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Self-reassurance reduces neural and self-report reactivity to negative life events

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Abstract

Adverse life events are inescapable, but how we relate to setbacks and challenges matters. Using fMRI, we invited participants to engage in self-criticism and self-reassurance toward written descriptions of negative life events (mistakes, setbacks, failures). Our results identify that neural pain and trial-by-trial markers of intensity are suppressed under conditions of self-reassurance, relative to self-criticism. Engagement in self-reassurance can therefore reduce the 'sting' of negative life-events, both neural and self-report.

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Introduction

Adverse life events are inescapable, be it a disruption in a career, dissolution of a relationship, or even a world-wide pandemic. These factors are known to take a toll on both physical and mental health outcomes[1] which can increase the likelihood of mortality[2]. These disappointments (e.g., making mistakes), losses (e.g., of hoped love) and fears (e.g., of rejection) are all triggers to self-criticism[3,4]. Indeed, self-criticism is a common relating style people use to cope, often resulting in an individual taking the frustration and anger out on themselves, which compounds the experience of pain psychologically and neurophysiologically[4]. Whilst research has shown how self-criticism may increase both self-report[5,6] and neural[7,8] markers of pain, less well known is how self-reassurance - a compassionately-motivated cognitive relating style - may regulate how the brain responds toward negative life events.

Motivated to explore this timely and open question, we conducted an fMRI experiment which examined two distinct self-relating styles, self-criticism and self-reassurance[9], when participants imagined themselves responding to mistakes, setbacks or failures. Importantly, we designed our experiment to deliberately tease apart neural markers of negative emotion, which we refer to as 'neural pain', first by manipulating an emotional – neutral contrast at the first level of fMRI analysis, and explored how this activation may differ across self-criticism and self-reassurance. To anticipate our findings, we associated brain activation of neural pain which differs under conditions of self-criticism and self-reassurance, specifically showing how self-reassurance can down-regulate neural markers of negative emotion and pain.

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Results

First, group-level one-sample t-tests of the whole brain contrasts of emotional - neutral stimuli were conducted overall. We refer to this contrast as neural pain to indicate an effect of negative emotion, and examined how this effect may differ across self-criticism and self-reassurance. For neural pain during self-criticism, we observed activation in the "salience" (midcingulo-insular), "default-mode" (medial frontoparietal), and the occipital network[10]. Whilst neural pain during self-reassurance recruited activation in regions such as the medial-prefrontal cortex (MPFC) and visual cortex, we observed no activation of the salience network as shown under self-criticism. Across both these contrasts, clusters were formed at a cluster-level threshold of $p < .05$, corrected for family-wise error, with clusters formed with a voxel-level height threshold at $p < .001$, uncorrected (cluster extent threshold K = 144).

We next conducted a repeated-measures contrast between self-criticism (emotional – neutral) minus self-reassurance (emotional – neutral), as a marker of neural pain which differs between these two mental strategies. Here, we identified brain activation across bilateral hippocampus (with a cluster which also included left putamen and left insula), thalamus, ACC, and occipital lobe, revealing neural pain is driven by self-criticism but not self-reassurance (cluster-level threshold of $p < .05$, corrected for family-wise error, with clusters formed with a voxel-level height threshold at $p < .001$, uncorrected, with a cluster extent threshold of K = 110). A repeated-measures contrast between self-reassurance (emotional – neutral) minus self-criticism (emotional – neutral) returned non-significant. Our experimental design is shown in Figure 1, Figure 2 depicts the whole-brain results, and Figure 3 depicts trial-by-trial markers of intensity (reported in

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the method section, under 'trial-by-trial markers of intensity'). Tables of thresholded brain output are available online as supplementary material.

