that high harm avoidance volunteers showed increased amygdala activity in reaction to negative critical distractors that they failed to ignore (Most, Chun, Johnson, & Kiehl, 2006). The effect observed here could be analogously assigned to a lesser amygdala engagement in participants with higher Non-reacting scores. This would be coherent with the results of one study reporting a negative correlation between mindfulness trait and amygdala grey matter volume (Taren et al., 2013). Nevertheless, Taren et al. employed a different measure of dispositional mindfulness, the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003). Thus, their results can hardly be compared to ours. Moreover, a recent paper reported a differential association between the MAAS and FFMQ scores and regional brain anatomy. In particular, the Non-reacting score was uniquely related with diminished cortical thickness in the superior prefrontal cortex (Zhuang et al., 2017). The functional meaning of this association is not clear, and can even seem counterintuitive, given the role of this region in cognitive control processes (Boisgueheneuc et al., 2006). Interestingly, decreased grey matter volume in the same region has been reported to negatively correlate with divergent thinking in healthy subjects (Tu, Kuan, Li, & Su, 2017). Moreover, Chen et al. (2014) found an inverse relationship between creativity and resting-state functional connectivity between superior prefrontal and anterior cingulate cortices. This correlation was fully mediated by cognitive flexibility abilities. These results suggest that Non-reacting could be related to neural signatures of cognitive flexibility, a main feature of mindfulness (Moore & Malinowski, 2009). However, considering the behavioural nature of our study, this interpretation is, at the moment, largely speculative, advocating for future neuroimaging investigations.

In summary, our results suggest that the affective benefits associated with mindfulness could be linked to the modification of early automatic attentional processes, rather than enhanced top-down cognitive control mechanisms. In particular, mindfulness appears to support a faster recovery, or disengagement, of cognitive resources from emotional stimuli, rather than dampening the emotional response *per se*. An obvious limitation of the present study is that our conclusions are based on a correlational approach, making interpretations in terms of causal relations very speculative. Future longitudinal studies are mandatory for shedding light on the causal role of mindfulness on the early attentional processes toward emotional stimuli. These findings cast new light on the possible mechanisms underlying mindfulness intervention efficiency in different mood disorders, since exaggerated attentional capture by emotional stimuli has been reported, for example, in post-traumatic stress disorder (Olatunji, Armstrong, McHugo, & Zald, 2013) and anxiety (Olatunji, Ciesielski, Armstrong, Zhao, & Zald, 2011). Future research, employing tasks similar to that of the present study, could investigate the impact of mindfulness-based psychotherapeutic interventions on both the neural and behavioural early response to emotional stimuli in these populations.

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Compliance with Ethical Standards

Author Dominique Makowski declares that he has no conflict of interest. Author Marco Sperduti declares that he has no conflict of interest. Author Samantha Lavallée declares that she has no conflict of interest. Author Serge Nicolas declares that he has no conflict of interest. Author Pascale Piolino declares that she has no conflict of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2018.11.004.

References

Andrews, M., & Baguley, T. (2013). Prior approval: The growth of Bayesian methods in psychology. *British Journal of Mathematical and Statistical Psychology, 66*(1), 1–7.
Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment, 13*(1), 27–45.
Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., & Williams, J. W. G. (2008). Construct validity of the five facet mindfulness questionnaire in meditating and nonmeditating samples. *Assessment, 15*(3), 329–342. https://doi.org/10.1177/1073191107313003.
du Boisgueheneuc, F., Levy, R., Volle, E., Seassau, M., Duffau, H., Kinkingnehun, S., et al. (2006). Functions of the left superior frontal gyrus in humans: A lesion study. *Brain, 129*(12), 3315–3328.
Brown, K. W., Goodman, R. J., & Inzlicht, M. (2012). Dispositional mindfulness and the attenuation of neural responses to emotional stimuli. *Social Cognitive and Affective Neuroscience, 8*(1), 93–99.
Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84*(4), 822.
Chen, Q., Yang, W., Li, W., Wei, D., Li, H., Lei, Q., et al. (2014). Association of creative achievement with cognitive flexibility by a combined voxel-based morphometry and resting-state functional connectivity study. *NeuroImage, 102*, 474–483.
Chiesa, A., Serretti, A., & Jakobsen, J. C. (2013). Mindfulness: Top–down or bottom–up emotion regulation strategy? *Clinical Psychology Review, 33*(1), 82–96.
Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review, 30*(2), 203–216.
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
Cosme, D., & Wiens, S. (2015). Self-reported trait mindfulness and affective reactivity: A motivational approach using multiple psychophysiological measures. *PloS One, 10*(3), e0119466.
Creswell, J. D., Way, B. M., Eisenberger, N. I., & Lieberman, M. D. (2007). Neural correlates of dispositional mindfulness during affect labeling. *Psychosomatic Medicine, 69*(6), 560–565.
Etz, A., & Vandekerckhove, J. (2016). A Bayesian perspective on the reproducibility project: Psychology. *PLoS ONE, 11*(2), https://doi.org/10.1371/journal.pone.0149794.
Gabry, J., & Goodrich, B. (2016). rstanarm: Bayesian applied regression modeling via stan. *R Package Version, 2*(1).
Gardiner, J. M. (2001). Episodic memory and autonoetic consciousness: A first–person approach. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 356*(1413), 1351–1361.
Grossman, P. (2011). Defining mindfulness by how poorly I think I pay attention during everyday awareness and other intractable problems for psychology's (re) invention of mindfulness: comment on Brown et al. (2011).
Hajcak, G., Dunning, J. P., & Foti, D. (2009). Motivated and controlled attention to emotion: Time-course of the late positive potential. *Clinical Neurophysiology, 120*(3), 505–510.
Heeren, a., Douilliez, C., Peschard, V., Debrauwere, L., & Philippot, P. (2011). Cross-cultural validity of the Five Facets Mindfulness Questionnaire: Adaptation and validation in a French-speaking sample. *Revue Europeene de Psychologie Appliquee, 61*(3), 147–151. https://doi.org/10.1016/j.erap.2011.02.001.
Jarosz, A. F., & Wiley, J. (2014). What are the odds? A practical guide to computing and reporting Bayes factors. *The Journal of Problem Solving, 7*(1), 2.
Jeffreys, H. (1961). *Theory of probability* (3rd ed.). Oxford: Oxford University Press.
Kong, F., Wang, X., Song, Y., & Liu, J. (2016). Brain regions involved in dispositional mindfulness during resting state and their relation with well-being. *Social Neuroscience, 11*(4), 331–343.
Kruschke, J. K. (2010). What to believe: Bayesian methods for data analysis. *Trends in Cognitive Sciences, 14*(7), 293–300.
Kruschke, J. K., Aguinis, H., & Joo, H. (2012). The time has come: Bayesian methods for data analysis in the organizational sciences. *Organizational Research Methods, 15*(4), 722–752.
Lu, H., Song, Y., Xu, M., Wang, X., Li, X., & Liu, J. (2014). The brain structure correlates of individual differences in trait mindfulness: A voxel-based morphometry study. *Neuroscience, 272*, 21–28.
Lutz, A., McFarlin, D. R., Perlman, D. M., Salomons, T. V., & Davidson, R. J. (2013). Altered anterior insula activation during anticipation and experience of painful stimuli in expert meditators. *Neuroimage, 64*, 538–546.
Makowski, D. (2018). The psycho Package: An efficient and publishing-oriented workflow for psychological science. *Journal of Open Source Software, 3*(22), 470.
Makowski, D., & Dutriaux, L. (2017). Neuropsydia.py: A python module for creating experiments, tasks and questionnaires. *Journal of Open Source Software, 2*(19), https://doi.org/10.21105/joss.00259 259.
Marchewka, A., Żurawski, Ł., Jednoróg, K., & Grabowska, A. (2014). The Nencki Affective Picture System (NAPS): Introduction to a novel, standardized, wide-range, high-quality, realistic picture database. *Behavior Research Methods, 46*(2), 596–610. https://doi.org/10.3758/s13428-013-0379-1.
Mathewson, K. J., Arnell, K. M., & Mansfield, C. A. (2008). Capturing and holding attention: The impact of emotional words in rapid serial visual presentation. *Memory & Cognition, 36*(1), 182–200.
McHugo, M., Olatunji, B. O., & Zald, D. H. (2013). The emotional attentional blink: What we know so far. *Frontiers in Human Neuroscience, 7*, 151. https://doi.org/10.3389/fnhum.2013.00151.
Modinos, G., Ormel, J., & Aleman, A. (2010). Individual differences in dispositional mindfulness and brain activity involved in reappraisal of emotion. *Social Cognitive and Affective Neuroscience, 5*(4), 369–377.
Moore, A., & Malinowski, P. (2009). Meditation, mindfulness and cognitive flexibility. *Consciousness and Cognition, 18*(1), 176–186.
Morey, R. D., Rouder, J. N., & Jamil, T. (2015). BayesFactor: Computation of Bayes factors for common designs. *R Package Version 0.9, 9* 2014.
Most, S. B., Chun, M. M., Johnson, M. R., & Kiehl, K. A. (2006). Attentional modulation of the amygdala varies with personality. *Neuroimage, 31*(2), 934–944.