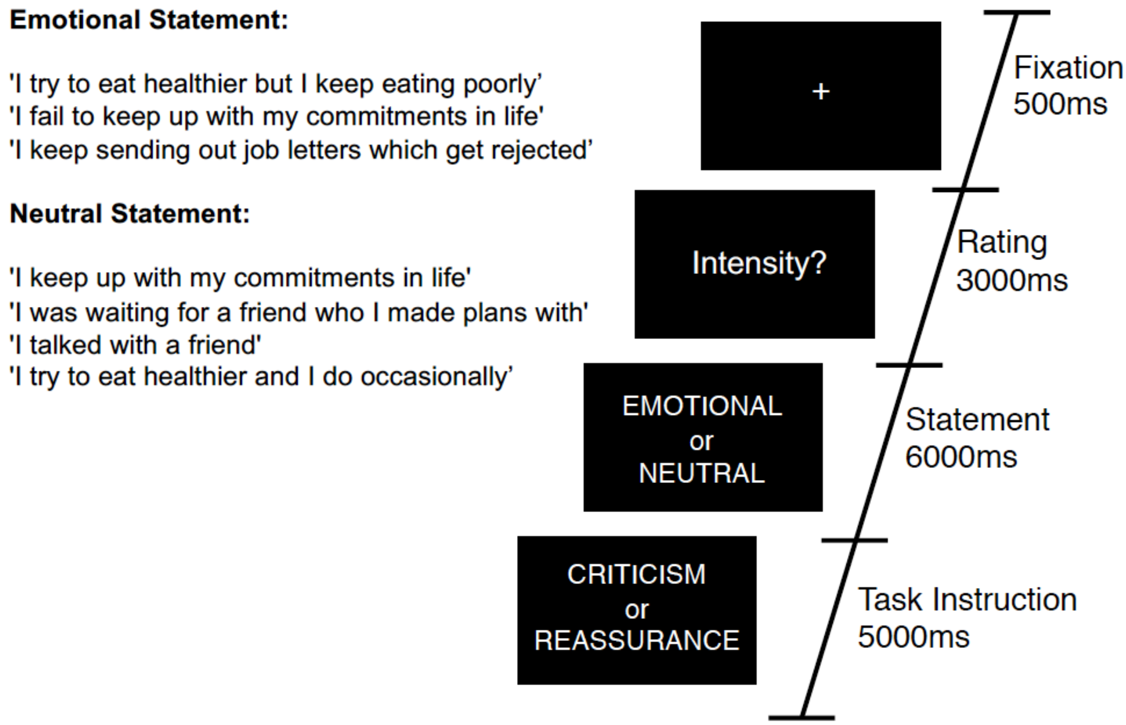

Figure 1. Task diagram for a typical trial. Participants were presented with 30 alternating trials of emotional or neutral statements which describe a mistake, setback or failure. Across 8 scan runs of 6 minutes each, participants were asked to engage with these statements from two different perspectives – four blocks of self-criticism, and four blocks of self-reassurance (order counterbalanced across participants). Example statements are presented inset.

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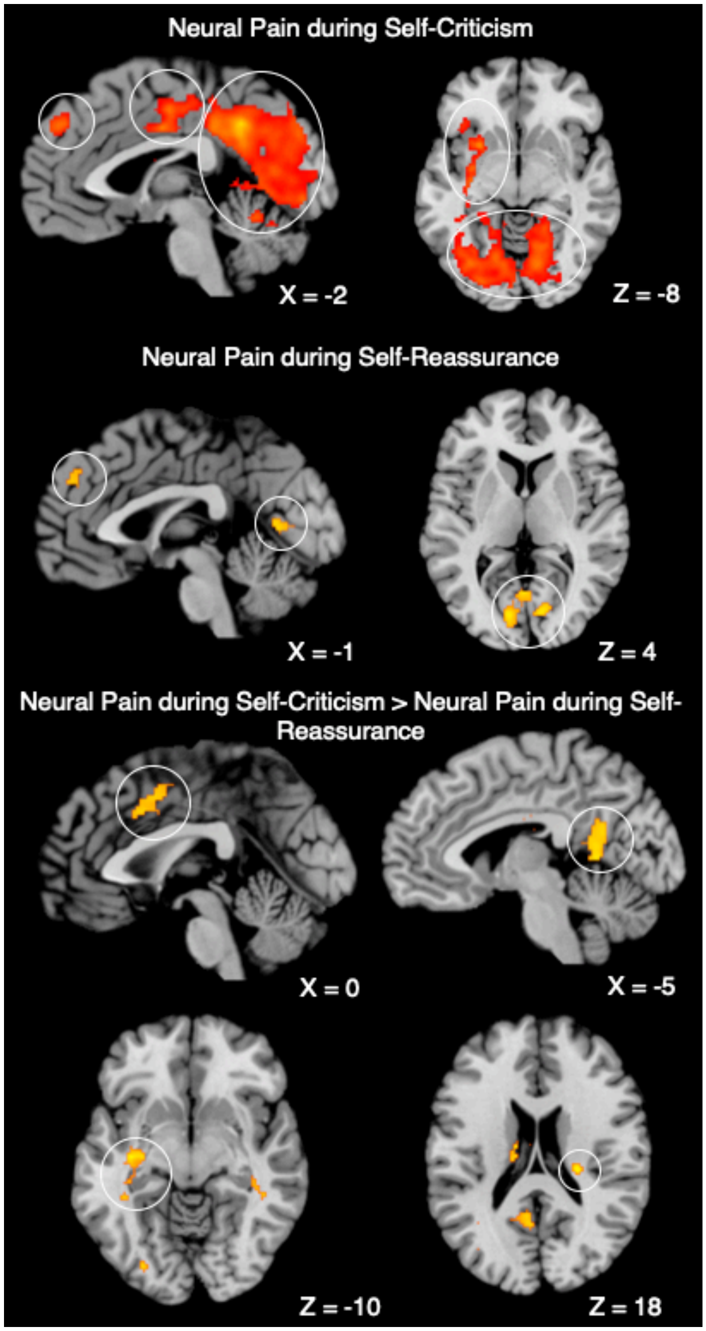