Most, S. B., Chun, M. M., Widders, D. M., & Zald, D. H. (2005). Attentional rubbernecking: Cognitive control and personality in emotion-induced blindness. *Psychonomic Bulletin & Review, 12*(4), 654–661.
Murakami, H., Nakao, T., Matsunaga, M., Kasuya, Y., Shinoda, J., Yamada, J., et al. (2012). The structure of mindful brain. *PloS One, 7*(9), e46377.
Olatunji, B. O., Armstrong, T., McHugo, M., & Zald, D. H. (2013). Heightened attentional capture by threat in veterans with PTSD. *Journal of Abnormal Psychology, 122*(2), 397.
Olatunji, B. O., Ciesielski, B. G., Armstrong, T., Zhao, M., & Zald, D. H. (2011). Making something out of nothing: Neutral content modulates attention in generalized anxiety disorder. *Depression and Anxiety, 28*(5), 427–434.
R Development Core Team. (2008). R: A Language and Environment for Statistical Computing. Vienna, Austria. Retrieved from http://www.r-project.org.
Slagter, H. A., Lutz, A., Greischar, L. L., Francis, A. D., Nieuwenhuis, S., Davis, J. M., et al. (2007). Mental training affects distribution of limited brain resources. *PLoS Biology, 5*(6), e138.
Taren, A. A., Creswell, J. D., & Gianaros, P. J. (2013). Dispositional mindfulness co-varies with smaller amygdala and caudate volumes in community adults. *PLoS One, 8*(5), e64574.
Taylor, V. A., Grant, J., Daneault, V., Scavone, G., Breton, E., Roffe-Vidal, S., et al. (2011). Impact of mindfulness on the neural responses to emotional pictures in experienced and beginner meditators. *Neuroimage, 57*(4), 1524–1533.
Tu, P.-C., Kuan, Y.-H., Li, C.-T., & Su, T.-P. (2017). Structural correlates of creative thinking in patients with bipolar disorder and healthy controls: A voxel-based morphometry study. *Journal of Affective Disorders, 215*, 218–224.
Wagenmakers, E.-J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Love, J., et al. (2018). Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychonomic Bulletin & Review, 25*(1), 35–57.
Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin, 120*(1), 3.
Zhuang, K., Bi, M., Li, Y., Xia, Y., Guo, X., Chen, Q., et al. (2017). A distinction between two instruments measuring dispositional mindfulness and the correlations between those measurements and the neuroanatomical structure. *Scientific Reports, 7*(1), 6252.