Figure 2. Neural pain across self-criticism and self-reassurance. **Neural Pain during Self-Criticism: Left.** Sagittal image of MPFC (Left Circle), ACC (Middle Circle), and Left Lingual Gyrus and Cerebellum (Right Circle). **Right.** Axial image of Subcortical Regions (Top Circle) and Bilateral Visual Cortex (Bottom Circle). **Neural Pain during Self-Reassurance: Left.** Sagittal image of MPFC (Left Circle) and Visual Cortex (Right Circle). **Right.** Axial image of Visual Cortex. **Neural Pain during Self-Criticism – Neural Pain during Self-Reassurance: Top Left.** Sagittal image of ACC. **Top Right.** Sagittal image of posterior cingulate. **Bottom Left.** Axial image of left putamen. **Bottom Right.** Axial image of Right Hippocampus. Coordinates reported in MNI-space. *N* = 40.

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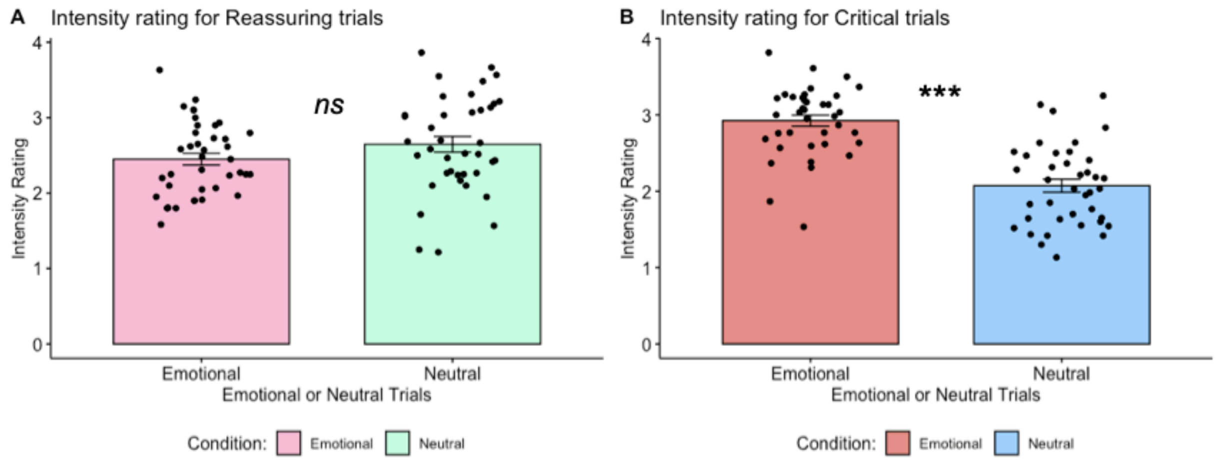

Figure 3. Trial-by-trial ratings of intensity for self-critical and reassuring trials. **Left.** Intensity ratings for self-reassuring trials, across emotional versus neutral stimuli. One-sample paired t-test returned non-significant, $p > .05$, *ns.* **Right.** Intensity ratings for self-critical trials, across emotional versus neutral stimuli. One-sample paired t-tests revealed self-report ratings of intensity for emotional stimuli were greater than neutral stimuli, $p < .001$. Error bars indicate standard error.

Discussion

Here we investigated neural markers of negative emotion and pain when participants engaged in self-criticism and self-reassurance toward negative life events (i.e., mistakes, setbacks or failures). Across both self-criticism and self-reassurance, our fMRI study revealed common activation across diverse regions such as the visual cortex (associated with mental imagery), salience network (associated with processing pain and threat), and default-mode network (associated with self-referential thought)[10]. Brain activation overall was more extensive for self-critical than self-reassuring trials, even though both contrasts did activate similar regions such as the MPFC and visual cortex. Furthermore, self-reassurance did not activate regions such as the insula, anterior cingulate cortex and amygdala. In addition, self-report ratings of intensity for emotional stimuli were supressed for self-reassuring versus self-critical trials. Importantly, a contrast of neural pain between self-criticism minus self-reassurance revealed brain activation in

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regions such as the anterior cingulate cortex, insula and hippocampus. Taken together, our data show that neural and self-report markers of negative emotion, pain and memory are supressed during self-reassurance compared with self-criticism, providing evidence for how cultivating a reassuring self-relating style can regulate neural markers of pain and negative emotion.

Whilst recruitment of the insula and anterior cingulate cortex have previously been shown for self-criticism[7,11], it is important to remark on bilateral hippocampus activation within the current experiment, which may be an indicator of autobiographical memory recall[12,13]. Whilst our paradigm instructions were for participants to engage in self-critical thoughts from the stimuli presented, it is entirely possible that for reference participants engaged in their own first-person accounts from situations in their own lives[14]. Future work to explore the role of first-person memory in self-reassurance would be crucial to examine how it may differ to spontaneous engagement in self-reassurance.

To position our results in the broader literature on the neuroscience of empathy and compassion, we have shown that brain regions for processing negative emotion toward others[15–17] were shown to not be recruited during compassion to the self. Specifically, we have shown that neural markers of pain are suppressed during attempts to be compassionate and reassuring to one's suffering. Our data suggest that engagement in self-reassurance is a way to reduce the 'sting' of negative life-events, both neural and self-report, which is a timely finding in our current global environment.

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Methods:

Whilst the program of research within the present paper has been reported on previously, this examined the (neuro)physiological correlates of a brief, two-week compassion training paradigm[4]. Here we focus on the novel whole brain markers of criticism and reassurance which have not been reported previously. As our fMRI method as reported in the previous paper is also the same imaging method used for the present paper, we have reproduced the method for clarity under a CC BY open access licence.

Participants:

40 participants (Mean age = 22 years, SD = .49, 27 female) took part in the present study. The University of Queensland Health and Behavioural Sciences, Low & Negligible Risk Ethics Sub-Committee approved the experimental protocol, and this project complies with the provisions contained in the *National Statement of Ethical Conduct in Human Research* and complies with the regulations governing experimentation on humans. Participants provided informed and voluntary, written and/or electronic consent.

fMRI Stimuli:

We created 60 written stimuli in total, consisting of a personal mistake, setback or failure. 30 statements were of emotional valence whereas 30 were neutral (i.e., “I fail to keep up with my commitments in life”, and “I keep up with my commitments in life”, respectively). Our neutral stimuli were created to describe a non-emotive, non-intense control to counterbalance the emotional stimuli set. For both emotional and neutral sets we assessed two metrics, valence (1-5, where 1 = Very Unpleasant) and intensity (1-5, where 1 = Not Intense). Our emotional statements (n = 30) were revealed to be sufficiently unpleasant (M = 1.89) and intense (M = 3.54), with all neutral statements (n = 30)

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described as less unpleasant (*M* = 3.80) and comparatively not intense (*M* = 2.34).

fMRI Design:

Within the scanner we examined participant's neural responses to the validated (affective and neutral) written stimuli when engaged in self-criticism and self-reassurance (Figure 1). After each trial within a block of either self-criticism or self-reassurance, participants rated how intense their degree of self-criticism or self-reassurance was to each statement (button-press on an MR-compatible button box which ranged from 1-4, where 1 = not very intense, and 4, very intense). A typical trial consisted of stimuli presented for a 6 second duration, followed by a rating of intensity for a 3 second duration, and an inter-trial-interval of .5 seconds. The first order of instruction for a particular block, that is, self-reassurance verses self-criticism, was counterbalanced for a total of 8 blocks. As our focal contrast, we manipulated the emotionality of the statements within scan runs ("emotive" vs "neutral"), in a counterbalanced order across participants. 30 statements were quasi-randomized across participants and presented for a total of 30 trials per fMRI run (~6.5 min total duration) over a total of 8 repeated fMRI runs. Participants were given 10 practice trials of emotional and neutral stimuli, and rated stimuli on intensity.

fMRI Acquisition and Pre-Processing:

We collected our fMRI data on a 3-Tesla Siemens Trio MRI scanner utilizing a 64-channel head-coil. A gradient-echo, echo-planar "fast imaging" (EPI) sequence were used to acquire functional images, with the following sequence parameters: 60 horizontal slices (2 x 2-mm in-plane voxel resolution and 2-mm slice thickness plus 10% gap), repetition time (TR) 1000 ms; echo time (TE) 30 ms. Eight identical fMRI runs of 292 images (6 minutes each) were acquired. A 3D high-resolution, unified and denoised T1-weighted

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MP2RAGE image across the entire brain was also acquired and used as anatomical reference for subsequent pre-processing in SPM12 (TR = 4000 ms, TE = 2.93 ms, FA = 6°, 176 cube matrix, voxel size = 1-mm). Functional imaging data were pre-processed and analyzed using SPM12, implemented in MATLAB. Structural T1-scans were co-registered to the average of the spatially realigned functional slices. Next, an inbuilt segmentation routine was applied to register each structural T1-image to the standard MNI template in MNI space. These transform parameters elicited from segmentation were subsequently applied to all realigned images, resliced to a 2x2x2-mm resolution and smoothed with 6-mm full-width-at-half-maximum (FWHM) isotropic Gaussian kernel.

fMRI First and Second-Level Analyses:

For first-level data analysis, block-related neural responses to stimuli were modelled as 2 separate conditions (all combinations of emotional/neutral, self-criticism/self-reassurance) and convolved with the canonical hemodynamic response function (HRF). For group level analysis, whole-brain contrasts of self-criticism (emotional-neutral) stimuli were reported at a cluster-level threshold of $p < .05$, corrected for family-wise error, with clusters formed with a voxel-level height threshold at $p < .001$, uncorrected, with a cluster extent threshold of K = 144. Whole-brain contrasts of self-reassurance (emotional-neutral) stimuli were reported at a cluster-level threshold of $p < .05$, corrected for family-wise error, with clusters formed with a voxel-level height threshold at $p < .001$, uncorrected, with a cluster extent threshold of K = 144. Whole-brain repeated-measures contrasts of self-criticism (emotional-neutral) - self-reassurance (emotional-neutral) stimuli were reported at a cluster-level threshold of $p < .05$, corrected

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for family-wise error, with clusters formed with a voxel-level height threshold at $p < .001$, uncorrected, with a cluster extent threshold of K = 110.

Brain regions shown to be significant had their anatomical labels identified with the Automated Anatomical Labelling (AAL) toolbox implemented in SPM12. Next, in order to examine correlations between the level of neural activation (i.e. difference in response between emotion verses neutral) and the mindset participants engaged in (i.e. self-criticism versus self-reassurance), we performed additional region of interest (ROI) analyses. For each ROI, we identified peak clusters which showed significantly greater activation overall for emotion vs neutral stimuli, and used these coordinates to extract the average contrast parameter estimates (i.e. levels of activation, Beta weights) with 5-mm radius spheres centred on those peaks for each mindset (i.e., self-criticism and self-reassurance).

Trial-by-trial markers of intensity:

Analysis of participant's mean level of intensity ratings for reassuring trials (emotional stimuli: $M = 2.45$, $SD = 0.48$, neutral statements: $M = 2.63$, SD = 0.64) and critical trials (emotional stimuli: $M = 2.92$, $SD = 0.45$, neutral stimuli: $M = 2.07$, $SD = 0.52$) revealed intensity ratings were significantly higher for critical (emotional – neutral) but not for reassuring (emotional – neutral) trials ($t(38) = 7.300$, $p < 0.001$, and $t(38) = -1.372$, $p = 0.178$, *ns*, respectively).

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Author Contributions: JJK, RC and JNK conceived and designed the experiment; acquired, analysed and interpreted the data; and wrote the manuscript.

Competing Interests Statement: The authors declare no competing interests.

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